Aspects of the Internal Environment of Buildings in the Field of Agricultural Pre-production

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Abstract

Livestock farming is an important segment of agricultural production that faces challenges in terms of sustainability and effective management. Growing requirements for food production, stricter environmental regulations and economic demands are forcing farmers to look for innovations aimed at long-term stability and profitability of farms. Sustainability in this area includes ecological, economic and social aspects, with an emphasis on minimizing negative environmental impacts, optimizing costs and ensuring animal welfare. Effective breeding management is closely related to the use of modern technologies that enable accurate monitoring of housing conditions and automated operation management. Sensor systems play a key role in monitoring microclimatic conditions, air quality, dust, or light and noise levels. The implementation of smart sensors makes it possible to optimize ventilation, temperature control and improve overall breeding conditions, thus achieving higher productivity and lower operating costs. The article analyzes key aspects of the indoor environment of agricultural buildings and the importance of sensors in the monitoring of housing areas. The benefits of these systems in terms of improving animal health, reducing the ecological burden and managing operations more efficiently are discussed. Research suggests that the use of sensory technologies and IoT solutions in livestock farming represents a necessary step towards sustainable and technologically advanced agriculture.

Keywords: *Agricultural; Buildings; Environment; Farming*

1. Introduction

Currently, livestock farming is one of the key pillars of agricultural production, but at the same time it faces growing challenges in terms of sustainability and effective management [1]-[3]. Increasing global requirements for food production, environmental regulations and economic demands are forcing farmers to look for solutions that will ensure the long-term stability and profitability of their operations [4].

Sustainability in livestock farming includes several dimensions – ecological, economic and social. The ecological side refers to minimizing the negative impact on the environment [5], especially in the field of greenhouse gas emissions, efficient use of water and soil, as well as reducing waste production [6],[7]. Economic sustainability is about optimising costs, increasing productivity and ensuring long-term competitiveness [8]. The social aspect includes ensuring animal welfare, protecting workers' health, and having a positive impact on rural communities [9]-[10].

The efficient operation of the farm is closely linked to innovations and modern technologies that make it possible to optimize nutrition, health care and reproduction of animals. Automation and digitalisation bring accurate monitoring of housing conditions, increasing animal comfort and reducing veterinary care costs [11],[12]. Intelligent sensor systems can monitor air quality, temperature, humidity or ammonia levels in stables in real time, which contributes to the rapid identification of problems [13] and improved decision-making processes [14].

The importance of sustainability and efficiency in livestock farming is constantly increasing in line with growing consumer demands for quality and ethically produced food. Current trends indicate a shift towards greener and more technologically advanced solutions that will ensure a balanced approach between high productivity and conservation of natural resources [15]-[17].

In the following parts, the manuscript will focus on specific measures that allow to achieve a more sustainable and efficient operation of livestock farms, with an emphasis on innovations, modern technologies and sensors within breeding processes. In connection with the above-mentioned facts, this article deals with selected aspects of the internal environment of agricultural buildings, with a focus on the role of sensorics in the monitoring of housing areas. It stresses its importance in the context of sustainability and efficient management of livestock farming.

2. Aspects of the internal environment of buildings in the field of primary agricultural production

The indoor environment of buildings in the field of primary agricultural production plays a key role in ensuring optimal conditions for animal husbandry, plant cultivation and processing of agricultural products [18]. A number of factors that affect productivity, animal health and welfare, as well as the efficiency of crop production, need to be taken into account.

2.1 Microclimatic conditions

The microclimate in buildings intended for primary agricultural production includes temperature, air humidity, ventilation, lighting and air composition [19]. Each of these factors has an impact on animal and plant welfare:

- Temperature: It must be regulated according to the needs of a specific species of animals or crops.
- Air humidity: Excessively dry or humid air can cause health problems in both animals and plants.
- Ventilation: Ensures the supply of fresh air and the removal of harmful gases.
- Lighting: Properly adjusted lighting intensity and length can promote plant growth and animal fertility.

2.2 Air quality

Air pollution in animal and plant buildings can be caused by the accumulation of gases, dust and microorganisms [20],[21]. Level monitoring is important:

- Ammonia (NH3), which is produced by the decomposition of organic waste,
- Carbon dioxide (CO2), which is a product of animal respiration,
- Methane (CH4), which is excreted during fermentation processes.

