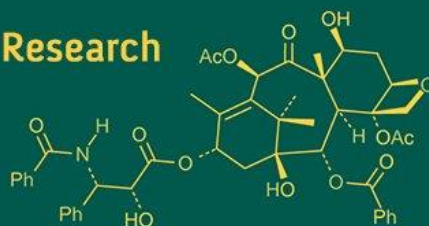


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(7): 415-421
www.biochemjournal.com
Received: 28-04-2026
Accepted: 30-05-2026

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Cognitive behaviour in livestock: A new direction for scientific management, productivity and future challenges: A review

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i7f.9037>

Abstract

Livestock farming has evolved beyond traditional practices to incorporate scientific approaches that emphasize not only physical management but also the mental and behavioural aspects of animals. This article explores the concept of cognitive behaviour in livestock, highlighting animals' abilities to learn, remember and respond to their environment. It discusses how cognitive processes such as learning, memory, emotions and individual personality traits influence animal welfare and productivity. Drawing upon classical theories and recent studies, the article demonstrates that livestock are intelligent and sensitive beings whose behaviour directly affects outcomes such as milk yield, health and reproductive efficiency. Furthermore, the role of positive human-animal interaction and social behaviour in reducing stress and improving management practices is examined. The integration of modern technologies, including artificial intelligence and sensor-based monitoring systems, is also discussed as a means to better understand and predict animal behaviour. In addition, the article addresses the impact of climate change on livestock behaviour and the need for adaptive management strategies. Overall, it emphasizes that understanding cognitive behaviour is essential for sustainable, efficient and welfare-oriented livestock farming in the future.

Keywords: Livestock, cognitive behavior, dairy management

Introduction

In countries like India, livestock farming is not merely an economic activity but a vital component of rural livelihood, food security, and socio-economic sustainability. Traditionally, livestock animals were primarily regarded as production units, with management practices largely focused on nutrition, health care, reproduction, and genetic improvement. However, recent advances in animal science and behavioural research have significantly transformed this conventional outlook. Scientific evidence now indicates that livestock animals are sentient and cognitively capable beings that can perceive, learn, memorize, adapt to their surroundings, and respond to various environmental and management-related stimuli. This growing recognition has led to the emergence of the concept of *cognitive behaviour* in livestock science, which emphasizes the mental processes involved in learning, decision-making, problem-solving, social interaction, and adaptation. Understanding cognitive behaviour has opened new avenues for scientific livestock management by integrating animal welfare, behavioural responses, productivity, and sustainability into a unified framework. Consequently, cognitive-based management approaches are increasingly being explored to improve animal welfare standards, enhance production efficiency, reduce stress-related disorders, and address future challenges associated with intensive livestock production systems.

Concept of Cognitive Behaviour

Cognitive behaviour refers to the complex mental processes through which animals acquire, process, store, and utilize information from their environment to regulate their actions and responses. These processes include learning, memory, perception, attention, problem-solving, decision-making, and social recognition. In livestock animals, cognitive behaviour plays a crucial role in enabling individuals to adapt to changing environmental conditions,

management systems, and social interactions within a herd. Unlike simple reflexive or instinctive responses, cognitive behaviour involves the interpretation of experiences and the application of previously acquired knowledge to future situations.

The scientific foundation of animal cognition was significantly advanced by the pioneering work of Edward C. Tolman, who introduced the concept of *cognitive maps* in 1948^[7]. Tolman proposed that animals are capable of forming internal mental representations of their surroundings, allowing them to navigate environments and make purposeful decisions rather than merely responding through stimulus-response mechanisms. His findings challenged the traditional behaviourist perspective and established the basis for modern cognitive science in animals. Subsequently, Donald Griffin further expanded the field through his influential work on animal consciousness and cognitive ethology. Griffin (1992)^[5, 12] argued that animals possess the capacity for conscious awareness and can process experiences in ways that influence their future behaviour. His research emphasized that behavioural responses in animals often reflect intentionality, perception, and emotional experiences rather than purely automatic reactions. This perspective contributed substantially to the growing recognition of animals as sentient beings with measurable cognitive capacities.

