REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 24 October 2023; Revised: 12 November 2023; Accepted: 06 December 2023

Enhancing Livestock Production: A Comprehensive Examination of Swine Health and Sustainable Management Practices

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Abstract

Livestock production particularly swine farming, plays a pivotal role in meeting the global demand for high-quality protein. Through the use of sensor such as cameras, which integrate visual, aural and mobility data, it is feasible to observe animals in a non-intrusive way and assess their well-being and productivity. This comprehensive research highlights the use of cutting-edge technologies to important problems while examining various facets of swine health and sustainable management practices. It looks into the welfare issues that the swine business has, with an emphasis on the welfare of the pigs throughout their lives. The study of swine technology applications includes activity tracking, moment of lameness detection, sound identification, infrared thermal imaging and camera-based physiological and behavioural evaluation. Analyzing the technical duties performed but specialist in swine production provides insight into the abilities needed to use the newest technologies. The technologies provide useful information on stress management, early illness identification and general health monitoring, which helps to raise standards for the welfare of the swine population. The assessment emphasizes the necessity of cooperation between swine industry participants, experts and professionals who are essential to the accurate production of animals. Pig experts can take on a more comprehensive role as advisors in conveying accurate livestock agricultural technology and its implications to their clients because they act as advocates for their clients and the animals, interpreters of benchmarking data as well as stewards in regulatory along with traceability programs.

Keywords: Pigs, Health Issues, Specialists, Livestock Production, Monitoring

INTRODUCTION

In the field of contemporary agriculture, maximizing livestock output is crucial to satisfy the expanding demand for animal products worldwide while taking sustainability issues into account. As an essential part of the livestock industry, swine need to be carefully examined to improve their management and overall health (1). It is projected that there will be nine billion people and the world needs to see a 70% increase in global food output, a market for meat and other animal products is growing and rising on a worldwide scale (2). Demand is anticipated to rise as food preferences move in favor of animal-based protein as economic situations in emerging nations improve. Farmers are forced by economies of scale to develop and extend their businesses, which raises output. As such, it is anticipated that farms overseen by fewer farmers would have a higher number of elevated heads.

Furthermore, farmers are becoming older on average (3). Especially in developed nations, the observational ability and practical expertise that farmers once depended on to ensure effective daily herd management are no longer sufficient given these conditions (growing farm sizes and animal populations) (4). With the growing market for goods obtained from animals, two more important factors that are propelling the adoption of contemporary livestock management techniques are worth mentioning: management of the environmental effect of livestock and animal welfare. These are delicate subjects with a lot of international and national legal regulations. Methods for tracking and managing required and optional regulatory obligations need to be quick,

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easy to use and efficient, given the importance of these concerns. Thus, the need for automated real-time monitoring in the cattle business is growing (5). The rates at which sludge accumulates on different farm types differ considerably, contingent upon a number of variables such as feed variety, bedding composition, environmental conditions and the pre-treatment techniques applied to eliminate particles prior to lagoon entry (6). Therefore, to forecast the rate of sludge formation utilizing various process models, the exact farm site, farming methods and farming strategies must be understood. Sludge volume can go up or down depending on what bedding and manure particles reach the lagoon. To manage manure and recycle sewage calories, more land is needed as a result of livestock operations expanding, yet the existing receiving ground area is not sufficient (7). By producing reused water for cleaning, solid fertilizer and cleaning substances, reducing odor pollution and reducing land area requirements, manure's productivity has increased thanks to solid-liquid (S/L) separating management. Because agricultural techniques vary and have an impact on the physio-chemical properties of manure, modeling gas emissions from Munich miniature swine (MMSs) has been difficult (8). Figure (1) represents swine production as an established practice for handling manure before it is applied in the field of composting. Composting lowers bacterial and pathogen abundance while increasing nutritional density.

