Diversitas Journal
ISSN 2525-5215
Volume 9, Issue Special 1 (jan./mar 2024) p. 0203 – 0224
https://diversitasjournal.com.br/diversitas_journal

eSwine Farming: A QR Code-Driven Monitoring System for Improve Efficiency and Profitability

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A B S T R A C T

As technology advances, many traditional activities are at risk of being lost, including the practice of swine farming. Swine farming is an ancient practice that dates back to 4900 BC, but its effectiveness may decrease as individuals increasingly rely on newer technological solutions. However, with the advent of QR codes, swine farming has taken on a new dimension, enabling farmers to collect real-time data on swine growth, health, and production. This study is specifically designed to improve the efficiency and profitability of swine farming, empowering farmers with accurate and timely information on the status of their swine. The system allows farmers to collect data quickly and easily on individual pigs, which can then be analyzed to identify any issues. This information can be used to help farmers make informed decisions about how to manage their swine farming operations, expand into new and more effective practices, and increase profitability. The eSwine system is a significant innovation in swine farming technology, providing a functional, usable, reliable, compatible, secure, efficient, maintainable, and portable tool for farmers to manage their operations more effectively. With an average weighted mean of 3.64, eSwine is an essential asset for any farmer looking to maximize their profits while maintaining the health and welfare of their swine.

RESUMO

À medida que a tecnologia avança, muitas atividades tradicionais correm o risco de serem perdidas, incluindo a prática da suinocultura. A suinocultura é uma prática antiga que remonta a 4.900 a.C., mas a sua eficácia pode diminuir à medida que os indivíduos dependem cada vez mais de soluções tecnológicas mais recentes. No entanto, com o advento dos códigos QR, a suinocultura assumiu uma nova dimensão, permitindo aos agricultores recolher dados em tempo real sobre o crescimento, saúde e produção dos suínos. Este estudo foi concebido especificamente para melhorar a eficiência e rentabilidade da suinocultura, capacitando os agricultores com informações precisas e oportunas sobre o estado dos seus suínos. O sistema permite que os agricultores coletem dados de forma rápida e fácil sobre suínos individuais, que podem então ser analisados para identificar quaisquer problemas. Esta informação pode ser usada para ajudar os agricultores a tomar decisões informadas sobre como gerir as suas operações de criação de suínos, expandir para práticas novas e mais eficazes e aumentar a rentabilidade. O sistema eSwine é uma inovação significativa na tecnologia de criação de suínos, fornecendo uma ferramenta funcional, utilizável, confiável, compatível, segura, eficiente, de fácil manutenção e portátil para os agricultores gerirem as suas operações de forma mais eficaz. Com uma média ponderada de 3,64, o eSwine é um ativo essencial para qualquer agricultor que procura maximizar os seus lucros enquanto mantém a saúde e o bem-estar dos seus suínos.

ARTICLE INFORMATION

Article process:
Submitted: 11/15/2023
Approved: 04/18/2024
Published: 03/21/2024

DOI: 10.48017/dj.v9iSpecial1.2866

Introduction

In the global landscape of agriculture and animal husbandry, swine farming plays a significant role in meeting the ever-growing demand for pork products. With the world's population steadily increasing, the importance of efficient and sustainable farming practices cannot be overstated. Swine farming is a comprehensive practice that involves the responsible raising and nurturing of domestic pigs, encompassing essential activities such as breeding, farrowing, weaning, and finishing. This farming method boasts a rich and storied history, dating back as far as approximately 4900 BC, a fact substantiated by the research conducted by Moeller and Crespo (2009). Nevertheless, as society increasingly depends on modern technological innovations, traditional swine farming strategies may gradually lose their effectiveness and viability over time. Swine farming, commonly known as pig farming, is an agricultural practice centered around raising domestic pigs for multiple purposes, including meat, leather, and various by-products. This industry is characterized by its high efficiency and profitability, as pork ranks among the most widely consumed meats worldwide. Swine farming encompasses a spectrum, spanning from small-scale family farms to large commercial operations, each specializing in raising different breeds of pigs to meet specific objectives.

Notably, in 2020, the Philippine swine enterprise achieved an impressive global ranking, securing the ninth position in terms of red meat production quantity and the number of breeding sows, as reported by PhilStar (2016). It underscores the prominence of the swine industry within the country and highlights its substantial contribution to the overall livestock sector. In fact, the swine industry holds a significant share, accounting for approximately 55% of the total animal industry, making it the largest contributor (Acosta, 2022).

Farmers in the Philippines are conscious of the importance of pig organizations as a substantial source of revenue for their own families, a backup source of funds for specific objectives, such as paying for children's education, and a possible application at some point in the payoff. Swine farming is one of the main livelihoods or sources of income in the province of Oriental Mindoro. Mainly agricultural cooperatives, own pig farms that are crucial for the benefit of the whole member. Keeping each livestock safe and healthy will provide farm owners a high profit as soon as they dispose of them.

For a large farm to have a well-balanced and well-organized monitoring system, it must embrace some emerging technology that is available now. One of the large swine farms in Oriental Mindoro, Philippines is Bansud Livestock Multi-Purpose Cooperative (BLMC), located at Bansud, Oriental Mindoro. BLMC was established and registered in 2000 with CDA LGA Reg. No.4700. It has 317 enterprising hog-raisers in Oriental Mindoro specifically in the town of Bansud. Daily, they are keeping and tracking the record of each swine from the day it was born up to the day of disposal or selling. Natural hazards are one of the things they avoid in terms of keeping all the records since they use log books or record books. Despite the crises dealing with the swine enterprise (including the american swine fever and unfolding of foot-and-mouth disease), nonetheless many Mindorenos are venturing into swine farming.

In line with this, problems arising from the scenario on the farm may affect the mode of monitoring to have precise and accurate data. One of the main problems that farm workers experience daily is the manual look-up of data on the log book that holds the information of the swine on the farm. Another problem is the temperature monitoring wherein they are not aware if the swine and piglets have an unusual increase in temperature. This is very important to manage and isolate the pig to prevent the spreading of viruses.

Addressing these challenges necessitates the integration of innovative technologies, implementation of best practices, and a steadfast commitment to sustainability and animal welfare. Within this context, comprehending the issues prevalent in swine farming becomes pivotal in developing effective solutions that promote a more resilient and responsible industry.

In connection with this, modern farming includes an adaptation of emerging technologies such as IoT-based and sensor-based systems. BLMC is very suitable to adapt technologies to manage data more efficiently and practically. Web-based systems do not only include appealing interfaces but also more powerful functions from scanning QR codes to generating a report via PDF format.

The purpose of this paper is to establish a secure and accurate monitoring system for swine and to help farmworkers and owners have a stabilized farm monitoring system that is user-friendly and at the same time hassle-free. With the use of a web-based monitoring system, managing and collecting swine information are made easier and more efficient. Manual storing of data and information is enhanced by having a local database that can retrieve data at any time by providing report generation, and also it is made for safe-keeping and preventing data loss. Specifically, this study aims to: (1) design and develop a QR-code-driven swine farm monitoring system for farm monitoring activities. (2) Integrate the QR-code system in giving unique identification to swine. (3) Provide reports regarding feed consumption, feed ratio and isolation reports. (4) Evaluate the system's functionality suitability, performance efficiency, usability, compatibility and security using ISO 25010 software quality standards.

Related Work

Previous studies have examined various aspects pertaining to the proposed swine monitoring system to improve efficiency and productivity. For instance, Catelo (2017) highlights an environmentally sustainable productivity growth of swine farming, particularly in developing countries like the Philippines. One proposed solution to enhance productivity is the advanced monitoring system utilizing RFID technology, as suggested by Dipay et al. (2018). The system, known as the Animal Identification and Records Monitoring Tool, streamlines comprehensive monitoring across extensive farm areas, reducing effort and time requirements. Such technological interventions align with the overarching goals of improving efficiency and sustainability in swine farming practices.

Sensor-based monitoring systems have gained momentum in swine farming due to their ease of use compared to traditional paper-based record-keeping methods. Frost et al. (2016) emphasize the integration of sensor data with databases, mathematical models, and knowledge bases to drive production advancements. To accommodate future innovations, it is advantageous to adopt a flexible system architecture that allows seamless addition of new elements and functions. Technological developments have ushered in significant changes to traditional swine farming practices, with sensor-based monitoring systems providing a significant leap in productivity.

Furthermore, the identification of livestock is essential to modern farming and successful farm monitoring. A decrease in their size and increment in their reading distance has led to the use of QR code technology in different areas commonly. Animal monitoring, tracking, and identification systems are some of the application areas where this technology is used effectively to prevent theft and fraud, increase efficiency, and collect and store essential data (Dogan, H. et.al, 2016).

