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On-field Pathogen Testing for Livestock Farms

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Abstract
Precision Livestock Farming (PLF) is a transformative approach that leverages advanced sensor technologies to enhance monitoring and management practices in the livestock industry. This paper focuses on the integration of sensor technologies for pathogen monitoring within the context of PLF. By employing a network of sensors, including but not limited to environmental, wearable, and imaging devices, PLF enables real-time data collection and analysis to detect, prevent, and manage pathogen outbreaks in livestock populations. The paper discusses the key components of PLF, its applications in pathogen monitoring, and the potential benefits for both animal health and farm productivity. Additionally, challenges and future directions in the implementation of PLF for pathogen monitoring are explored, emphasizing the need for interdisciplinary collaboration and technological advancements.

Keywords: Precision Livestock Farming (PLF), Sensor Technologies, Pathogen Monitoring, Livestock Health, Real-time Data Analysis, Environmental Sensors, Wearable Devices, Imaging Technology, Disease Prevention, Interdisciplinary Collaboration, Farm Productivity, Technological Advancements.

Introduction:

Precision Livestock Farming (PLF) represents a paradigm shift in the management of livestock, integrating cutting-edge sensor technologies to revolutionize monitoring and control practices. The advent of advanced sensors, such as environmental monitoring devices, wearables, and imaging technology, has opened new avenues for real-time data collection and analysis in the livestock industry. Among the myriad applications of PLF, this paper delves into its role in pathogen monitoring – a critical aspect of livestock health and farm productivity.

Livestock diseases, often caused by pathogens, pose significant challenges to global agriculture, impacting animal welfare, food security, and economic stability. Traditional methods of disease detection and prevention are often reactive and time-consuming, leading to substantial losses. In contrast, PLF offers a proactive and data-driven approach, allowing for the early identification, prevention, and management of pathogen outbreaks.

This paper examines the integration of sensor technologies within the PLF framework specifically for pathogen monitoring. By creating a network of sensors, PLF facilitates continuous and real-time surveillance of livestock environments, enabling prompt response to potential threats. The following sections discuss the key components of PLF in the context of pathogen monitoring, highlighting its potential benefits, challenges, and future directions. Emphasis is placed on the interdisciplinary nature of PLF implementation and the need for ongoing technological advancements to realize its full potential in safeguarding both animal health and farm productivity.

Literature Review:

1. **Precision Livestock Farming (PLF) Frameworks:** The literature on PLF emphasizes the integration of sensor technologies in livestock management. Studies by [Author1] and [Author2] discuss the core components of PLF, including environmental monitoring, animal wearables, and imaging devices. These frameworks serve as the foundation for efficient data collection and analysis in real-time.

2. **Sensor Technologies in Livestock Monitoring:** Various sensor technologies play a crucial role in PLF, as highlighted in works by [Author3] and [Author4]. Environmental sensors provide data on factors like temperature, humidity, and air quality, aiding in the early detection of potential disease vectors. Wearable devices, such as smart collars and tags, contribute to individual animal monitoring, while imaging technology allows for non-invasive health assessments.
3. **PLF Applications in Pathogen Monitoring:** The application of PLF for pathogen monitoring is explored in studies by [Author5] and [Author6]. These works discuss how the integration of sensor networks enables the continuous surveillance of livestock populations. Real-time data collection assists in identifying abnormal patterns or behaviors associated with potential pathogen outbreaks.
4. **Benefits of PLF in Disease Prevention:** Research by [Author7] and [Author8] emphasizes the preventive aspects of PLF in managing livestock diseases. The ability to detect early signs of infection and implement timely interventions can significantly reduce the spread of pathogens, leading to improved animal health and decreased economic losses for farmers.
5. **Challenges in PLF Implementation:** Despite its potential, the implementation of PLF faces challenges, as discussed by [Author9] and [Author10]. Issues such as data privacy, interoperability of sensor systems, and the initial investment costs are explored. Understanding these challenges is crucial for developing effective strategies for widespread adoption.
6. **Interdisciplinary Collaboration for PLF Success:** The interdisciplinary nature of PLF is underscored by [Author11] and [Author12]. Collaboration between veterinarians, agronomists, data scientists, and engineers is essential for designing holistic PLF solutions. These studies highlight the need for a multidisciplinary approach to address the complexity of livestock management.
7. **Future Directions and Technological Advancements:** Literature by [Author13] and [Author14] delves into the future directions of PLF and the necessary technological advancements. Integration with emerging technologies like artificial intelligence and blockchain is explored. Additionally, research emphasizes the need for user-friendly interfaces and educational programs to facilitate widespread adoption among farmers.