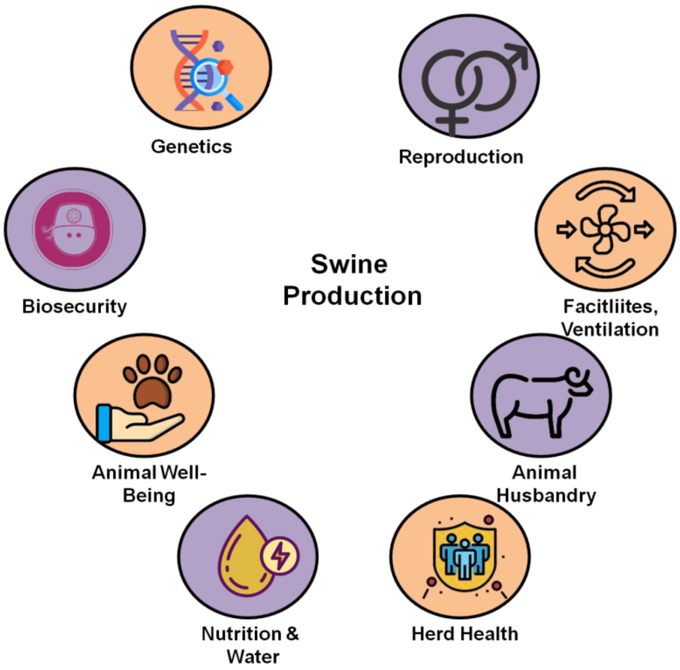

Figure (1). Swine production

Source: (Author)

The gas emissions resulting from the two distinct manure management techniques, windrow composting and stockpiling, which are employed in Australian feedlots, were quantified. They used a micrometeorological method (9). Despite being the best material for improving pig housing (based on the qualities of various enrichment materials mentioned in the recommendation), straw is difficult to incorporate into slatted floor systems because it can clog the manure system. Micrometeorological methods have the advantages that are non-intrusive, measuring emissions over wider regions, offering higher dynamic sampling rates and having the capacity to verify enhanced thermal estimations derived from observations with the chambers. Micrometeorological mass balance (MMB) is a relatively new technique for measuring emissions from tiny, well-defined source locations. They have been employed to quantify pollutants from the storage of animal wastes ponds and small field plots with varying chemical or fertilizer treatments (10). A balanced approach that guarantees both economic viability as well as environmental responsibility in the livestock industry, the goal is to improve swine health along with sustainable management practices through the implementation of strong disease prevention measures, optimized nutrition and the integration of modern technology.

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The paper (11) suggested that thematic issues were divided into four divisions according to their main areas of interest: obstacles in planning and developing silvopasture, livestock performance, environmental advantages, fodder production, quality understanding of some of the biophysical and socioeconomic aspects of silvopastoral systems has improved as a result of the material provided, but it has highlighted significant study gaps. The study (12) suggested educating swine veterinarians and the people they serve about precision livestock farming. It provided a broad overview of the technology that was available, reviewing investigation, economically available technology, talking about the implications, future possibilities for pig farmers and practitioners. The article uses the common swine sector audit's (CSSA) pig welfare criteria to explain how the welfare of pigs might be improved by using these applications that meet stakeholder expectations in the pork sector.

The study (13) examined the potential and obstacles that sensor technology offered to assist animal producers in increasing the amount of meat and animal products they produce. The article examined how animals can benefit from big data, AI, sensors and machine learning producers in improving animal welfare, cutting expenses and growing a higher number of creatures per acre. It delves at the various obstacles and constraints that technology poses presents. The study (14) provided a critical assessment of the latest developments in Precision Livestock Farming (PLF) technology, especially big data, block-chain and biometric sensors, to digitalize animal husbandry. Real-time tracking of each animal's health and activities was made possible using physiological scanners using either non-invasive or invasive methods. The research (15) suggested the application of the article's comprehensive literature review, which focuses on two key areas: animal health and grazing. The present sensors, software and data analysis approaches were presented in the overview. This explained the growing transparency of data sources and emphasized prospects for machine learning in the cattle industry. It was discovered that there were a number of research hurdles and ML used in PLF was in its infancy.