Barcodes and QR codes have become pivotal in bridging the offline and online realms, offering precise and timely information to farmers about the status of their pigs. This technology facilitates efficient data gathering and evaluation, enabling early problem detection. QR codes have gained popularity due to their high data storage capacity, fast scanning capabilities, and omnidirectional readability, as highlighted by Tiwari (2016). However, Focardi et al. (2019) caution about the need for standard mechanisms to ensure the authenticity and confidentiality of QR code content, addressing vulnerabilities such as redirection to malicious websites or malware infections.

In terms of data genuineness and security, Khandal and Somwanshi (2017) stress the importance of using QR codes for identity modules, where decrypted data is used to fill in details and access restricted areas by authorized users. Additionally, Tarjan et al. (2016) emphasize the need for a universal system model for traceability in food production, with QR codes emerging as a potential solution for carrying essential data and ensuring readability across various content, sizes, error correction levels, and printing materials.

Yang et al. (2018) propose a cloud-based Digital Farm Management System (DFMS) integrated with identification technology, aiming to provide farm managers with services across different locations and devices. This system aims to aggregate accurate data for diverse crops and multiple batches, facilitating efficient management across farms.

To maintain a well-balanced and efficiently organized monitoring system, large-scale farms must embrace new technologies. A crucial aspect of their daily operations involves diligently recording and tracking the progress of each swine from birth until disposal or sale.

Traditional methods, such as log books or record books, are susceptible to natural hazards and thus fall short of ensuring comprehensive record-keeping. Recognizing this, Catelo (2017) emphasizes the importance of a centralized web-based monitoring system in achieving environmentally sustainable swine farm productivity growth, particularly in developing countries like the Philippines. In recent years, there has been an increased emphasis on individual pig identification to enable accurate tracing of slaughtered pigs back to their farm of origin.

In the realm of animal agriculture, Neethirajan (2020) delves into the role of digitalization through precision livestock farming (PLF) technologies in addressing concerns related to animal welfare, environmental sustainability, and public health. PLFs, encompassing biosensors, big data, and blockchain technologies, facilitate real-time data collection, enabling proactive management strategies and the maintenance of a sustainable and safe food supply. There are studies emphasize the significance of adopting information and communication technology (ICT) in agriculture, highlighting its benefits for farmers. Through mobile applications, farmers gain access to innovative techniques, irrigation details based on moisture control and temperature, crop maintenance information, pesticide details, weather forecasts, and market updates. Swine farming, akin to any agricultural industry, confronts diverse challenges that significantly impact economic viability, sustainability, and animal welfare. From disease outbreaks and environmental concerns to ethical considerations and labor shortages, swine farmers must navigate a complex and ever-evolving landscape to ensure safety, quality, and profitability.

The scenario on the farm can present challenges that affect the precision and accuracy of monitoring systems, thereby impacting the collection of reliable data. Among the primary issues faced by farm workers on a daily basis is the manual retrieval of data from logbooks that contain important information about the swine on the farm. Additionally, monitoring temperature fluctuations poses another challenge, as farm workers may not be aware of unusual increases in temperature among swine and piglets. Swift identification of such abnormalities becomes vital to effectively manage and isolate affected pigs, thus preventing the spread of viruses. Furthermore, other related studies as shown in Table 1 presents various works focused on the intersection of technology and livestok management.

Table 1.
Summary of Related Studies

Author and Year	**Title of Existing Studies**	**Technology**	**Common Application**	**Outcomes**
Lyons, C.; Bruce, J.; Fowler, V.; English, P. 1995	A comparison of Productivity and Welfare of Growing Pigs in Four Intensive Systems	Housing Conditions and Pig Performance	Impact of housing on pig performance	Improved pig productivity and well-being
Sahin, C.; Bolat, E.D. 2009	Development of Remote Control and Monitoring of Web-based Distributed OPC system	IoT-based Piglet Shed Monitoring	Accurate data recording and analysis	Enhanced piglet health and growth
Li, L.H.; Huang, R.L.; Huo, L.M.; Li, J.X.; Chen, H. 2012	Design and Experiment on Monitoring Device for Layers Individual Production Performance Parameters	IoT-based Environmental Monitoring	Monitoring and controlling farm environment	Improved farm environment management
Mungroo, N.; Neethirajan, S. 2014	Biosensors for the Detection of Antibiotics in Poultry Industry—A Review	Biosensors	Animal industry	Limited applicability due to factors like sensor types, size, properties, and environmental conditions
Godfray, H.C.J.; Garnett, T. 2014	Food security and sustainable intensification	Livestock Production	Ensuring future meat, milk, and egg supply	Addressing future food insufficiency

Table 1.
Continued

Author and Year	Title of Existing Studies	Technology	Common Application	Outcomes
Pan, L.; Xu, M.; Xi, L.; Hao, Y., Changchun, China, 10–11 December 2016	Research of Livestock Farming IoT System Based on RESTful Web Services	IoT Technology in Agriculture	IoT-based sensor networks for livestock sectors	Enhanced operational efficiency
Ahmed, S.T.; Mun, H.S.; Islam, M.M.; Yoe, H.; Yang, C.J. 2016	Monitoring Activity for Recognition of Illness in Experimentally Infected Weaned Piglets Using Received Signal Strength Indication ZigBee-based Wireless Acceleration Sensor	Disease Prediction using ZigBee	Monitoring movement for disease prediction	Early disease detection in piglets
Vranken, E.; Berckmans, D. 2017	Precision Livestock Farming for Pigs	Technological Integration in Swine Production	Enabling farm owners to make informed decisions and receive early warning	Enhanced decision-making, early detection of ilness and abnormalities
Neethirajan, S. 2017	Recent Advances in Wearable Sensors for Animal Health Management	Biosensors	Animal health monitoring, disease preventiion, antibiotic detection	Early detection of illnesses, lower mortality rates, reduced antibiotic usage, prevention of anibiotic resistance
Racewicz, P.; Sobek, J.; Majewski, M.; Rozanska-Zawieja, J. 2018	The Use of Thermal Imaging Measurements in Dairy Cow Herds	Sensors and Imaging	Monitoring pig health, welfare, and production	Enhanced pig health and productivity
Benjamin, M.; Yik, S. 2019	Precision Livestock Farming in Swine Welfare: A Review for Swine Practitioners	Manual Management	Demand for Good Health and Behavior in Swine	Optimal Body Weight, Behavior, and Posture Glossy Skin, Absence of Disease Symptoms
Choi, H.; Mayakrishnan, V.; Kim, T.; Lim, D.; Park, S.. 2019	Livestock Production in Korea: Recent Trend and Future Prospects of ICT Technology	Developmental Stages of Smart Livestock Farming	Enhancing food security in Korea	Enhanced farming automation Energy management, IoT integration Improved food self-sufficiency Increased farm productivity
Trendov, N.M.; Varas, S.; Zeng, M. 2019	Digital Technologies in Agriculture and Rural Areas	Smart Agricultural Farming (ICT-based)	Meeting future food demand through ICT-based solutions	Increased food production
Van der Burg, S.; Bogaardt, M.J.; Wolfert, S. 2019	Ethics of Smart Farming: Current Questions and Directions for Responsible Innovation Towards the Future	ICT-based Smart Swine Farming	Application of ICT in swine industry	Improved swine farming practices
Bacco, M.; Barsocchi, P.; Ferro, E.; Gotta, A.; Ruggeri, M. 2019	The Digitisation of Agriculture: A Survey of Research Activities on Smart Farming	Innovative Technologies	Collaborative efforts to increase farm productivity	Enhanced farm productivity
FAO. Rome, Italy, 2009 and Emadi, M.H.; Rahmanian, M., 2020	The State of Food and Agriculture: Livestock in Balance	Food Security	Addressing food insecurity due to population growth	Meeting increased food demand
Lekagul, A.; Tangcharoensathien, V.; Liverani, M.; Mills, A.; Rushton, J.; Yeung, S. 2021	Understanding antibiotic use for pig farming in Thailand: A qualitative study	Manual Management	Physical Management & Manual Observation of Pigs	High Labor Costs, Missed Early Illness Signs Poor Performance, Econnomic Losses
Pandey, S.; Kalwa, U.; Kong, T.; Guo, B.; Gauger, P.; Peters, D.; Yoon, K. 2021	Behavioral Monitoring Tool for Pig Farmers: Ear Tag Sensors, Machine Intelligence, and Technology Adoption Roadmap	Remote Monitoring Sensor Boards	Health and Behavior Monitoring of Swine Herds Remotely	Effective real-time data collection from pigs' ears, ID of welfare and behavior characterisitcs, potential for remote monitoring