Recent advancements in behavioural neuroscience and precision livestock research have provided stronger empirical evidence supporting cognitive abilities in farm animals. Studies have demonstrated that dairy cattle, buffaloes, sheep, goats, and other livestock species are capable of recognizing familiar caretakers, distinguishing between individual herd members, remembering feeding routines, and responding differently to positive or negative human interactions. Research by Proudfoot (2025)^[22] indicated that dairy animals can identify specific locations, anticipate routine management practices, and modify their behavioural responses based on previous experiences. Such findings suggest that livestock animals possess advanced learning and memory capabilities that directly influence their welfare, productivity, and adaptability. Furthermore, cognitive behaviour in livestock is closely associated with emotional states and stress responses. Animals exposed to enriched and welfare-oriented environments generally exhibit improved learning ability, reduced fearfulness, and enhanced social behaviour compared to animals maintained under stressful or restrictive conditions. This relationship highlights the importance of integrating cognitive and behavioural understanding into modern livestock management systems.

Learning, Memory and Adaptive Behaviour in Livestock

Learning and memory are fundamental components of cognitive behaviour that significantly influence the adaptability, welfare and productivity of livestock animals. These cognitive processes enable animals to acquire information from their surroundings, retain past experiences, and modify their behaviour according to changing environmental and management conditions. In livestock production systems, learning and memory contribute to the establishment of feeding habits, social interactions, handling responses, adaptation to housing systems, and recognition of routine management practices. The ability of animals to remember and respond to previous experiences is essential

for their survival, efficient resource utilization, and overall behavioural stability.

Learning in animals can be defined as a relatively permanent change in behaviour resulting from experience or repeated exposure to specific stimuli. One of the earliest scientific explanations of associative learning was provided by Ivan Pavlov through the theory of *classical conditioning* (1927)^[14, 21]. Pavlov demonstrated that animals could associate a neutral stimulus with a biologically significant event, eventually producing a conditioned response even in the absence of the original stimulus. This principle is highly relevant in livestock management, where animals often learn to associate sounds, visual cues, or human activities with feeding, milking, or handling procedures. For example, dairy cows rapidly adapt to fixed feeding schedules and milking routines, exhibiting anticipatory behavioural responses before the actual event occurs. Such conditioned learning helps reduce stress and improves the efficiency of farm operations.

Memory, which refers to the ability to store and retrieve learned information, is equally important in shaping livestock behaviour. Animals utilize memory to recognize familiar environments, caretakers, herd members, and management routines. According to Broom and Fraser (2007)^[1, 8], animals retain both positive and negative experiences in memory and use these experiences to guide future behavioural responses. Positive interactions with handlers can lead to reduced fear, improved cooperation, and enhanced welfare, whereas repeated exposure to stressful or painful events may result in fear conditioning, aggression, or avoidance behaviour. Thus, memory plays a critical role in determining how livestock respond to management practices and human-animal interactions.

Recent advances in behavioural science and precision livestock technologies have further strengthened the understanding of learning and memory in farm animals. Modern studies integrating artificial intelligence, machine learning, and automated behavioural monitoring systems have demonstrated that livestock behaviour follows consistent and measurable patterns. Research conducted by Liu *et al.* (2024)^[18] revealed that behavioural responses in animals can be predicted through AI-based analysis of movement, feeding behaviour, and social interactions, indicating that learning processes in livestock are highly organized and quantifiable. These technological advancements provide valuable opportunities for early detection of stress, disease, and abnormal behaviour, thereby improving management efficiency and animal welfare.

Moreover, the role of learning and memory extends beyond routine adaptation and directly influences productivity and health. Animals that are well adapted to management systems generally exhibit better feed intake, reproductive performance, milk production, and lower stress levels. Conversely, animals exposed to unpredictable environments or negative handling practices often show impaired learning ability, increased anxiety, and reduced productive efficiency. Therefore, understanding the cognitive mechanisms underlying learning and memory is essential for designing welfare-oriented and scientifically efficient livestock management systems. In contemporary animal science, learning and memory are increasingly recognized as measurable indicators of cognitive competence and behavioural adaptability.

Behavioural Individuality and Personality Traits in Livestock

Recent advances in animal cognition and behavioural science have demonstrated that livestock animals exhibit consistent individual differences in temperament, behavioural responses, and coping strategies, collectively referred to as animal personality. Personality in animals is defined as a set of stable behavioural traits that remain relatively consistent across time and different environmental situations. These traits influence how animals interact with their surroundings, respond to stress, adapt to management practices, and establish social relationships within a group. Recognition of personality differences in livestock has emerged as an important area of research because behavioural individuality can directly affect welfare, productivity, and management efficiency.