SWINE INDUSTRY'S WELFARE CHALLENGES

Customers anticipate that food generated from animals will be prepared with consideration for the sake of the animals' well-being (16). Certain guidelines and policies have been created to guarantee the public that animals have gotten the right care. Pig comfort, lameness, body condition, prolapsed and sickness detection are some of the issues related to individual and collective pig welfare that will be covered. Figure (2) represents the number of pigs and yield of pork.

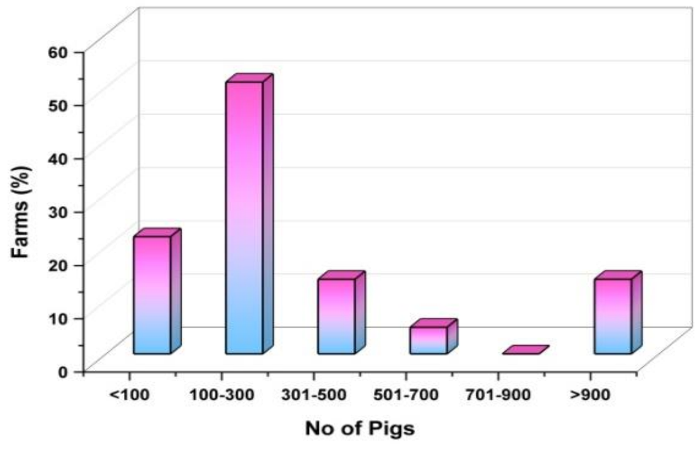

Figure (2). Number of pigs and yield of pork

(Source: Author)

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Group Welfare

Individuals who are sick or injured constitute a vulnerable group with specific requirements and preferences at the group level. The illness includes changed behavior, such as huddling, relaxing, shivering, as well as adjustments to social interactions coupled with decreased eating and drinking. After immunization, cook observed the piglets' spatial distribution and saw more times when they cuddled together, which was linked to a fever reaction (17). Evaluation of pigs that are not aware of human presence helps to observe the behavior patterns that they exhibit. Pig thermal comfort behavior, as demonstrated by the way they lie in the enclosure and posture themselves, indicates if a pig is too hot, too cold, or just right. Oral activities that are detrimental to pigs include biting the tail, flank and ears. Biting the tail can result in wounds as well as partial or complete amputation. Excessively aggressive social feeding behavior and a stressful environment are two of the numerous contributing reasons for tail biting (18). Pigs with bitten tails were more likely to have lower weights, respiratory infections, locomotor issues, abscesses and arthritis, according to slaughter surveys. An additional thought on tail biting is the necessity for prompt euthanasia of pigs with open wounds (such as flank and tail biting) that are not expected to heal after two days of therapy.

Physical State

Food quality is assessed by calculating the body condition score (BCS), which is an evaluation of the composition of the body. Obtaining predictive markers of body status is valuable because of the associations with shoulder sores and lameness. Research on dairy cattle indicated that there are temporal correlations between cattle with a BCS between lameness and poor health of less than two were most likely to become lame as well as cows with a larger BCS decline were more likely to become lame yet they were less likely to recover in the next 15 days (19). According to survey results, sows with BCS and disability culls from the breeding herd had lower back fat.

SYNOPSIS OF APPLICATIONS FOR SWINE HEALTH

It provides an overview of issues related to the well-being of individuals and groups of pigs, including disability, physical state, rupture, pig comfort, hostile conduct and disease detection; it links research and applications for remote monitoring in precision cattle husbandry.

