APPLICATION OF SENSORY ANALYSIS IN LIVESTOCK FARMS IN SERBIA: A COMPARATIVE ANALYSIS WITH THE EU AND DEVELOPED EUROPEAN COUNTRIES

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ABSTRACT

Development of precision agriculture, particularly through the use of sensory technologies, has had a significant impact on livestock farming worldwide. This study examines the use of sensory technologies in Serbian livestock farms in comparison to the EU and other developed European countries. Primary research question is how the use of sensory technologies in the Serbian livestock production compares to the EU and what factors influence these differences. To answer this question, a comparative analysis was conducted based on secondary data from academic publications, reports and documents of relevant organizations. Research methodology includes a systematic literature review, collection of data on technology adoption rates and a comparative analysis to identify key trends, challenges and opportunities. Results show that sensory systems such as temperature and humidity sensors and animal health monitoring sensors are widely used in the EU (e.g. over 60% in the Netherlands), but are only used to a limited extent in Serbia (in 2023, only 15% of farms used basic sensors to control environmental parameters and 5% used health monitoring systems). Factors contributing to this discrepancy include financial constraints, limited technological infrastructure and insufficient farmer education. Serbian livestock farming can be significantly improved through the increased use of sensor technologies. These technologies can increase productivity, reduce disease outbreaks and improve animal welfare. Policy recommendations include increased government support, financial incentives and training programs for farmers to close the technology gap.

Keywords: *sensory technology, livestock facilities, precision agriculture, animal welfare, environmental sustainability*

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INTRODUCTION

Livestock farming is a cornerstone of agriculture, particularly in rural areas where it supports economic growth and employment (Banhazi et al., 2012; Berckmans, 2017; Schulthess et al., 2024). In recent years, technological advancements in the form of sensory technology have begun to revolutionize livestock farming by enabling better monitoring and control of animal health, welfare, and environmental conditions (Oljača i sar., 2008; Berckmans, 2017). The use of temperature, humidity, and air quality sensors, as well as advanced animal health monitoring systems (Image 1), can lead to higher productivity, reduced disease transmission, and improved overall welfare in livestock facilities (Rutten et al., 2018; Chapagaee, 2024).

Image 1. Environmental factors affecting livestock facilities

In Serbia, the adoption of these technologies has been slower compared to more developed European countries. However, with an increasing emphasis on sustainable farming practices, there is a growing interest in integrating sensory technologies into the livestock sector (Banhazi et al., 2012; Neethirajan, 2020; FAO, 2022). This paper will examine the current status of sensory technology implementation in Serbia's livestock facilities, analyze the benefits and challenges, and compare these findings with practices in the EU and other advanced European nations.

MATERIAL AND METHODS

This paper employs a comparative analysis based on secondary data obtained from academic publications, industry reports, and government documents on the implementation of sensory technologies in livestock farming in Serbia, the EU, and select European countries (Eurostat, 2023; European Commission, 2024). The following methods were used:

- **Literature Review**: A comprehensive review of the available literature on the application of sensory technologies in livestock facilities.
- **Data Collection**: Statistical data on the adoption of sensory technology, animal welfare, and environmental conditions from Serbia, the EU, and developed European countries were gathered from relevant reports.
- **Comparative Analysis**: A comparison was made of the adoption rates, technological applications, and impacts on livestock productivity and welfare.

RESULTS AND DISCUSSION

Adoption of Sensory Technology in Serbia vs. EU

The adoption of sensory technology in livestock facilities (Image 2) has seen varying levels of implementation across Europe (Vuksanović, 2024). While the EU has been at the forefront of integrating advanced technologies, Serbia's uptake has been slower, primarily due to financial constraints, limited access to advanced systems, and lack of awareness among farmers.
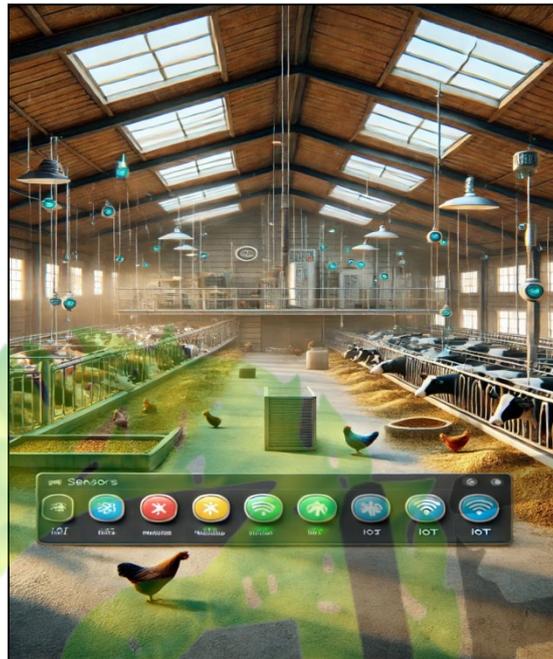