Table 1.
Continued

Author and Year	Title of Existing Studies	Technology	Common Application	Outcomes
Bailey, D.; Trotter, M.; Tobin, C.; Thomas, M. 2021	Opportunities to Apply Precision Livestock Management on Rangelands	Smart Equipment	Automated Tools/Sensors for Health & Behavior	Enahnced Data-Driven Decision Making
Hashem, N.M.; Hassanein, E.M.; Hocquette, J.-F.; Gonzalez-Bulnes, A.; Ahmed, F.A.; Attia, Y.A.; Asiry, K.A. 2021	Agro-Livestock Farming System Sustainability during the COVID-19 Era: A Cross-Sectional Study on the Role of Information and Communication Technologies	Promoting livestock production in developing countires	Farm Productivity, Food Security	Enhanced protein-rich food production
Schillings, J.; Bennett, R.; Rose, D.C. 2021	Exploring the Potential of Precision Livestock Farming Technologies to Help Address Farm Animal Welfare	Precision Livestock Farming	Automated detection of individual animal health & behavior	Data-driven decision-making
Micle, D.; Deiac, F.; Olar, A.; Drenţa, R.F.; Florean, C.; Coman, I.G.; Arion, F.H. 2021	Research on Innovative Business Plan. Smart Cattle Farming Using Artificial Intelligent Robotic Process Automation	Data-based Technologies	Generation and utilization of target data through internet systems	Improved decision-making
Long, S.; He, T.; Kim, S.W.; Shang, Q.; Kiros, T.; Mahfuz, S.U.; Wang, C. 2021	Live Yeast or Live Yeast Combined with Zinc Oxide Enhanced Growth Performance, Antioxidative Capacity, Immunoglobulins and Gut Health in Nursery Pigs	Weaning Stress and Pig Health	Effect of stress on pig health and performance	Reduced mortality and improved growth

Materials and Methods

This research endeavor synergistically harnessed developmental and descriptive methodoologies to realize its aims. While the developmental phase centered on system design and implementation, the subsequent evaluation phase embraced a descriptive perspective to assess the system's effectiveness and functionality.

Software Materials

eSwine offers versatile accessibility, compatible with desktop computers, laptops, and mobile phones. This project utilized a diverse array of software tools. Notably, XAMPP served as the PHP development environment, facilitating program creation and testing on a local web server. FileZilla enabled seamless file exchange by connecting to external FTP servers. Additionally, Chrome was employed to access the internet and operate the web-based application.

Research site and data collection

The study was conducted at a commercial swine farm called Bansud Livestock Multipurpose Cooprative located in Bansud, Oriental Mindoro, Philippines. The farm involves 317 hog-raisers. A record-keeping system was in place, utilizing traditional log books or record books to document the daily progress of each swine from birth to disposal or sale.

QR Code System Development

The QR code-driven monitoring system was developed to enhance the monitoring process. The system's components and requirements were carefully considered, including aspects such as the operating system, programming language, disk space, RAM, CPU cores, bandwidth, database, and Bluetooth module. The QR code-driven system involved scanning and examining the details of each pig, facilitating efficient and accurate data collection.

Agile Framework

An agile framework was adopted for the design and development of the study, ensuring a systematic and iterative approach. The framework involved continuous release cycles with gradual modifications before the final release. Stakeholder involvement and feedback were integrated throughout the project. The framework included phases as shown in Figure . 1, such as requirement collection, analysis, design, coding, testing (including acceptance testing and unit testing), and maintenance.

Figure 1.
Agile Process

Figure 1 followed continuous release cycles with small, gradual modifications before the final release. It employs techniques to address project difficulties early on, involving stakeholders and obtaining feedback throughout the project. In the requirement collection phase, information is gathered through client interviews and testing to understand the system's functionality and features. The analysis phase focuses on identifying errors and bugs to make necessary modifications. Collaboration with swine farmers helps brainstorm potential solutions and improvements. The design phase builds the system around user needs, starting with a preliminary design and coding to incorporate target adopter recommendations followed by testing to ensure the system operates correctly, including acceptance testing and unit testing. The maintenance phase occurs after system implementation and client evaluation.

System Architecture

The system architecture involved diverse components and processes. Swine were labeled with unique QR codes for identification, while a thermal sensor detected their temperature for health-related data. Data input by staff through a computer interface was stored in a centralized database. Daily monitoring involved scanning QR codes using a mobile device for real-time access to detailed information. The system also allowed data deletion when necessary. The stored data within the database facilitated generating essential reports.

Figure 2.
System Architecture

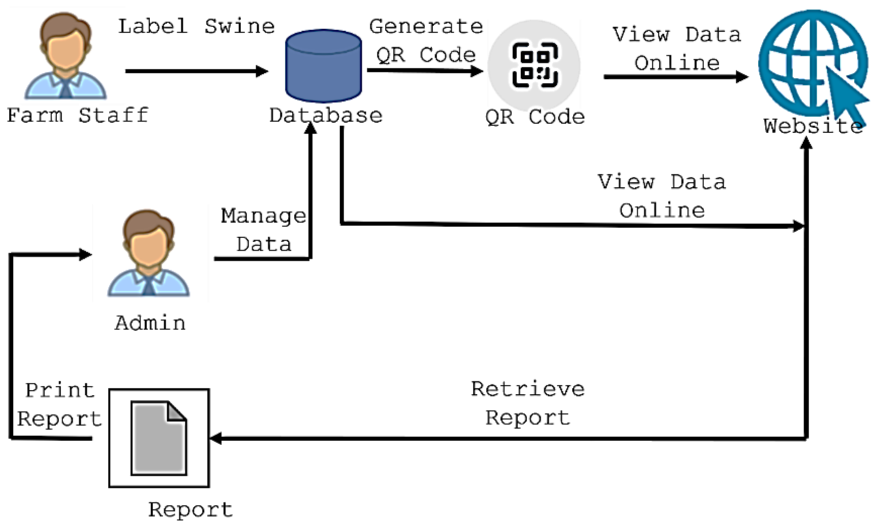


Figure 2 illustrates the diverse components and processes involved in the system. The first step entails labeling the swine and assigning each one a unique QR code, serving as their distinctive identifier. Concurrently, a thermal sensor detects the swine's temperature, providing valuable health-related data for monitoring purposes. Data input by the staff through a computer interface is subsequently save into the database, which serves as a centralized storage repository for all collected data and forms the foundation for generating comprehensive reports. Daily monitoring of the swine is facilitated by scanning the QR codes attached to the pigs' ear tags. The utilization of a mobile device for scanning the QR codes empowers users to conveniently access specific and detailed information about each entity, which displays on the screen. This mobile-enabled feature enhances accessibility and facilitates real-time access to relevant data, contributing to streamlined monitoring and informed decision-making processes. The system also allows the deletion of records when necessary, ensuring data accuracy and providing flexibility. The stored data within the database serves as a valuable backup and use for generating essential reports, including feed consumption and isolation reports. These reports track the swine's weekly progress and contribute to informed decision-making processes. The system architecture exemplifies a comprehensive approach encompasses swine labeling, QR code scanning, data input and storage, mobile device integration, record management, and report generation. By seamlessly incorporating these functionalities, the system offers a holistic solution for efficient and effective monitoring of swine, all presented in a user-friendly manner.

Use Case Diagram

The use case diagram illustrated interactions between users and admins within the system. Staff members monitored swine and accessed information about performance and health. Admins validated data, reviewed records, and managed the database. Both users and admins could perform actions like updating, editing, deleting, and downloading data, ensuring effective data management and utilization.