Moment of lameness

Wretched sows are predicted to exhibit altered behavior because of their limited ability to move about physically, pain, overall discomfort and illness-related behaviours. Non-resolved lame sows were found to shift positions, sit back additionally and come into touch compared to the normal control sows, using the wall in groups. Those behavioral shifts seen as an attempt to escape the group and find refuge, or they could be seen as symptoms of suffering. Regretfully, lameness goes unnoticed. Economical promotes nursing lame sows till they reach a late gestation and moderate to severe condition. This is because fewer workers are responsible for managing a larger number of animals. Other characteristics of lameness include swaying from side to side, shorter or irregular steps and decreased walking speed. Topological research and tracking of the motion of these creatures can be used to identify these visual traits. An objective imaging-based lameness detection system for sows is probably in the works, given the effectiveness of disability diagnosis using image analysis in dairy cattle. In this work, we use it to track movement between successive photos of a movie and compare it with each sow's actual forward movement.

Accelerometers attached to sows' legs have been shown to be effective in detecting the number of steps made during eating, posture and stepping behaviour. It seems that the most practical approach in terms of economics and ecology is the data obtained from ear tags for detecting the start of farrowing. At the same time, sows chewed on gadgets that were abandoned differently. The most decoupled bodily element in the locomotory system is the ear. However researchers found that ear tag accelerometers applied to sows might predict lameness based on a comparison of high activity (distance traveled) and rest periods (lying down). Table (1) shows the comparison of accelerometer 14 before indications of mild lameness; lame sows exhibited reduced levels of

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high activity (distance). Accelerometer sensitivity to identify unmoved behaviour, such as how long an animal lies down (96.4%), whereas additional variables, like how long an animal walks (77.5%) and stands (70.3%), were shown to have lesser accuracy.

Table (1). Comparison of Accelerometers and application
(Source: Author)

Hardware comparisons -Accelerometers	
Sensor device and examples	R Smartbow WSN Remote Insights Examples
Feature	Beneficial for monitoring motion almost immediate measurements included in wireless sensor networks (WSN) wearable sensors
Fallback	Need outside processing to get velocity and displacement information. Information is not absolute; it is relative. Weak (prone to breaking with sow-like behaviour)
Application	Motion detection and observation, such as walking as well as tracking of a position's status (e.g., laying, standing)

Monitoring Activity at the Pen Level: Grower and Nursery Pigs

Video pictures are used to evaluate hostile behaviours at the activities that take place at the pen level, including chasing, biting tails along with fins, clashing, as well as head-on collisions, in an effort to enhance welfare and automate pig monitoring. Pigs' sleeping habits (thermal comfort behavior), their standing, moving postures, along with their lateral and sternal recumbencies are distinguished by sensor data. Depth mapping monitoring has demonstrated its ability to follow pig movements, eating, drinking and aggressive behaviours (20). Because pigs tend to pile up and lie close together, using sensor monitoring to keep an eye on each pig's movements within a big herd is difficult. An automated warning system for "outbreaks" of tail-biting was developed using 3D cameras and machine learning as a means of pen monitoring. Researchers observed pigs' non-docked tail position because of tail docking (21). According to this research, a higher percentage of wounded pigs had a lower tail posture than did the pigs whose tail posture was at its peak one week before the outbreak. Figure (3) shows the swine export and monthly port.

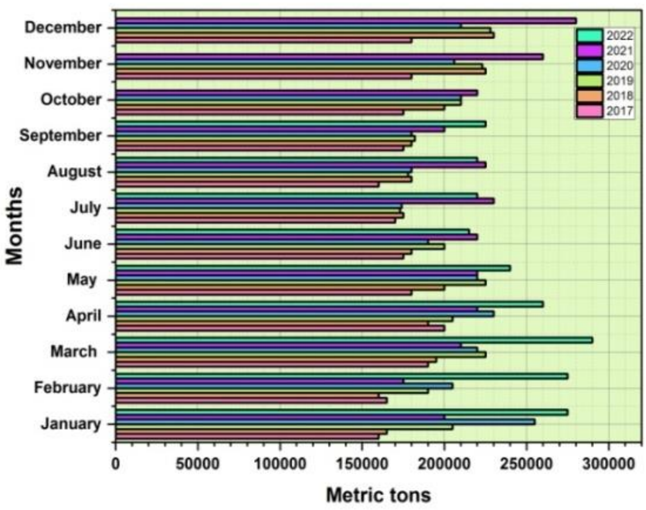

Figure (3). Swine export and monthly port
(Source: Author)