In summary, the existing literature provides a comprehensive understanding of the role of PLF in pathogen monitoring, highlighting its potential benefits, challenges, and the importance of interdisciplinary collaboration. As the field continues to evolve, ongoing research is crucial for refining existing frameworks and exploring innovative solutions to enhance livestock health and farm productivity.

Results and Discussion:

1. Pathogen Monitoring Efficacy of PLF: Studies conducted by [Author15] and [Author16] reveal promising results regarding the efficacy of PLF in pathogen monitoring. Real-time data from sensor networks allow for early detection of abnormal patterns, facilitating timely responses to potential disease outbreaks. This proactive approach has shown to significantly reduce the impact of pathogens on livestock populations.

2. Improved Animal Health and Welfare: The integration of PLF in pathogen monitoring contributes to enhanced animal health and welfare, as demonstrated in research by [Author17]. Timely interventions based on sensor data enable quick identification and isolation of infected individuals, preventing the spread of diseases within the herd. This leads to overall improvements in the well-being of livestock.

3. Economic Implications for Farmers: Economic benefits of PLF in disease prevention are highlighted by [Author18] and [Author19]. The proactive nature of pathogen monitoring translates to reduced treatment costs, lower mortality rates, and improved productivity. Farmers adopting PLF strategies experience financial gains, reinforcing the economic viability of precision technologies in livestock management.

4. Challenges and Limitations: Despite its potential, challenges associated with PLF are acknowledged in studies by [Author20] and [Author21]. Issues such as data accuracy, sensor calibration, and the need for standardized protocols are discussed. Additionally, concerns regarding the interpretation of sensor data and the potential for false positives/negatives necessitate ongoing research to refine PLF implementations.

5. Interplay of Environmental and Animal Sensors: The interplay between environmental sensors and wearable devices is explored in works by [Author22] and [Author23]. The combination of data from both sources provides a comprehensive understanding of the livestock environment and individual animal health. Integrating these components optimally enhances the reliability and accuracy of pathogen monitoring systems.

6. Role of Data Analytics in PLF: Advanced data analytics and machine learning techniques play a pivotal role in maximizing the utility of PLF for pathogen monitoring, as evidenced by studies from [Author24] and [Author25]. These approaches enable the extraction of meaningful insights from large datasets, facilitating more accurate disease predictions and supporting informed decision-making by farmers.

7. Future Directions and Research Opportunities: Research by [Author26] and [Author27] outlines future directions for PLF in pathogen monitoring. Exploring the integration of emerging technologies, such as edge computing and IoT advancements, presents opportunities for further innovation. Additionally, addressing the socio-economic implications and ensuring accessibility for small-scale farmers are important avenues for future research.

In conclusion, the results and discussions in the literature highlight the substantial benefits of PLF in pathogen monitoring, ranging from improved animal health to economic gains for farmers. However, challenges and limitations underscore the need for ongoing research to refine and optimize PLF implementations. The interplay of environmental and animal sensors, coupled with advanced data analytics, forms the foundation for successful precision livestock management, with potential for transformative impacts on the agriculture industry.

Methodology:

1. System Architecture and Sensor Deployment: Design a comprehensive PLF system architecture, considering environmental sensors (e.g., temperature, humidity, air quality), wearable devices (e.g., smart collars, RFID tags), and imaging technology. Develop a deployment plan for these sensors within the livestock environment to ensure optimal coverage for pathogen monitoring.

2. Sensor Calibration and Validation: Calibrate environmental sensors to ensure accuracy and reliability. Perform validation studies to assess the precision of wearable devices in capturing vital parameters related to animal health. Regular calibration checks and validation procedures should be established to maintain the integrity of the sensor data.

3. Data Collection and Transmission: Implement a robust data collection mechanism to gather information from deployed sensors. Utilize wireless communication protocols for real-time data transmission to a centralized database or cloud platform. Ensure data security measures to protect sensitive information related to livestock health.

4. Data Preprocessing and Fusion: Preprocess raw sensor data to handle outliers, noise, and missing values. Explore data fusion techniques to integrate information from different sensor types, providing a more comprehensive understanding of the livestock environment. Develop algorithms for real-time data processing to enable timely decision-making.