Figure 3.
Use Case Diagram

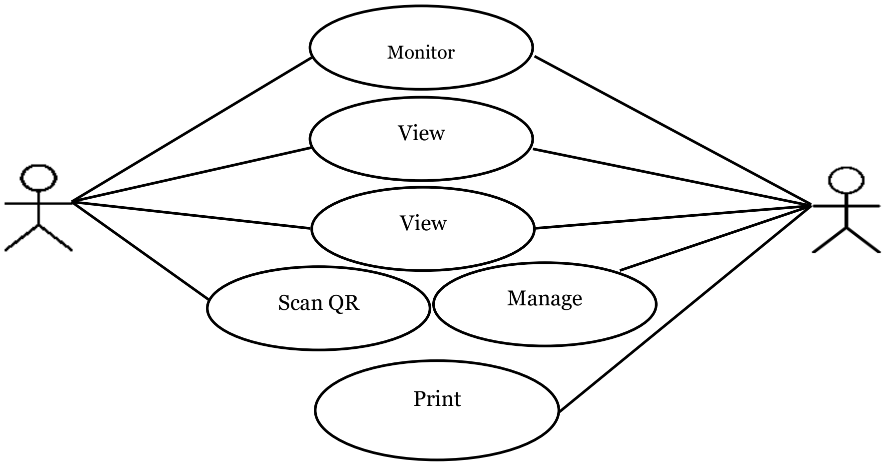


Figure 3 provides an insightful overview of the interactions between users and admins within the system, illustrating their respective roles and functions. The staff assumes a position of monitoring the swine and accessing relevant information. They possess the capability to view statistical data, enabling them to gain comprehensive insights into the animals' overall performance and health. Moreover, they can access and review records associated with each, allowing for thorough tracking and analysis.

On the other hand, the admin assumes a crucial role in ensuring the accuracy and validity of the data stored within the system. They possess the authority to validate the data entered by staff and meticulously review records to verify their integrity. This validation process is a cornerstone for maintaining reliable and trustworthy information within the system.

Additionally, both admin and staff can manage the data stored in the database. They can perform actions such as updating, editing, or deleting records as required. This flexibility ensures effective data management, guaranteeing that the information within the system remains current and relevant. Furthermore, the system allows users and admin to download the data if necessary, facilitating further analysis, reporting, or sharing of the data beyond the confinement of the system

These materials and methods collectively formed the foundation of the study's approach to revolutionizing swine farming through the implementation of a QR code-driven monitoring system.

Descriptive Method

The descriptive method of research was involved systematic observation, recording, and analyzing various aspects of the system's features, functionalities, and user interaction. A purposive sampling was used in selecting the respondents. A total of fifty (50) respondents answered the evaluation survey. The respondents consisted of twenty (25) Swine farmers, fifteen (15) employees of livestock cooperative, ten (10) IT experts. The effectiveness and functionality of the system were evaluated using ISO 25010. A web hosting was employed to test the operation of the website and how it communicates with users as they move around the interface. A webpage can be freely shared by users through web hosting. Functions are submitted for testing so that they can be examined to see whether they could potentially cause problems. The database server was examined for any potential conflicts once a sizable number of accounts had connected to it. Additionally, the many forms, schedules, and other data submitted by the users were reviewed. The website's functionalities, user-friendliness, design and template effectiveness, information distribution, and appointment system were the main focus of the testing and assessment technique. Evaluation of the system took place when the system was being tested by the adapter to know if the system is functional, reliable, efficient, usable, secure, compatible, maintainable, and portable. Functionality indicates how well the system and if it met the required needs and produced the desired results when performing its job. Reliability refers to how well the system operated despite any faults or issues under specific situations. Efficiency denotes the system's resource utilization performance under specific constraints. Usability indicates how successful the system was used to attain a goal in a timely and efficient manner. Security refers to how well the system safeguarded user data and how well it managed to reduce data vulnerability. Compatibility includes the compatibility or ability of a system to operate hardware or software components while supporting its needed functionality. Maintainability specifies how well the system adapts to changes and maintains its fundamental functionalities before and after various degrees of modification. Portability refers to how well a system can run and adapt in various software, hardware, and installation contexts, as well as any other types of transfer.

In the study conducted, survey instrument was recognized as indispensable tool for data collection. It encompassed questionnaires, interviews, and observations. In this study, both survey questionnaires and interviews were utilized as data gathering mechanisms servign as mechanism to evaluate the effectiveness and performance of the system during its implementation.

Table 2 showcases the curated list of questions aimed at assessing the oevrall performance of the eSwine. These questions serve as a pivotal survey instrument meticulously designed to gather valuable feedback and insights from diverse stakeholders. The survey targets selected respondents from the livestock cooperative, swine farmers in Rosacarra, Poblacion, Salcedo, Tiguisan in Bansud, Oriental Mindoro, all falling within the defined scope of the study. Furthermore, participation extends to IT experts. Through the inclusion of these specific groups, the study aims to gather input from both end-users and individuals possessing expertise in the system.

Table 2.

Survey Questionnaire

Criteria	Indicators		Rate 4	3	2	1
1. Functional Suitability	1.1	The set of functions covers all the specified tasks and user objectives.				
	1.2	The system provides the correct results with the needed degree of precision.				
	1.3	The set of functions facilitates the accomplishment of specified tasks and objectives.				
	1.4	The system provides well-defined information.				
2. Performance Efficiency	2.1	The response and processing times and efficiency rates of the system, when performing its functions, meet requirements.				
	2.2	The amounts and types of resources used by the e-trading application, when performing its functions, meet requirements.				
	2.3	The maximum limits of the parameters meet the requirements.				
	2.4	The system's performance and operation provide a competitive advantage for the farmers.				
3. Usability	3.1	The E-trading application is appropriate for the user's needs.				
	3.2	The system has attributes that make it easy to operate and control.				
	3.3	The system users are protected against making errors.				
	3.4	The user interface enables pleasing and satisfying interaction for the user.				
4. Reliability	4.1	The system meets the needs for reliability under normal operation.				
	4.2	The system is operational and accessible when required for use.				
	4.3	The system operates as intended despite the presence of hardware or software faults.				
	4.4	In the event of an interruption or a failure, the E-trading application can recover the data directly affected and re-establish the desired state of the system.				
5. Security	5.1	The system ensures that data are accessible only to those authorized to have access.				
	5.2	The system prevents unauthorized access to, or modification of, computer programs or data.				
	5.3	The actions or events can be proven to have taken place, so that the events or actions cannot be revoke later.				
	5.4	The actions of an entity can be traced uniquely to the entity.				
	5.5	The identity of a subject or resource can be proven to be the one claimed.				
6. Compatibility	6.1	The system can perform its required function effectively without affecting other functions.				
	6.2	The system can easily share information on its function.				
	6.3	As a whole.				
7. Maintainability	7.1	The system is composed of discrete components such that a change to one component has minimal impact on other components.				
	7.2	An asset can be used in more than one system, or in building other assets.				
	7.3	The effectiveness and efficiency with which it is possible to assess the impact of an intended change on one or more of its parts, diagnose a system for deficiencies or causes of failures, or identify parts to be modified.				
	7.4	The system can be effectively and efficiently modified without introducing defects or degrading existing system quality.				

Table 2.
Continued

Criteria	Indicators		Rate 4	3	2	1
8. Portability	8.1	The system can effectively and efficiently be adapted for different or evolving hardware, software, or other operational or usage environments.				
	8.2	The effectiveness and efficiency with which the system can be successfully installed and/or uninstalled in a specified environment.				
	8.3	The system can replace another specified software product for the same purpose in the same environment				

The proponents employed a five-point Likert scale, with mean range interpretations as follows: (1) 0.00 to 1.49 indicating poor, (2) 1.50 to 2.49 denoting fair, (3) 2.50 to 3.49 signifying good, (4) 3.50 to 4.49 representing very good, and (5) 4.50 to 5.00 indicating excellent, as illustrated in Table 3 below.

Table 3.
Likert Scale

Scale	Range	Verbal Interpretation
5	4.50 – 5.00	Excellent
4	3.50 – 4.49	Very Good
3	2.50 – 3.49	Good
2	1.50 – 2.49	Fair
1	0.00 – 1.49	Poor

Results and Discussion

1. Web-Based Swine Monitoring Page

The following figures compromised the function of the web-based monitoring page and show the process of the system.

Figure 4.
Piglet Dashboard

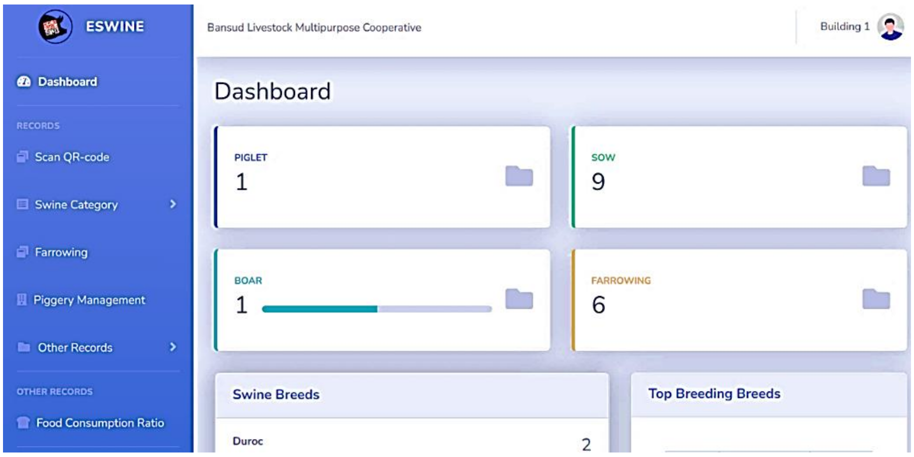


Figure 4 shows the monitoring page of the system of the piglet. On the left side of the navigation bar, users can choose between piglet, sow, and boar depending on the record that they want to view and monitor. Upon clicking the category of piglet, the corresponding page appears on the right side of the side navigation.