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Thermal Imaging Infrared

According to a number of studies, infrared thermography used to non-invasively measure how heat is dissipated in certain animals or bodily parts to identify illnesses like mastitis to quickly identify problems, including mastitis, locomotors issues and respiratory ailments in cows, a number of non-invasive ways to track an animal's heat dissipation is by infrared thermography. Tables (2) and (3) represent the comparison of the application. Pigs' udder, eyes and base of the ear had the strongest association with body temperature when measured with infrared thermography (22). Piglets in groups had individual illnesses identified through the use of infrared thermography. High skin temperatures are known to occur after immunization and huddling reactions have been seen in piglets as long as 20 hours after vaccination.

Table (2). Comparison of thermometer and application

(Source: Author)

Hardware comparisons-Thermometers		
Sensor device and examples	**Thermal Imaging (Television)**	**Thermometers Contained with the portable sensors**
Feature	Fantastic work in low-light conditions, remote (non-invasive) sensing, quick readings (often 15–60 fps)	Useful for variations in temperature is cheap
Fallback	Expensive (from several thousand to several hundred dollars per unit)	Slow to notice alterations, Not a ready-made setup
Application	Remote temperature sensing Low light imaging	

Sound Identification

It is possible to identify heat-related stress and high-frequency pain (23) "screams" resulting from fighting or tail biting by using sound recordings and a voice analysis algorithm. Utilizing variations in the acoustic variables, algorithms are brought by infectious pathogens. If there aren't enough microphones or the barn is noisy, sound detection hindered (24). It would be advantageous to be able to reliably differentiate between vocalizations connected to stress and those are normal, as this would allow pigs to "speak for themselves" regarding their well-being.

Table (3). Comparison of Micrometer and application

(Source: Author)

Hardware comparisons -Microphones	
Sensor device and examples	Sound talks R Monitor
Feature	Beneficial for variations in sound and frequency. Quick reads Low-cost
Fallback	Noise can easily contaminate
Application	Sustaining on a regular physiological process (in barns or pens) categorization by auditory Measurements of acceleration

4.2.3 Camera behaviour and physiology

The process of image processing converts the obtained pictures into indicators of activity (animal position and movement). Pig weight aggressiveness and gait patterns have been estimated using imaging in pigs. With the 1 kilogram (25), Pig growth rates might be tracked and computed by specialists. An analysis study employing cameras in two dimensions (2D) provides digital data. Cameras come with a high-definition camera for studying night (26) time activity or in low light, infrared is very useful and depth sensors are crucial for figuring out how close the camera is facing the beast (27). A Light emitting diode (LED) emits an infrared light pulse many times per second and the time interval between the pulse as well as each pixel's return is recorded (28). Table (4) represents the comparison of the application's low power consumption and flexibility of depth-based cameras to adjust to changing lighting and backdrop circumstances, making them desirable (29). They shield the sensors from outside hazards, including insects, dust, nitrogen and moisture.

Table (4). Comparison of Cameras and application

(Source: Author)

Hardware comparisons-Cameras		
Examples of sensor devices	dynamic, 2D Lorax	3D (RGBD) Intel RealSense Microsoft Kinect RYegrow R
Feature	useful for large amounts of data, high accuracy and detailed positional and color variational data	Remote (non-invasive) sensing quick readings A person.
Fallback	Needs to be filtered in order to find accurate data. Performance is influenced by the illumination.	The illumination influences creativity. Covers to protect from environmental factors could be necessary.
Application	Character recognition using optical means	motion awareness Extraction of topology Location and behavior of animals

Live Weight, Physical State and Anatomy

The body mass and height of individual pigs determine how the swine output is managed, which influences the herd in parameters like lighting, which affects creative thinking. It could be required to use covers to protect against environmental elements (30). Spatial concession that enables sows to lie back entirely installs one component of an animal-based CSIA metric. Research has indicated the potential for the development of automated mass and weight measurement using 3D form extraction for pig calculations.