5. Disease Modeling and Prediction: Employ machine learning and data analytics techniques to develop disease models based on historical data and known pathogen patterns. Implement predictive algorithms to identify potential outbreaks and assess the risk of disease transmission within the livestock population.

6. Decision Support System: Design a decision support system that interprets the analyzed data and provides actionable insights to farmers. Incorporate user-friendly interfaces for easy interpretation of results. Ensure that the system allows for manual interventions based on the recommendations provided by the PLF system.

7. Interdisciplinary Collaboration: Foster collaboration between veterinarians, agronomists, data scientists, and engineers throughout the PLF implementation. Regular communication and knowledge exchange are essential to address the diverse challenges associated with livestock management, sensor technologies, and disease prevention.

8. Pilot Testing and Feedback: Conduct pilot testing of the PLF system in a controlled livestock environment. Gather feedback from farmers, veterinarians, and other stakeholders to assess the system's usability, effectiveness, and potential areas for improvement. Iteratively refine the system based on the received feedback.

9. Scale-Up and Accessibility: Develop strategies for the scalable deployment of PLF systems across different livestock operations. Consider the diverse needs of farmers, including those in small-scale and resource-limited settings. Ensure that the PLF technology remains accessible and adaptable to various agricultural contexts.

10. Ethical Considerations and Regulations: Address ethical considerations related to data privacy, animal welfare, and responsible use of technology. Adhere to relevant regulations and standards governing livestock management and sensor technologies. Establish guidelines for responsible PLF implementation to mitigate potential risks and ensure ethical practices.

This methodology provides a comprehensive framework for the implementation of Precision Livestock Farming for pathogen monitoring, integrating sensor technologies, data analytics, and interdisciplinary collaboration. Continuous monitoring, refinement, and adaptation are essential to ensure the effectiveness of the PLF system in safeguarding livestock health and improving overall farm productivity.

Conclusion:

Precision Livestock Farming (PLF), through the integration of advanced sensor technologies for pathogen monitoring, emerges as a transformative approach with significant implications for livestock management. The literature review highlighted the foundational principles of PLF, emphasizing its potential benefits in early disease detection, improved animal health, and enhanced farm productivity. The results and discussion section further illustrated the positive outcomes of PLF implementation, such as reduced economic losses, enhanced animal welfare, and the proactive prevention of disease outbreaks.

The interplay between environmental sensors, wearables, and imaging technology showcased the synergistic power of diverse sensor types in creating a holistic understanding of the livestock environment. The successful deployment of PLF systems relies on accurate sensor calibration, robust data collection mechanisms, and advanced data processing techniques. Moreover, the collaborative efforts of interdisciplinary teams, involving veterinarians, agronomists, data scientists, and engineers, were underscored as pivotal for the success of PLF in practice.

Challenges and limitations, including issues related to data accuracy, sensor calibration, and potential socio-economic disparities, were acknowledged. Ongoing research and technological advancements are essential to address these challenges and unlock the full potential of PLF for pathogen monitoring.

The proposed methodology outlined a systematic approach for designing, implementing, and refining PLF systems. From system architecture and sensor deployment to ethical considerations and scalability, each step contributes to the development of a robust PLF framework. Pilot testing and continuous feedback mechanisms were emphasized, recognizing the dynamic nature of livestock management and the need for adaptive solutions.

In conclusion, Precision Livestock Farming, when applied to pathogen monitoring, represents a promising avenue for revolutionizing the livestock industry. As technological advancements continue, and interdisciplinary collaboration deepens, the potential for PLF to contribute to sustainable agriculture, improved animal welfare, and global food security becomes increasingly evident. Continuous research, development, and collaboration are imperative to harness the full potential of PLF and propel the livestock industry into a more efficient, resilient, and sustainable future.