Figure 5.
Adding Piglet Page

Figure 5 displays the adding page of the piglet. This is composed of piglet ID, sire, dam, pig type, swine type, and building number of the swine. The data being entered were saved to the database and the corresponding data were shown in table format and ascendingly ordered.

The components of the adding page include the following fields:

1. Piglet ID: This field captures the unique identification number assigned to each piglet, allowing for individual tracking and record-keeping.
2. Sire: The sire field records the identification or name of the piglet's father, enabling the tracking of lineage and genetic information.
3. Dam: The dam field records the identification or name of the piglet's mother, facilitating lineage tracking and genetic analysis.
4. Pig Type: This field specifies the piglet's classification or category based on specific criteria such as age or weight, aiding in an effective management and grouping of piglets.
5. Swine Type: The swine type field indicates the broader classification or category of the piglet, such as crossbreed, providing relevant information for breeding and genetic analysis purposes.
6. Building Number: This field captures the assigned building number or location of the swine housing facility where the piglet is situated, aiding in the easy identification and management of piglets in different areas.

Figure 6.
Piglet Page

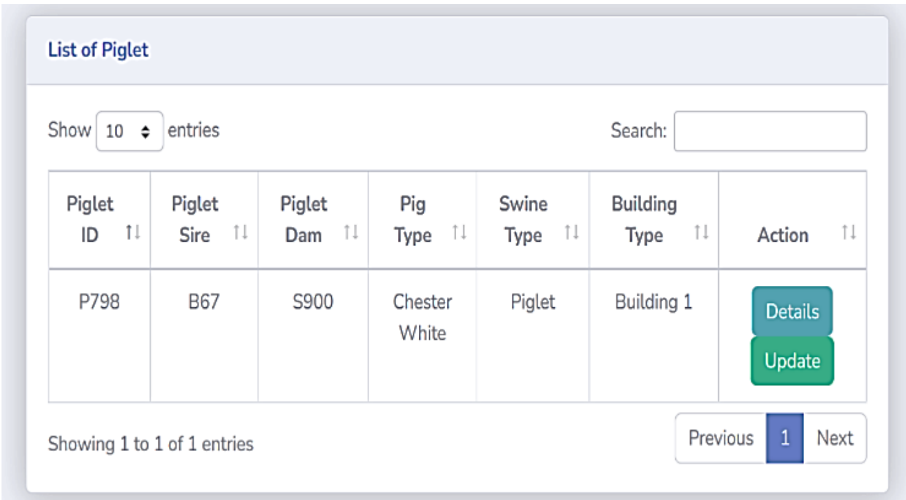


Figure 6 showcases the piglet list that is inside certain buildings. The data presented in this figure was the data being entered by the user previously on the adding record page. The user can view the details and update the swine type if the specific swine has undergone a transition into the sow phase.

Figure 7.
Update Piglet

Fsigure 7 caters the user to update the swine type of the piglet. If the farm owner or manager wants to give the piglet a new transition phase into a sow, they can update the record. Then the record of a particular swine was copied to the table of sow but still retains the data from the piglet table.

Figure 8.
Boar Dashboard

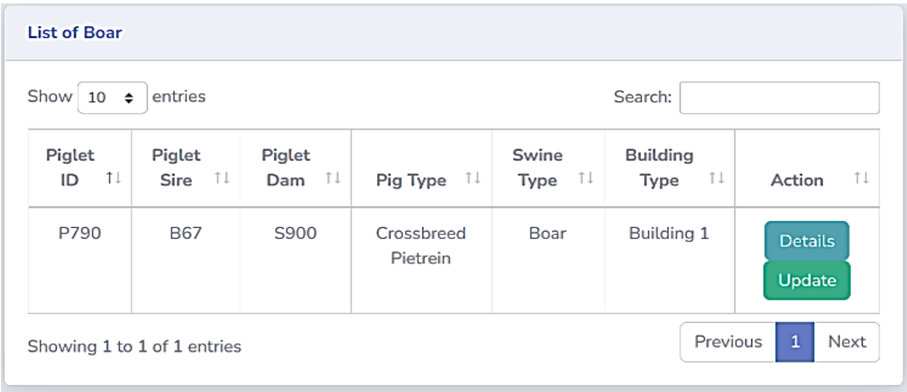
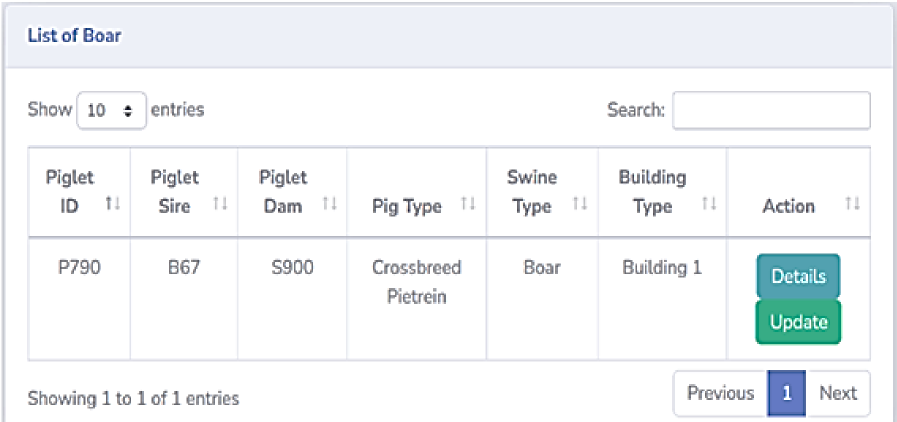


Figure 8 presents the monitoring page of the system for boar. When the user chose the category of boar, the corresponding page should appear on the right of the side navigation..

Figure 9.
Add Boar Page

Figure 9 shows the adding page of the boar composed of piglet ID, sire, dam, pig type, swine type, and building number of the swine. The data being entered were saved to the database and were shown to the data table that was ascendingly ordered.

Figure 10.
Boar Page


List of Boar

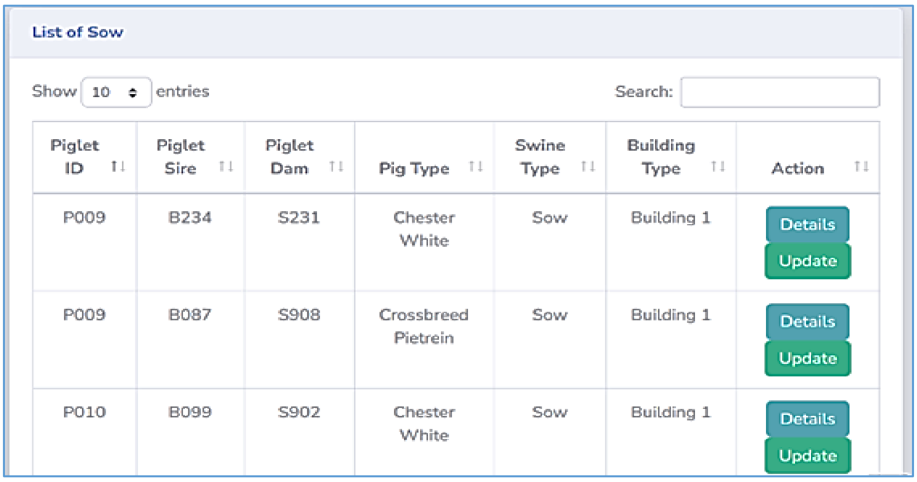
Show 10 entries Search:

Piglet ID	Piglet Sire	Piglet Dam	Pig Type	Swine Type	Building Type	Action
P790	B67	S900	Crossbreed Pietrein	Boar	Building 1	Details Update

Showing 1 to 1 of 1 entries Previous 1 Next

Figure 10 illustrates shows the boar list that is inside a certain building. The data presented in this figure was the data being entered by the user previously on the adding record page. The user can view the details and update the swine type if the specific swine has undergone a transition into the sow phase.