RIGHTS TO DATA, OPENNESS AND TRACEABILITY

The implementation of Blockchain technology, which is an unchangeable digital ledger capable of tracking every transaction involving a food item as it moves through the food chain, (31) has the potential to enhance transparency regarding production practices, farm documentation, policymakers, dictatorial agencies and pharmaceutical businesses will benefit from better data gathering for global health surveillance (32). The integration of automatic data collecting with suppliers using sensors allows for the capture and recording of many animal properties, including meat quality, feed conversion rates, growth rates, wellness, ages and close-out/kill-out plans for provider profit that involve exporting or culling animals at the best times to save costs and control the usage of medicinal drugs (33). The farmer’s feedback on their management techniques supports the optimization of animal well-being and production profitability. Sensors gather and integrate current farm data from meat factories combined with information on specific animals or groups of animals.

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POSSIBILITIES

The following are some potential industries for precision livestock farming: Workforce development: Simplifying labor needs, reducing the inefficiencies of repetitive jobs, saving time and drawing in a different type of stock person are possible with an automated, objective approach to monitoring and collecting data (34). Using precision livestock farming techniques might transform our industry by focusing time and money on creating treatment plans along with protocols that are predictive. The public anticipates personalized care and positive human-animal interactions from producers. Although it is assumed that large commercial producers will embrace technology sooner rather than later, precision livestock farming can be scale-neutral (35). For instance, Herd Dogg (herd dogg.com, Ashland, OR) offers as little as twenty-five pasture-raised animal's annual remote health and behaviour monitoring services. Smaller producers have the chance to carve out a niche for themselves, get direct connections to customers and tell the unique tale of each animal.

COLLABORATING AND FIGHTING FOR STAKEHOLDERS

Practitioners maintain a balanced perspective on current and developing resources by collaborating with regulatory authorities, producer groups, veterinary and animal scientific associations. Professionals have a responsibility to acquire, implement and/or oversee new technology. For a variety of reasons, farmers can be hesitant to adopt precision livestock farming (36). It is stated that 5% of wearable sensor technology has rigorous scientific validation using data from the labor industry. Livestock producers can be reluctant to use precision livestock farming practices due to past experiences with the high expenditures of acquiring and upkeep of new hardware, including laptops in addition to protracted staff educational bend. One other thing to consider is the absence of broadband internet connectivity in rural regions the biggest technological challenge. An Internet or cellphone connection is necessary for remote data collection and transmission. It is possible to merge two areas of upcoming technical improvements with precision livestock farming instruments; however, they will require a great deal more development study. Combining doplar radar technology with the potential to allow remote detection of heart rate and breathing is another promising technique. By decreasing network complexity, these technologies can offer more effective means of recording swine physiology and well-being (37).

Expert and Advisor in Precision Livestock Production

The importance of statistics and technology for managing pigs tools for providing important construction metrics in herd or batch reports. Descriptive data (such as farrowing dates) and diagnostic data (such as cause of death and response to therapy) are among (38) the data inputs that the farms supply. Animals are observed using sensors that digitize physiological characteristics, producing data that is predictive and prescriptive without information bias. Decision-making aided by this data are used to predict trends and behavioural tendencies. One thing to think about is a way to determine whether or not someone has been lame after taking an analgesic (39). Therefore, if farmers are able to explicitly assess the financial results of mitigating methods, pig welfare can be enhanced.