References:

1. Benjamin, M., and Yik, S. (2019). Precision livestock farming in swinewelfare: a review for swine practitioners. Animals 9:133. doi: 10.3390/ani9040133
2. Beeman AQ, Njus ZL, Pandey S, Tylka G.L. The Effects of ILeVO and VOTiVO on Root Penetration and Behavior of the Soybean Cyst Nematode, Heterodera glycines. Plant Diseases (2019), 103(3):392-397. doi: 10.1094/PDIS-02-18-0222-RE.
3. Berckmans, D. (2014). Precision livestock farming technologies for welfare management in intensive livestock systems. Rev. Sci. Tech. Off. Int. Epiz. 33, 189–196. doi: 10.20506/rst.33.1.2273
4. Weltin, A., Slotwinski, K., Kieninger, J., Moser, I., Jobst, G., Wego, M., ... & Urban, G. A. (2014). Cell culture monitoring for drug screening and cancer research: a transparent, microfluidic, multi-sensor microsystem. *Lab on a Chip*, *14*(1), 138-146.
5. T. Kong, R. Brien, Z. Njus, U. Kalwa, and S. Pandey, "Motorized actuation system to perform droplet operations on printed plastic sheets", Lab Chip, 16, 1861-1872 (2016).
6. Riahi, R., Tamayol, A., Shaegh, S. A. M., Ghaemmaghami, A. M., Dokmeci, M. R., & Khademhosseini, A. (2015). Microfluidics for advanced drug delivery systems. *Current Opinion in Chemical Engineering*, *7*, 101-112.
7. T. Kong, S. Flanigan, M. Weinstein, U. Kalwa, C. Legner, and S. Pandey, "A fast, reconfigurable flow switch for paper microfluidics based on selective wettingof folded paper actuator strips", Lab on a Chip, 17 (21), 3621-3633 (2017).
8. Steeneveld W, Tauer LW, Hogeveen H, Oude Lansink AGJM. Comparing technical efficiency of farms with an automatic milking system and a conventional milking system. J Dairy Sci. (2012) 95:7391–8. doi: 10.3168/jds.2012-5482
9. Werkheiser I. Precision Livestock Farming and Farmers' Duties to Livestock. J Agric Environ Ethics. (2018) 31:181–95. doi: 10.1007/s10806-018-9720-0
10. Parashar, S. Pandey, "Plant-in-chip: Microfluidic system for studying root growth and pathogenic interactions in Arabidopsis", Applied Physics Letters, 98, 263703 (2011).

11. McEwen, S. A., and Collignon, P. J. (2018). Antimicrobial resistance: a one health perspective. Microbiol. Spectr. 6:2017. doi: 10.1128/microbiolspec.arba-0009-2017
12. Steeneveld W, Tauer LW, Hogeveen H, Oude Lansink AGJM. Comparing technical efficiency of farms with an automatic milking system and a conventional milking system. J Dairy Sci. (2012) 95:7391–8. doi: 10.3168/jds.2012-5482
13. Kashiha, M., Bahr, C., Ott, S., Moons, C. P. H., Niewold, T. A., Ödberg, F. O., et al. (2014). Automatic weight estimation of individual pigs using image analysis. Comp. Electr. Agricult. 107, 38–44. doi: 10.1016/j.compag.2014.06.003
14. Pandey S, White MH. Parameter-extraction of a two-compartment model for whole-cell data analysis. J Neurosci Methods. 2002 Oct 30;120(2):131-43. doi: 10.1016/s0165-0270(02)00198-x.
15. Leach, K. A., Whay, H. R., Maggs, C. M., Barker, Z. E., Paul, E. S., Bell, A. K., et al. (2010). Working towards a reduction in cattle lameness: 1. Understanding barriers to lameness control on dairy farms. Res. Vet. Sci. 89, 311–317. doi: 10.1016/j.rvsc.2010.02.014
16. Jensen JP, Beeman AQ, Njus ZL, Kalwa U, Pandey S, Tylka GL. Movement and Motion of Soybean Cyst Nematode Heterodera glycines Populations and Individuals in Response to Abamectin. Phytopathology. 2018 Jul;108(7):885-891.
17. Xin, H. (1999). Environment and behavior 1: recent advances in assessment and management of heat stress in domestic animals assessing swine thermal comfort by image. J. Anim. Sci. 77, 1–9. doi: 10.2527/1999.77suppl_21x
18. Lee, J., Jin, L., Park, D., and Chung, Y. (2016). Automatic recognition of aggressive behavior in pigs using a kinect depth sensor. Sensors 16:631. doi: 10.3390/s16050631
19. Liu, L. S., Ni, J. Q., Zhao, R. Q., Shen, M. X., He, C. L., and Lu, M. Z. (2018). Design and test of a low-power acceleration sensor with Bluetooth Low Energy on ear tags for sow behaviour monitoring. Biosystems Engineering. Academic Press. 176, 162–171. doi: 10.1016/j.biosystemseng.2018.10.011
20. Lima, E., Hopkins, T., Gurney, E., Shortall, O., Lovatt, F., Davies, P., et al. (2018). Drivers for precision livestock technology adoption: a study of factors associated with adoption of electronic identification technology by commercial sheep farmers in England and Wales. PLoS ONE. 13:e0190489. doi: 10.1371/journal.pone.0190489
21. Xiao, L., Ding, K., Gao, Y., and Rao, X. (2019). Behavior-induced health condition monitoring of caged chickens using binocular vision. Comp. Electr. Agricult. 156, 254–262. doi: 10.1016/j.compag.2018.11.022
22. Preylo BD, Arikawa H. Comparison of vegetarians and non-vegetarians on pet attitude and empathy. Anthrozoos. (2008) 21:387–95. doi: 10.2752/175303708X371654
23. Shepherd M, Turner JA, Small B, Wheeler D. Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution. J Sci Food Agric. (2020) 100:5083–92. doi: 10.1002/jsfa.9346
24. S. Pandey, A. Bortei-Doku, and M. White, "Simulation of biological ion channels with technology computer-aided design", Computer Methods and Programs in Biomedicine, 85, 1-7 (2007).
25. Z. Njus, T. Kong, U. Kalwa, C. Legner, M. Weinstein, S. Flanigan, J. Saldanha, and S. Pandey, "Flexible and disposable paper-and plastic-based gel micropads for nematode handling, imaging, and chemical testing", APL Bioengineering, 1 (1), 016102 (2017).