Figure 11.
Sow Dashboard


List of Sow

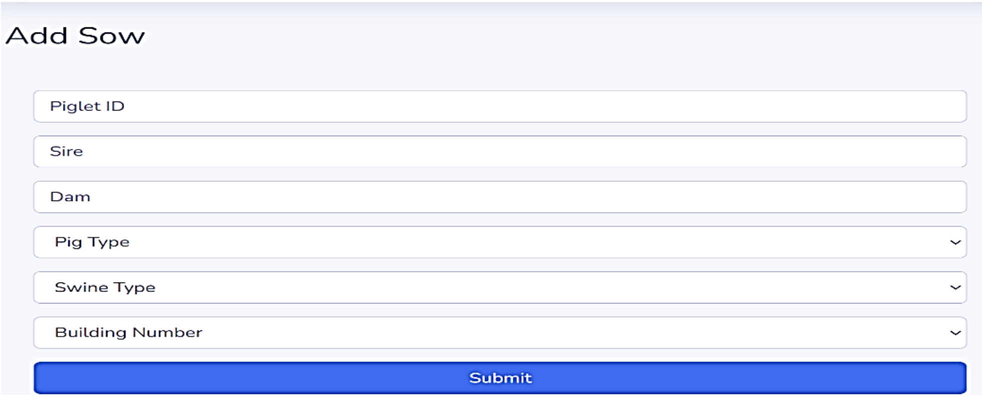
Show 10 entries Search:

Piglet ID	Piglet Sire	Piglet Dam	Pig Type	Swine Type	Building Type	Action
P009	B234	S231	Chester White	Sow	Building 1	Details Update
P009	B087	S908	Crossbreed Pietrein	Sow	Building 1	Details Update
P010	B099	S902	Chester White	Sow	Building 1	Details Update

Figure 11 shows the monitoring page of the system for sow. When the user chose the category of the sow, the corresponding page should appear on the right of the side navigation. All of the updated data and changes of the farm worker from the piglet table were shown here on the sow page. The user also has the ability to view and update details anytime anywhere.

Figure 12 depicts the adding page of the sow. This is composed of piglet ID, sire, dam, pig type, swine type, and building number of the swine. The data entered will be saved to the database and will be shown in the data table that was ordered in ascending format.

Figure 12.
Add Sow Page



2. Integration of QR Code System

Figure 13 shows the page that was made to scan the QR code of each swine and display details as soon as the QR code was scanned. When the user placed the mobile phone on top of the QR code, the website detects the code and displays the data stored on the code.

Figure 13.
QR Code Scanning

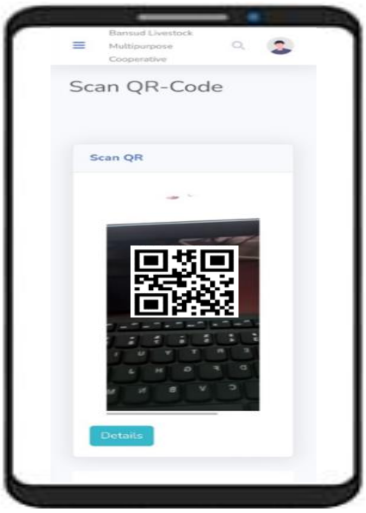


Figure 14.
QR Code Scanning Result Page

Figure 14 will display the details that correspond to the specific QR code given to the swine for their unique identification. The details that are being shown were connected to the data from the database.

Figure 15.

Farrowed Page Building 1

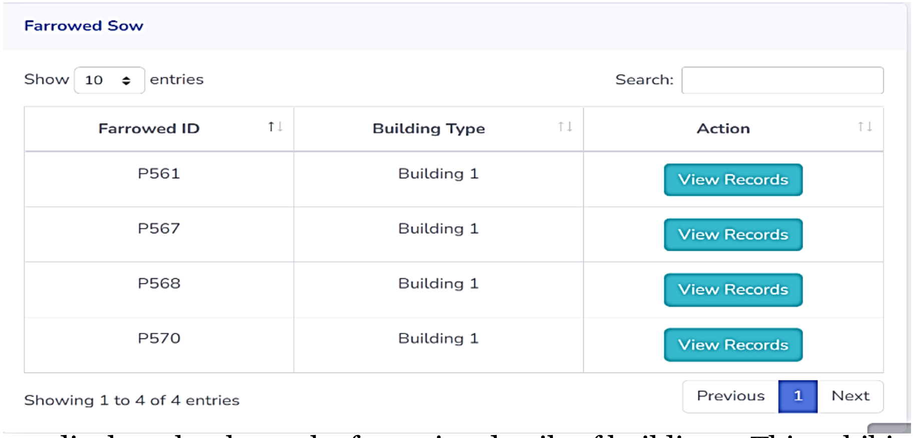


Figure 15 displays the shows the farrowing details of building 1. This exhibits the overall record of the sow and its breeding records.

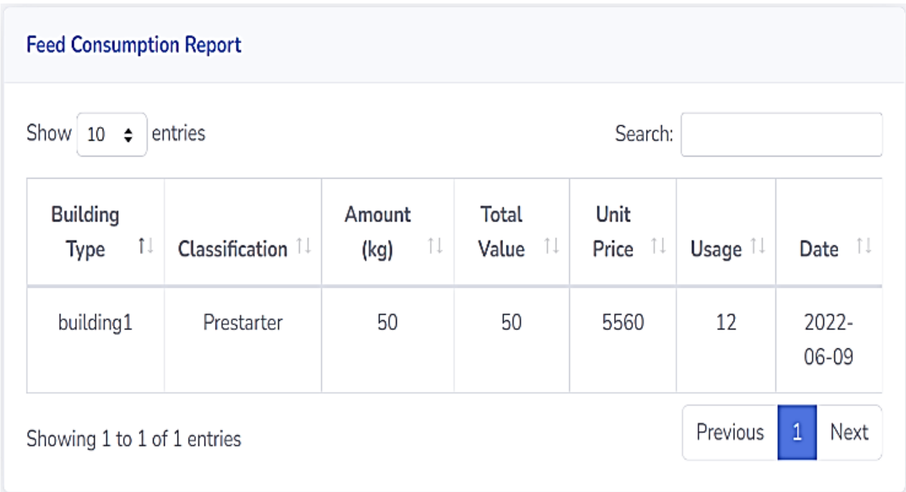
3. Report Generation

The figures below show the feed consumption record, feed ratio guide, isolation report, isolation and feed download reports.

Figure 16 shows the feed consumption record of the swine per building. It consists of the building number, classification, amount intake, total value, unit price, usage, and the date it was recorded. These data were recorded based on how often they gave food to each swine. In the case of BLMC farm, they are giving food to the swine three times a day.

Figure 16.

Feed Consumption Record



The feed consumption record includes the following data points:

1. Building Type: Each swine housing unit is assigned a unique building number, enabling the identification and differentiation of various locations within the farm.
2. Classification: The swine classified into different categories based on age, weight, or nutritional requirements. It allows for targeted feeding strategies and proper allocation of resources.

3. Amount: The quantity of feed consumed by the swine in each feeding instance is recorded, providing insights into the individual or collective appetite of the swine within the building.
4. Total Value: The total value indicates the cumulative amount of feed consumed by the swine over a specific period. It reflects the overall feed consumption and helps evaluate the efficiency of feed utilization.
5. Unit Price: The unit price represents the cost associated with each unit of feed provided to the swine, allowing for the calculation of the total feed expenditure.
6. Usage: The usage column indicates the number of feedings per day or the frequency at which the swine receive their feed. In the case of the commercial farm, the swine's feed three times a day.
7. Date: The date on which feed consumption is recorded, enabling the tracking of consumption trends over time.

Figure 17 .
Food Ratio Guide

Food Ratio

Age of Pig (Weeks)	Weight (kg)	Daily Gain (g)	Feed Consumption per day (kg)	Water Consumption per day (L)
4	7	210	0.35	0.9
6	12	400	0.75	1.9
8	21	625	1.0	2.5
10	30	655	1.2	3.0
12	40	710	1.4	3.6
14	51	805	1.7	4.2
16	65	970	1.9	4.8

Figure 17 displays the suggested feeding ratio as a guideline to help ensure that all swine receive an appropriate diet to support their growth and achieve their target weight. The feeding ratio is a recommended proportion of nutrients and feed components provided to meet their nutritional requirements.