Proper ventilation and air filtration reduce the risk of respiratory diseases in animals and fungal infestation of crops.

2.3 Hygiene and sanitary conditions

Thorough hygiene is essential to prevent disease and ensure quality production [22],[23]. The main measures include:

- regular cleaning and disinfection of premises,
- control of water and feed sources,
- minimizing the spread of pathogens through workplaces.

2.4 Impact of Building Materials

The materials used in agricultural buildings should be durable, resistant to moisture and chemicals, and provide optimal thermal insulation [24]. For example:

- Concrete is durable, but requires protection from chemical degradation,
- Plastics and composite materials have the advantage of longevity and corrosion resistance,
- Wooden structures can be an eco-friendly choice, but they require protection from insects and mold.

2.5 Energy efficiency

Energy-efficient buildings contribute to the sustainability of primary agricultural production. The use of renewable energy sources, such as solar panels, biogas, and efficient heating systems, can reduce operating costs and the ecological footprint [25]-[27].

2.6 Ergonomic and safety aspects

Occupational safety in agricultural construction is essential for the protection of both workers and animals [28],[29]. Ergonomic solutions and minimizing the risk of accidents include:

- appropriate organization of space,
- sufficient lighting and ventilation,
- Safe floors and surfaces that minimise slipping.

Aspects of the internal environment of buildings in the field of primary agricultural production have a direct impact on productivity, health and economic efficiency. Properly designed buildings, taking into account climatic conditions, air quality, hygiene and energy efficiency, are crucial for sustainable and efficient agricultural production.

3. Sensors for monitoring the internal environment of housing areas of buildings

Nowadays, improving the quality of livestock welfare is an important aspect of effective breeding. The quality of the indoor environment in housing has a direct impact on the health, productivity and overall welfare of animals [30],[31]. Monitoring environmental parameters using sensor systems allows for the optimization of conditions and early detection of possible problems [32], for example in relation to key factors (air temperature and humidity, gas concentration, dust and air quality, light and noise levels, and others).

Sensor technologies – Different types of sensors are used to measure the above parameters [33]-[36]:

- Temperature and humidity sensors – e.g. digital sensors provide accurate measurements in real time.
- Air Quality Sensors - Sensors such as MQ-135, CO_2 sensors (NDIRs) can detect harmful gases.
- Sensors monitoring environmental dustiness - Laser sensors enable the monitoring of suspended particles.
- Photometric sensors – Lighting sensors are used to optimize light conditions.
- Acoustic sensors – measurement of noise level using microphone sensors.

Data implementation and use – Modern sensory systems enable real-time data collection, processing, and visualization [37]. Data can be transmitted to a central control system via IoT technologies (Wi-Fi, LoRaWAN, ZigBee) [38]. Automated control systems enable:

- Dynamic ventilation control based on air quality.
- Control of heating and cooling according to temperature conditions.
- Optimization of lighting according to the daily routine of animals.
- Early warning of dangerous conditions through notifications.

Benefits and future of sensor technology – The use of sensors in the monitoring of housing areas [39] brings several advantages:

- Improving animal health and welfare – better living conditions reduce stress and morbidity.
- Increase productivity – optimizing the environment leads to better production results.
- Efficient traffic management – automation helps minimize human intervention and reduce costs.
- Environmental protection - Regulating harmful gas emissions reduces the ecological footprint.

In the future, further developments in the field of artificial intelligence and machine learning can be expected, which will enable predictive analysis and adaptive management of the environment in real time [40]-[42]. Sensory technology therefore plays a key role in modern livestock breeding. Accurate monitoring of the indoor environment in the housing areas makes it possible to improve animal conditions, optimize operating costs and increase the overall efficiency of farm production. Investing in sensory systems thus appears to be a necessary step towards sustainable and technologically advanced farming.

4. Conclusion

The introduction of sensory systems in livestock farming represents an important step towards ensuring the sustainability and efficiency of agricultural production. Monitoring key parameters such as temperature, humidity, air quality and lighting makes it possible to optimise animal welfare, improving animal health and productivity. At the same time, modern technologies help reduce the ecological footprint and operating costs of farmers. The future in this area is towards the use of artificial intelligence and predictive analysis, which will enable even more accurate and efficient management of breeding processes.

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