Image 2. Sensor types and placements in livestock facilities (source: authors)

The comparative data presented in Table 1 highlights significant disparities between Serbia and EU countries regarding the adoption of sensory technologies in livestock farming.

Table 1. Adoption of Sensory Technology in Livestock Facilities (Percentage of Farms)

Country	Temperature/Humidity Sensors	Animal Health Monitoring Systems	Environmental Monitoring (Air Quality, CO_2)
Serbia (2023)	15%	5%	10%
EU Average (2023)	40%	30%	35%
Germany	50%	45%	40%
Netherlands	60%	50%	55%
France	45%	35%	40%
United Kingdom	55%	45%	50%

Source: Eurostat; European Commission; FAO.

The adoption rate in Serbia remains low, particularly for animal health monitoring systems (5%) compared to the EU average (30%) and leading countries like the Netherlands (50%) (Eurostat, 2023; European Commission, 2024). Key factors contributing to Serbia's slower adoption include limited financial resources, lack of awareness among farmers, and insufficient governmental incentives.

In contrast, countries like Germany and the Netherlands exhibit higher adoption rates due to robust support mechanisms, including government subsidies, advanced farmer education programs, and well-established technological infrastructures. The Netherlands, for instance, benefits from a strong agricultural technology sector, facilitating easy access to cutting-edge sensory systems (Kopler et al., 2023; European Commission, 2024).

Impact on Animal Welfare and Productivity

The implementation of sensory technologies has proven to enhance animal welfare and increase productivity in livestock facilities (Neethirajan, 2020). In the EU, farms that utilize temperature and humidity sensors, as well as real-time animal health monitoring systems (Image 3), report fewer cases of disease outbreaks, higher reproductive rates, and better growth rates in animals (Caja et al., 2016; Rutten et al., 2018).
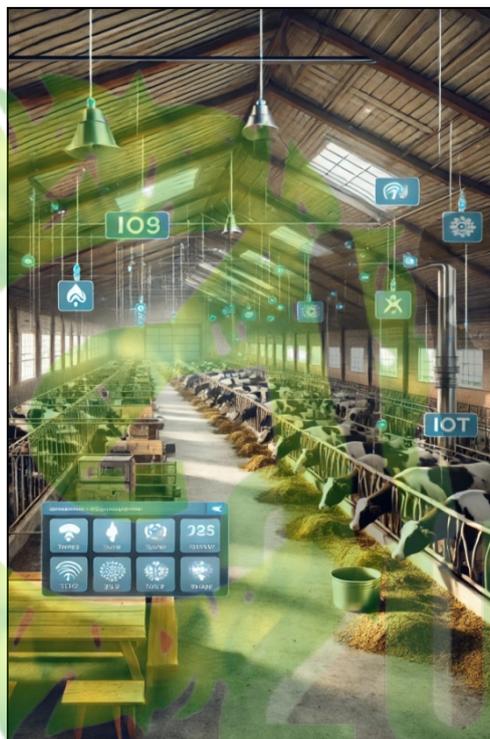

Image 3. Wireless sensor network (WSN) implementation examples (source: authors)

Table 2 demonstrates the positive impact of sensory technologies on livestock productivity and welfare. In the EU, farms utilizing temperature and humidity sensors report a 15% increase in productivity and a 10% improvement in animal welfare.

Table 2. Impact of Sensory Technology on Livestock Productivity and Welfare (Percentage Improvement)

Technology	Impact on Productivity	Impact on Animal Welfare
Temperature/Humidity Sensors	+15%	+10%
Animal Health Monitoring Systems	+20%	+25%
Environmental Monitoring	+10%	+15%
Serbia (estimated)	+5%	+5%

Source: Eurostat; European Commission; FAO.

Animal health monitoring systems contribute even more significantly, with productivity gains of 20% and welfare improvements of 25%.