Figure 18.
Isolation Page

List of Isolated Swine

Show 10 entries   Search:

Piglet ID	Temperature	Date Recorded	Building Type
P453	38.9	2021-11-04	Building 1
P867	38.9	2022-06-06	build1

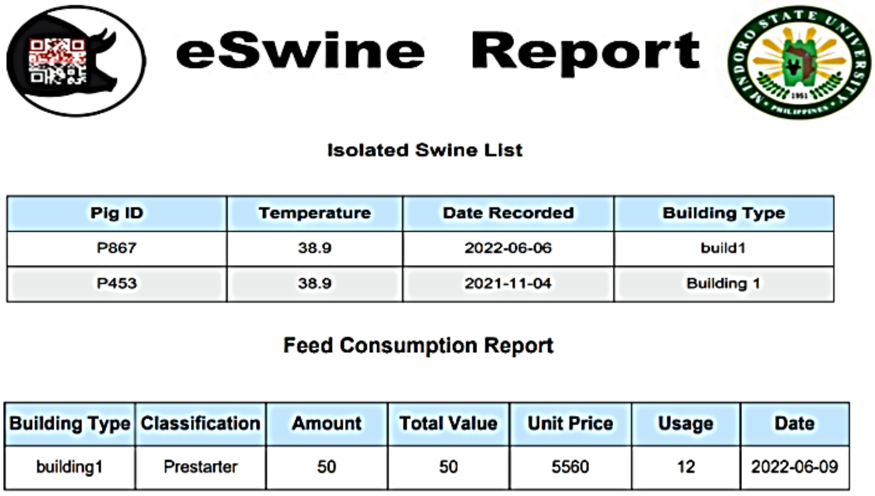
Showing 1 to 2 of 2 entries   Previous 1 Next

Figure 18 presents the isolated record of the swine from all the buildings present on the farm. The data needed for these are the piglet ID, the temperature of the swine, the date recorded, and the location of the swine. All of these data are being recorded in the database.

These data are important to the side of the admin so that they can monitor and isolate the swine in case they got sick or become unhealthy.

Figure 19.

Isolation and Feed Download Reports



eSwine Report

Isolated Swine List

Pig ID	Temperature	Date Recorded	Building Type
P867	38.9	2022-06-06	build1
P453	38.9	2021-11-04	Building 1

Feed Consumption Report

Building Type	Classification	Amount	Total Value	Unit Price	Usage	Date
building1	Prestarter	50	50	5560	12	2022-06-09

Figure 19 demonstrate the admin side of the system. The admin can download the report based on the data entry of the farm staff assigned per building. All of the data entered by the farm staff is reflected on the admin side board and the admin can view the overall record of the swine from each building.

Evaluation Result

4. ***Evaluate the system's functionality, reliability, efficiency, usability, security, compatibility, maintainability, and portability using ISO 25010 software quality standards.***

Following the development and implementation of eSwine, the proponents proceeded to evaluate its performance using ISO 25010 as a guiding framework. This evaluation encompassed feedback from a comprehensive sample size comprising 50 respondents. The detailed outcomes of this evaluation is presented in Table 4.

Table 4.

Summary of System Evaluation Results

Criteria	Mean	Rank	Verbal Interpretation
1. Functional Suitability	3.68	1	Very Good
2. Usability	3.64	4.5	Very Good
3. Reliability	3.64	4.5	Very Good
4. Compatibility	3.63	6	Very Good
5. Security	3.66	2	Very Good
6. Performance Efficiency	3.60	8	Very Good
7. Maintainability	3.61	7	Very Good
8. Portability	3.65	3	Very Good
Overall Mean	**3.64**		**Very Good**

The evaluation results of the eSwine system indicate a commendable performance across various criteria. Functional Suitability stands out as the top-performing criterion, earning a mean score of 3.68 and securing the first rank, denoted as "Very Good," underscoring its effectiveness in meeting functional requirements. Following closely are Security and Portability, ranking second and third respectively with mean scores of 3.66 and 3.65, both assessed as "Very Good," highlighting the system's robust security measures and adaptability across platforms. Usability and Reliability share the fourth position, each scoring 3.64, also deemed "Very Good," reflecting a high level of user-friendliness and consistent performance.

Compatibility ranks sixth with a score of 3.63, maintaining the "Very Good" rating, indicating strong alignment with diverse environments. While Performance Efficiency ranks eighth with a mean score of 3.60, it still earns a "Very Good" assessment, suggesting potential areas for efficiency improvement. Similarly, Maintainability secures the seventh position with a score of 3.61, reaffirming the system's ease of maintenance. The overall mean score of 3.64 reflects the system's consistent "Very Good" performance across all evaluated criteria, affirming its reliability and effectiveness in fulfilling swine management needs.

These evaluation results serve as a summary assessment of the system's performance and characteristics. They provide valuable insights into specific areas for improvement which can be addressed to enhance the system's overall quality

Conclusion

The QR-Code Driven Swine Farm Monitoring System was developed as a web-based solution with the aim of assisting farm owners and backyard farmers in effectively monitoring their swine data. The system aimed to minimize human errors and enhance operational efficiency within the swine farming process. By QR codes, the system offered a convenient method for identifying and retrieving specific swine details.

The QR code scanning functionality enabled the system to access stored data associated with individual swine, allowing quick and accurate information retrieval. The system employed a MySQL database to store and manage the swine records, ensuring easy data retrieval for farm owners and administrators. The availability of comprehensive data summaries facilitated various purposes such as financial analysis, performance evaluation, and planning. Additionally, the eSwine system offered the capability to generate reports in PDF format, providing valuable resources for future reference and decision-making.

Overall, the eSwine system successfully addressed the specific needs of swine farm monitoring, providing an efficient and reliable platform for data management. By incorporating QR codes and implementing a user-friendly web-based interface, the system aimed to modernize operations, enhance accuracy, and facilitate informed decision-making for farm owners and backyard farmer.

Recommendations

In light of the successful development and implementation of the QR Code Driven Swine Farm Monitoring System, the following recommendations are suggested: (1). Continuous updates and improvements be made to the system to ensure its compatibility with evolving technologies and farming practices. This could involve incorporating features such as real-time data monitoring and alerts to provide farm owners with timely information on swine health, productivity, and environmental conditions. (2). Efforts should be made to enhance the system's accessibility and user-friendliness, particularly for users with limited technical expertise. This could include providing comprehensive user manuals, tutorials, and customer support services to assist users in navigating the system effectively. (3). Consider the importance of data security in agricultural operations, it is recommended that robust measures be implemented to safeguard sensitive information stored within the system. This could involve encryption protocols, regular security audits, and user authentication mechanisms to prevent unauthorized access to farm data. (4). Collaboration with agricultural experts and stakeholders could provide valuable insights into additional features or functionalities that could be integrated into the system to better serve the needs of swine farmers. (5). Conduct routine security audits within the eSwine system. These audits will serve to uphold stringent data security measures, safeguarding the confidentiality and integrity of data. By implementing regular assessments, potential vulnerabilities can be identified and addressed promptly, thereby fortifying the system's resilience against security threats and enhancing trust among users.

Acknowledgment

The authors extend their sincere gratitude to the dedicated employees of the Bansud Livestock Cooperative whose invaluable insights and cooperation significantly contributed to the development and implementation of the eSwine system. They are deeply appreciative of the swine farmers whose cooperation and feedback provided essential perspectives in shaping the system to meet the practical needs of the swine farming community. Heartfelt thanks also go to the IT experts whose expertise and guidance were instrumental in ensuring the technical robustness and functionality of the system. The authors would also like to express their appreciation to the Research, Development, and Extension (RDE) office of the Mindoro State University for their steadfast support and encouragement throughout the project. Their collaborative efforts and resources have been indispensable in advancing the research and development initiatives aimed at enhancing agricultural practices in the region.

REFERENCES

Moeller, S., & Crespo, F. L. (2009). Overview of world swine and pork production. *Agricultural sciences*, *1*, 195-208. https://books.google.com.ph/books?hl=en&lr=&id=TxGuCwAAQBAJ&oi=fnd&pg=PA195&dq=Overview+of+World+Swine+and+Pork+Production+-+Steven+J.+Moeller,+Francisco+Le%C3%B3n+Crespo+&ots=zsk4wsVcIt&sig=T611wPdpPjc82wefaF4NoY--34A&redir_esc=y#v=onepage&q=Overview%20of%20World%20Swine%20and%20Pork%20Production%20-%20Steven%20J.%20Moeller%2C%20Francisco%20Le%C3%B3n%20Crespo&f=false.