Suitability of the Sensors

The assaults on farms, such as high-pressure washing, ammonia, dust and dampness, are commercially available. While security industry 2D cameras and microphone sensors can provide hardware for image and audio, the advancement of future sensing along with their applications testing in agricultural environments variations in ambient light, background noise, pest management, or weather can hinder the system's ability to identify as well as to identify a subject in commercial barns (40). Developers able to learn about the conditions and limitations under which this technology must function by participating in open-access development with farmers, Figure (4) shows sensing nodes as the intermediary, practitioners can let developers inside the farm with certain conditions in place so they can determine the design limitations that robust sensors need to meet.

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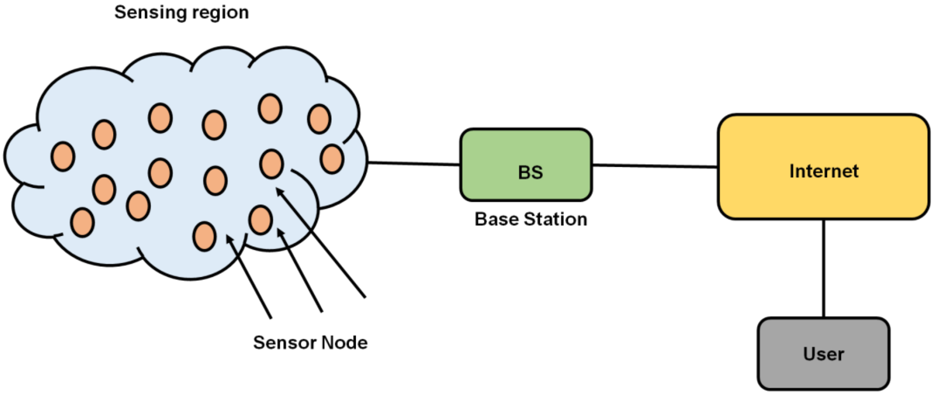

Figure (4). Sensing nodes

(Source: https://link.springer.com/article/10.1007/s00521-022-07027-5)

Technical Function of Practitioners of Swine

Animal welfare is a significant economic motivation as well as an ethical one with financial ramifications. Reducing mortality and morbidity is the most evident way that wellbeing and financial effectiveness go hand in hand. Timely euthanasia is the most compassionate solution to welfare issues such as ruptured hernias, uterine prolapse, seriously damaged or non-walking pigs and animals that are unlikely to respond to treatment (41). Realistically, animal genotype, pen activity or posture might be linked to these issues and prompt detection might improve well-being as well as profitability. In complex farms and systems, practitioners identify illness incidence, despite lacking specialized training in applied ethology, swine practitioners are able to distinguish between aberrant, normal physiology as well as risk factors for low well-being through their training and repeated visits to farms. Precision livestock farming technology aims to recognize certain creatures or groups of animals that require care and offer early indicators of those concerns (42). To ensure detection and prevent needless notifications, It is vital for medical practitioners along with their clients to ensure that the alarms are very precise and responsive.

CONCLUSION AND DISCUSSION

The World Bank projects that when the global population reaches over 9 billion in 2050, the demand for meat will need to continue to rise. Intensification is unavoidable. Precision livestock farming can give farmers information on the overall health of the herd and the wellbeing of individual animals by gathering as well as evaluating enormous amounts of data that are impossible for one person to gather and analyze on their own. Consumers and farmers are connected by the advancement of high-tech livestock farming coupled with the potential for cross-value chain connection in the pork industry. Farms can judge depending on customer behaviour and consumers will base their decisions on agricultural practices. Swine practitioners play a variety of roles in navigating precision livestock husbandry toward profitability for all parties involved farmers, stockmen and pigs. Efficiency and ethical responsibility in the livestock business rely on improving pig health and implementing sustainable management techniques. Proactively preventing diseases through strong bio security measures and well-planned vaccination programs is crucial for the welfare of swine herds. In addition to improve animal health, achieve optimal nutrition while maximizing feed efficiency has positive effects on the economy and the environment. The swine industry can create a future where raising pigs is a sustainable and ethical business that helps to feed the world's expanding population without harming the planet's natural resources.

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