In Serbia, the estimated benefits are modest (+5% for both productivity and welfare), reflecting the limited scope of current implementations. These figures underscore the potential for significant improvements if adoption rates increase. Sensory technologies enable real-time monitoring, early disease detection, and optimized environmental conditions, directly enhancing animal health and farm profitability (Rutten et al., 2018).

Economic Analysis of Sensory Technology Implementation

The economic feasibility of adopting sensory technologies in livestock farming is crucial for decision-making. Table 3 provides an overview of average costs associated with different types of sensory equipment, including initial investment costs, annual maintenance, and expected returns.

Table 3. Average Economic Indicators for Sensory Technology in Livestock **Farming**

Equipment Type	Average Initial Cost (€/unit)	Annual Maintenance Cost (€/year)	Expected Productivity Increase (%)	Return on Investment (ROI) (%)	Payback Period (years)
Temperature/ Humidity Sensors	3000	500	10	15	4
Animal Health Monitoring Systems	5500	800	20	25	3
Environmental Monitoring Systems	4000	600	15	20	3,5
Integrated Sensory Management Systems	12000	1500	25	30	2,5

Source: Eurostat; European Commission; FAO.

The results indicate that while integrated sensory management systems require the highest initial investment, they also offer the best return on investment (30%) and the shortest payback period (2.5 years). In contrast, simpler technologies such as temperature/humidity sensors have lower initial costs, but also offer more modest productivity gains and longer payback periods. This suggests that comprehensive systems are more economically viable in the long run, especially for larger operations that can better spread costs and maximize efficiency gains.

In addition to direct financial returns, sensory technologies (Image 4) improve farm operations by improving animal health monitoring, reducing veterinary costs and optimizing resource utilization. However, their introduction is often hampered by high initial costs, especially for smaller farms. Increasing financial support, e.g. in the form of subsidies or low-interest loans, could improve accessibility and encourage wider adoption. As technology advances and equipment costs fall, the long-term benefits of data-driven farming will become even more apparent, boosting both economic sustainability and productivity in the livestock sector.

Image 4. Integration of IoT and Big Data technologies for real-time monitoring (source: authors)

Factors Affecting the Adoption of Sensory Technology

The adoption of sensory technology in livestock farming is influenced by a variety of factors, including economic, educational, and infrastructural elements (FAO, 2022; Kopler et al., 2023). Understanding these factors is crucial for identifying the barriers and opportunities for improving technology uptake in Serbia. Table 4 summarizes key factors and compares Serbia's current status with best practices in the EU.

Table 4. Key Factors Influencing the Adoption of Sensory Technology in Livestock Farming

Factor	Serbia (Current Status)	EU (Best Practices)	Impact on Adoption
Financial Resources	Limited subsidies, high costs	Extensive subsidies, tax incentives	High
Farmer Education	Low awareness, limited training	Comprehensive training programs	High
Technological Infrastructure	Underdeveloped networks	Advanced digital infrastructure	Medium
Government Support	Minimal policy incentives	Strong policy frameworks	High
Market Demand	Low consumer pressure	High demand for sustainable products	Medium

Source: Eurostat; European Commission; FAO.

CONCLUSIONS

The use of sensory technology in livestock facilities holds significant potential to improve animal welfare, productivity, and environmental sustainability. While countries like Germany, the Netherlands, and the UK have made substantial progress in adopting

these technologies, Serbia remains behind, primarily due to financial and infrastructural barriers.

There is a clear opportunity for Serbia to integrate more advanced sensory technologies into its livestock sector. This could be achieved through government incentives, educational programs for farmers, and increased investment in technology. The future of Serbia's livestock sector could be greatly enhanced through the use of precision technologies, leading to higher productivity, improved animal health, and reduced environmental impact.

The integration of sensory technology in livestock facilities offers substantial benefits, including enhanced animal welfare, increased productivity, and improved environmental sustainability. Serbia's livestock sector lags behind its EU counterparts due to financial, educational, and infrastructural barriers.

Recommendations for Serbia:

- Government Incentives: Introduce subsidies, tax breaks, and low-interest loans to reduce the financial burden on farmers.
- Educational Programs: Implement comprehensive training for farmers on the benefits and use of sensory technologies.
- Public-Private Partnerships: Foster collaborations between the government, academic institutions, and technology providers.
- Pilot Projects: Establish demonstration farms to showcase the practical benefits of sensory technologies.
- Policy Development: Develop national strategies focused on digital agriculture and precision farming.

By addressing these areas, Serbia can enhance its livestock sector's productivity, sustainability, and competitiveness in the European market.

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