Philippine Star. (2016). Philippine beefs up competitiveness of swine industry https://www.philstar.com/business/agriculture/2016/03/12/1562207/philippine-beefs-competitiveness-swine-industry#:~:text=The%20Philippine%20swine%20industry%20is,kept%20by%20smallhold%20pig%20raisers.

Acosta, A. (2022, March 29) Pronutrients, Swine Philippine Swine Update.https://www.veterinariadigital.com/en/articulos/philippine-swine-update/

Catelo, M.A., (2017) Sustainable Productivity Growth in Philippine Swine Production Asian Journal of Agricultural Extension, Economics & Sociology Retrieved from https://zenodo.org

Dipay, J. M. B., Fabregas, A. C., & Ado, R. G. (2018). Animal Identification and Records Monitoring Tool using RFID (AIRMTR). *KnE Social Sciences*, 721-730. https://doi.org/10.18502/kss.v3i6.2415.

Frost, A. R., Schofield, C. P., Beaulah, S. A., Mottram, T. T., Lines, J. A., & Wathes, C. M. (2016). A review of livestock monitoring and the need for integrated systems. Computers and electronics in agriculture, 17(2), 139-159. https://www.sciencedirect.com/science/article/abs/pii/S0168169996013014.

Dogan, H., et.al, (2016) Use of Radio Frequency Identification Systems on Animal Monitoring. Suleyman Dimirel University. Isparta, Turkey Retrieved from https://www.researchgate.net/publication/308167938_Use_of_Radio_Frequency_Identification_Systems_on_Animal_Monitoring Retrieved date: March 26, 2021

Tiwari, S. (2016, December). An introduction to QR code technology. In 2016 international conference on information technology (ICIT) (pp. 39-44). IEEE. https://ieeexplore.ieee.org/abstract/document/7966807.

Focardi, R., Luccio, F. L., & Wahsheh, H. A. (2019). Usable security for QR code. Journal of Information Security and Applications, 48, 102369. https://www.sciencedirect.com/science/article/abs/pii/S2214212619301693,

Khandal, D., & Somwanshi, D. (2017, August). A novel cost-effective access control and auto filling form system using QR code. In 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI) (pp. 1-5). IEEE. https://ieeexplore.ieee.org/abstract/document/7275575

Tarjan, L., Šenk, I., Tegeltija, S., Stankovski, S., & Ostojic, G. (2016). A readability analysis for QR code application in a traceability system. Computers and Electronics in Agriculture, 109, 1–11. doi:10.1016/j.compag.2014.08.015 https://www.sciencedirect.com/science/article/abs/pii/S0168169914002142

Yang, Feng & Wang, Kaiyi & Han, Hanyun & Qiao, Zhong. (2018). A Cloud-Based Digital Farm Management System for Vegetable Production Process Management and Quality Traceability. Sustainability. 10. 4007. 10.3390/su10114007. https://www.researchgate.net/publication/328682719_A_Cloud-CloudBased_Digital_Farm_Management_System_for_Vegetable_Production_Process_Management_and_Quality_Traceability/citation/download

Neethirajan, S. (2020). Digitalization of Animal Farming. https://www.preprints.org/manuscript/202007.0040/v1

Lyons, C.; Bruce, J.; Fowler, V.; English, P. A comparison of Productivity and Welfare of Growing Pigs in Four Intensive Systems. *Livest. Prod. Sci.* **1995**, *43*, 265–274

Sahin, C.; Bolat, E.D. Development of Remote Control and Monitoring of Web-based Distributed OPC system. *Comput. Stand. Interfaces* **2009**, *31*, 984–993.

Li, L.H.; Huang, R.L.; Huo, L.M.; Li, J.X.; Chen, H. Design and Experiment on Monitoring Device for Layers Individual Production Performance Parameters. *Trans. Chin. Soc. Agric. Eng.* **2012**, *28*, 160–164.

Mungroo, N.; Neethirajan, S. Biosensors for the Detection of Antibiotics in Poultry Industry—A Review. *Biosensors* **2014**, *4*, 472–493.

Godfray, H.C.J.; Garnett, T. Food security and sustainable intensification. *Philos. Trans. R. Soc. B Biol. Sci.* **2014**, *369*, 20120273.

Pan, L.; Xu, M.; Xi, L.; Hao, Y. Research of Livestock Farming IoT System Based on RESTful Web Services. In Proceedings of the 5th International Conference on Computer Science Network Technology, Changchun, China, 10–11 December 2016; pp. 113–116.

Ahmed, S.T.; Mun, H.S.; Islam, M.M.; Yoe, H.; Yang, C.J. Monitoring Activity for Recognition of Illness in Experimentally Infected Weaned Piglets Using Received Signal Strength Indication ZigBee-based Wireless Acceleration Sensor. *Asian-Austral. J. Anim. Sci.* **2016**, *29*, 149–156.

Vranken, E.; Berckmans, D. Precision Livestock Farming for Pigs. *Anim. Front.* **2017**, *7*, 32–37.

Neethirajan, S. Recent Advances in Wearable Sensors for Animal Health Management. *Sens. Bio-Sensing Resh.* **2017**, *12*, 15–29.

Racewicz, P.; Sobek, J.; Majewski, M.; Rozanska-Zawieja, J. The Use of Thermal Imaging Measurements in Dairy Cow Herds. *Anim. Sci. Genet.* **2018**, *14*, 55–69.

Benjamin, M.; Yik, S. Precision Livestock Farming in Swine Welfare: A Review for Swine Practitioners. *Animals* **2019**, *9*, 133.

Choi, H.; Mayakrishnan, V.; Kim, T.; Lim, D.; Park, S. Livestock Production in Korea: Recent Trend and Future Prospects of ICT Technology. *FFTC Agric. Policy Platf.* **2019**. Available online: https://ap.fftc.org.tw/article/1616 (accessed on 10 January 2021)

Trendov, N.M.; Varas, S.; Zeng, M. *Digital Technologies in Agriculture and Rural Areas*; FAO: Rome, Italy, 2019; p. 26.

Van der Burg, S.; Bogaardt, M.J.; Wolfert, S. Ethics of Smart Farming: Current Questions and Directions for Responsible Innovation Towards the Future. *NJAS Wagening J. Life Sci.* **2019**, *90*, 100289.

Bacco, M.; Barsocchi, P.; Ferro, E.; Gotta, A.; Ruggeri, M. The Digitisation of Agriculture: A Survey of Research Activities on Smart Farming. *Array* **2019**, *3–4*, 100009.

FAO. *The State of Food and Agriculture: Livestock in Balance*; FAO: Rome, Italy, 2009; Volume 180, pp. 492–496.

Lekagul, A.; Tangcharoensathien, V.; Liverani, M.; Mills, A.; Rushton, J.; Yeung, S. Understanding antibiotic use for pig farming in Thailand: A qualitative study. *Antimicrob. Resist. Infect. Control* **2021**, *10*, 3.

Pandey, S.; Kalwa, U.; Kong, T.; Guo, B.; Gauger, P.; Peters, D.; Yoon, K. Behavioral Monitoring Tool for Pig Farmers: Ear Tag Sensors, Machine Intelligence, and Technology Adoption Roadmap. *Animals* **2021**, *11*, 2665.

Bailey, D.; Trotter, M.; Tobin, C.; Thomas, M. Opportunities to Apply Precision Livestock Management on Rangelands. *Agric. Spat. Anal. Model.* **2021**, *5*, 1–13.

Hashem, N.M.; Hassanein, E.M.; Hocquette, J.-F.; Gonzalez-Bulnes, A.; Ahmed, F.A.; Attia.

Y.A.; Asiry, K.A. Agro-Livestock Farming System Sustainability during the COVID-19 Era: A Cross-Sectional Study on the Role of Information and Communication Technologies. *Sustainability* **2021**, *13*, 6521.

Schillings, J.; Bennett, R.; Rose, D.C. Exploring the Potential of Precision Livestock Farming Technologies to Help Address Farm Animal Welfare. *Front. Anim. Sci.* **2021**, *2*, 639678.

Micle, D.; Deiac, F.; Olar, A.; Drența, R.F.; Florean, C.; Coman, I.G.; Arion, F.H. Research on Innovative Business Plan. Smart Cattle Farming Using Artificial Intelligent Robotic Process Automation. *Agriculture* **2021**, *11*, 430.

Long, S.; He, T.; Kim, S.W.; Shang, Q.; Kiros, T.; Mahfuz, S.U.; Wang, C.; Piao, X. Live Yeast or Live Yeast Combined with Zinc Oxide Enhanced Growth Performance, Antioxidative Capacity, Immunoglobulins and Gut Health in Nursery Pigs. *Animals* **2021**, *11*, 1626.