Studies on calves and dairy cattle have revealed substantial variation in exploratory behaviour, fearfulness, sociability, and adaptability among individuals. Research conducted by Woodrum Setser *et al.* (2024) ^[24] demonstrated that calves display distinct personality characteristics from an early age, with some individuals exhibiting highly curious, active, and exploratory behaviour, while others remain calm, cautious, or less interactive. These behavioural differences were found to influence feeding behaviour, social interaction, and adaptation to new environments. More exploratory calves generally adapted more rapidly to novel situations, whereas timid animals exhibited higher stress responses under unfamiliar management conditions.

The concept of personality variation has also been widely documented in other livestock species. In dairy cattle, bold and socially dominant animals have been observed to access feed resources more efficiently and adapt better to automated milking systems compared to shy or submissive individuals. Studies by Donald M. Broom and colleagues suggested that temperament influences stress tolerance, reproductive performance, and susceptibility to disease. In sheep and goats, behavioural differences in exploration, maternal care, and social bonding have been associated with variations in lamb survival, feeding behaviour, and adaptation to extensive production systems. Similarly, research in pigs has shown that aggressive or highly reactive individuals are more prone to social conflicts and stress-related injuries, whereas calm animals exhibit improved growth performance and welfare outcomes.

Behavioural individuality also influences the nature of human-animal interactions. Animals with positive and confident temperaments are generally easier to handle, exhibit lower fear responses toward caretakers, and show improved cooperation during milking, veterinary procedures, and transportation. In contrast, fearful or stress-sensitive animals may exhibit avoidance behaviour, aggression, or reduced productivity under intensive management systems. Therefore, understanding personality-related behavioural variation is becoming increasingly important for designing welfare-oriented and precision-based livestock management practices.

Emotional Intelligence and Mental States in Farm Animals

The study of emotions and mental states in livestock animals has become an increasingly important area of research in modern animal science, as accumulating scientific evidence confirms that animals are capable of

experiencing a wide range of emotional states that significantly influence their behaviour, welfare, health, and productivity. Emotions are generally defined as short-term affective responses to internal or external stimuli, while mental state refers to the overall psychological condition that shapes behavioural and physiological functioning over time. These emotional experiences influence how animals perceive their environment, interact socially, respond to stress, and adapt to management practices.

One of the pioneering contributions in this field was provided by Boissy *et al.* (2007) ^[3, 25], who demonstrated that livestock animals are capable of experiencing both negative emotions, such as fear, pain, stress, frustration, and anxiety, as well as positive emotional states including comfort, pleasure, curiosity, and social satisfaction. Their research showed that emotional conditions in animals can be assessed through behavioural responses, vocalization patterns, heart rate variability, and cortisol secretion. The authors concluded that emotional experiences directly influence welfare status and productive performance in farm animals.

Similarly, Broom (2010) ^[6] emphasized that emotional states play a critical role in determining animal welfare and adaptability. According to Broom, animals exposed to chronic stress, fear, or poor management conditions often exhibit behavioural abnormalities, suppressed immunity, reduced reproductive efficiency, and lower productive performance. In contrast, animals maintained under positive welfare conditions generally display improved feeding behaviour, better social interaction, and enhanced physiological stability.

Research by Grandin (2015) ^[11, 23] further highlighted the relationship between emotional state and livestock handling. Grandin observed that fear and stress during transportation, restraint, and handling significantly increase behavioural disturbances and reduce productivity in cattle and pigs. Her findings demonstrated that calm handling techniques and stress-reducing management practices improve animal welfare, reduce cortisol levels, and enhance behavioural cooperation during routine farm procedures.

Recent advances in cognitive ethology have provided additional evidence of emotional intelligence and adaptive behaviour in livestock species. A notable observational study reported in 2026 documented a cow using an external object as a tool to scratch inaccessible body regions. This behaviour reflected not only physical adaptability but also higher cognitive functioning, environmental awareness, and problem-solving ability. The study suggested that livestock animals possess the capacity for intentional and goal-directed behaviour rather than relying solely on instinctive reactions. Such findings strongly challenge the traditional perception of animals as passive production units and instead support the concept that they are cognitively aware and emotionally responsive beings.