26. S. Pandey, P.H. Brown, M.T. McHenry, "Plant root development as a measure of soil health", XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): 1123 (2014). doi: 10.17660/ActaHortic.2016.1123.6
27. Chengwu Tao, Baozhen Chen, Sumarlin William and Santosh Pandey, "A novel floating-gate biosensing device with controlled charge-modulation," 2007 IEEE/NIH Life Science Systems and Applications Workshop, Bethesda, MD, USA, 2007, pp. 257-260, doi: 10.1109/LSSA.2007.4400933.
28. Mainau, E., Dalmau, A., Ruiz-de-la-Torre, J. L., and Manteca, X. (2009). Validation of an automatic system to detect position changes in puerperal sows. Applied Animal Behaviour Science. 121, 96–102. doi: 10.1016/j.applanim.2009.09.005
29. Manteuffel, C., Hartung, E., Schmidt, M., Hoffmann, G., and Schön, P. C. (2015). Towards qualitative and quantitative prediction and detection of parturition onset in sows using light barriers. Comp. Electr. Agricult. 116, 201–210. doi: 10.1016/j.compag.2015.06.017
30. X. Ding, Z. Njus, T. Kong, W. Su, C. M. Ho, and S. Pandey, "Effective drug combination for Caenorhabditis elegans nematodes discovered by output-driven feedback system control technique", Science Advances, 3 (10), eaao1254 (2017).
31. Maselyne, J., Adriaens, I., Huybrechts, T., De Ketelaere, B., Millet, S., Vangeyte, J., et al. (2016a). Measuring the drinking behaviour of individual pigs housed in group using radio frequency identification (RFID). Animal. 10, 1557–1566. doi: 10.1017/S1751731115000774
32. U. Kalwa, C. M. Legner, E. Wlezien, G. Tylka, and S. Pandey, "New methods of cleaning debris and high-throughput counting of cyst nematode eggs extracted from field soil", PLoS ONE, 14(10): e0223386, 2019.
33. Zaninelli, M., Redaelli, V., Luzi, F., Bronzo, V., Mitchell, M., Dell'Orto, V., et al. (2018). First evaluation of infrared thermography as a tool for the monitoring of udder health status in farms of dairy cows. Sensors 18:862. doi: 10.3390/s18030862
34. J. Carr, A. Parashar, R. Gibson, A. Robertson, R. Martin, S. Pandey, "A microfluidic platform for high-sensitivity, real-time drug screening on C. elegans and parasitic nematodes", Lab on Chip, 11, 2385-2396 (2011).
35. Dong, R., Liu, Y., Mou, L., Deng, J., & Jiang, X. (2019). Microfluidics-based biomaterials and biodevices. *Advanced Materials*, *31*(45), 1805033.
36. J. Carr, A. Parashar, R. Lycke, S. Pandey, "Unidirectional, electrotactic-response valve for Caenorhabditis elegans in microfluidic devices", Applied Physics Letters, 98, 143701 (2011).
37. Yazdanbakhsh, O., Zhou, Y., and Dick, S. (2017). An intelligent system for livestock disease surveillance. Inform. Sci. 378, 26–47. doi: 10.1016/j.ins.2016.10.026
38. T. Kong, N. Backes, U. Kalwa, C. M. Legner, G. J. Phillips, and S. Pandey, "Adhesive Tape Microfluidics with an Autofocusing Module That Incorporates CRISPR Interference: Applications to Long-Term Bacterial Antibiotic Studies", ACS Sensors, 4, 10, 2638-2645, 2019.
39. Valente, K. P., Khetani, S., Kolahchi, A. R., Sanati-Nezhad, A., Suleman, A., & Akbari, M. (2017). Microfluidic technologies for anticancer drug studies. *Drug discovery today*, *22*(11), 1654-1670.
40. Dong, L., & Jiang, H. (2007). Autonomous microfluidics with stimuli-responsive hydrogels. *Soft matter*, *3*(10), 1223-1230.
41. Saldanha JN, Pandey S, Powell-Coffman JA. The effects of short-term hypergravity on Caenorhabditis elegans. Life Science Space Research. (2016) 10:38-46. doi: 10.1016/j.lssr.2016.06.003.

42. Bock, B. B., Van Huik, M. M., Prutzer, M., Kling, F., and Dockes, E. A. (2007). Farmers' relationship with different animals: the importance of getting close to the animals. Case studies of French, Swedish and Dutch cattle, pig and poultry farmers. Int. J. Sociol. Food Agricult. 15. doi: 10.48416/ijsaf.v15i3.290
43. S. Pandey, R. Mehrotra, S. Wykosky and M. H. White, "Characterization of a MEMS biochip for planar patch-clamp recording," International Semiconductor Device Research Symposium, 2003, Washington, DC, USA, 2003, pp. 278-279, doi: 10.1109/ISDRS.2003.1272095.
44. Bos, J. M., Bovenkerk, B., Feindt, P. H., and van Dam, Y. K. (2018). The quantified animal: precision livestock farming and the ethical implications of objectification. Food Ethics. Food Ethics. 2, 77–92. doi: 10.1007/s41055-018-00029-x
45. B. Chen, A. Parashar, S. Pandey, "Folded floating-gate CMOS biosensor for the detection of charged biochemical molecules", IEEE Sensors Journal, 2011.
46. Buller, H., Blokhuis, H., Lokhorst, K., Silberberg, M., and Veissier, I. (2020). Animal welfare management in a digital world. Animals 10, 1–12. doi: 10.3390/ani10101779
47. da Fonseca, F. N., Abe, J. M., de Alencar Nääs, I., da Silva Cordeiro, A. F., do Amaral, F. V., and Ungaro, H. C. (2020). Automatic prediction of stress in piglets (Sus Scrofa) using infrared skin temperature. Comp. Electr. Agricult. 168:105148. doi: 10.1016/j.compag.2019.105148
48. Fuchs, B., Sørheim, K. M., Chincarini, M., Brunberg, E., Stubsjøen, S. M., Bratbergsengen, K., et al. (2019). Heart rate sensor validation and seasonal and diurnal variation of body temperature and heart rate in domestic sheep. Vet. Anim. Sci. 8:100075. doi: 10.1016/j.vas.2019.100075
49. Jensen JP, Kalwa U, Pandey S, Tylka GL. Avicta and Clariva Affect the Biology of the Soybean Cyst Nematode, Heterodera glycines. Plant Dis. 2018 Dec;102(12):2480-2486. doi: 10.1094/PDIS-01-18-0086-RE.
50. Hemsworth, P. H., Barnett, J. L., and Coleman, G. J. (2009). The integration of human-animal relations into animal welfare monitoring schemes. Anim. Welfare. 18, 335–345.
51. Beeman AQ, Njus ZL, Pandey S, Tylka GL. Chip Technologies for Screening Chemical and Biological Agents Against Plant-Parasitic Nematodes. Phytopathology. 2016 Dec;106(12):1563-1571. doi: 10.1094/PHYTO-06-16-0224-R.
52. Horseman, S. V., Roe, E. J., Huxley, J. N., Bell, N. J., Mason, C. S., and Whay, H. R. (2014). The use of in-depth interviews to understand the process of treating lame dairy cows from the farmers' perspective. Anim. Welfare 23, 157–165. doi: 10.7120/09627286.23.2.157