Further evidence was provided by Bekoff (2018) ^[19], who reported that animals can remember previous emotional experiences and modify future behavioural responses accordingly. Positive interactions with humans were associated with reduced fearfulness and increased confidence, whereas repeated negative experiences resulted in avoidance behaviour, anxiety, and stress-related responses. These observations indicate that emotional memory significantly influences behavioural adaptation in livestock animals.

Studies conducted by Douglas *et al.* (2020) in dairy cattle also revealed that animals maintained in enriched and welfare-friendly environments exhibited greater curiosity, exploratory behaviour, and social interaction compared to animals reared under restrictive conditions. The researchers concluded that positive emotional states contribute to improved cognitive functioning, learning ability, and behavioural stability.

Modern precision livestock farming technologies and artificial intelligence-based behavioural monitoring systems have further improved the understanding of animal emotions. According to Liu *et al.* (2024) ^[17, 18], behavioural indicators such as facial expression, vocalization, body posture, and movement patterns can now be analyzed using AI systems to detect stress, discomfort, and emotional disturbances in livestock animals with high accuracy. These technologies offer valuable opportunities for early welfare assessment and improved management decision-making.

Cognitive Behaviour as an Indicator of Animal Welfare

Cognitive behaviour and animal welfare are closely interconnected aspects of modern livestock science, as the mental and emotional state of animals directly influences their health, adaptability, productivity, and overall well-being. Cognitive processes such as learning, memory, perception, and emotional responses determine how animals interpret and cope with their surrounding environment. When animals are exposed to stressful, uncomfortable, or fear-inducing conditions, their cognitive and physiological functions are adversely affected, leading to compromised welfare and reduced productive efficiency. Consequently, understanding the relationship between cognition and welfare has become essential for developing sustainable and humane livestock management systems.

One of the earliest and most influential contributions to the concept of animal welfare was made by Broom (1986) ^[4], who defined animal welfare as the state of an individual in relation to its attempts to cope with the environment. Broom emphasized that welfare should not merely be assessed through physical health and productivity but also through behavioural and psychological indicators. According to his findings, animals experiencing chronic stress, fear, pain, or environmental discomfort exhibit impaired coping ability, behavioural abnormalities, reduced immunity, and physiological disturbances. Such conditions negatively affect growth, milk production, reproductive performance, and disease resistance in livestock species.

Subsequent studies further strengthened the understanding that cognitive and emotional experiences directly influence animal productivity. Research conducted by Hemsworth and Coleman (2011) ^[13, 20] demonstrated that positive human-animal interactions play a crucial role in reducing stress and improving behavioural responses in livestock. Their studies revealed that animals handled calmly and gently by caretakers exhibited lower fear levels, reduced cortisol secretion, improved reproductive efficiency, and enhanced milk yield compared to animals exposed to rough or aversive handling practices. The authors concluded that the behaviour and attitude of stockpersons significantly influence both animal welfare and farm productivity.

Research in dairy cattle has shown that stressful handling practices, overcrowding, transportation stress, and poor housing conditions can negatively affect cognitive functioning and behavioural stability. Animals exposed to

chronic stress often display fearfulness, aggression, stereotypic behaviours, reduced feed intake, and impaired social interaction. Conversely, animals maintained in enriched and welfare-oriented environments demonstrate greater exploratory behaviour, improved learning ability, and enhanced adaptability to management routines. These findings indicate that cognitive well-being is an integral component of overall animal welfare.

Recent advances in behavioural science have further highlighted the influence of farmer behaviour on livestock mental health. A study by Gebert and Kühne (2024) ^[9, 10] reported that the emotional state and behavioural responses of livestock animals are strongly affected by the quality of human-animal interactions on farms. The researchers observed that compassionate handling, regular social contact, and predictable management routines reduced anxiety and stress-related behaviour in cattle and other farm animals. In contrast, inconsistent or harsh handling practices resulted in heightened fear responses, behavioural disturbances, and decreased welfare status. Their findings clearly demonstrated that farmer behaviour has both ethical and economic implications, as improved welfare conditions are associated with higher productivity and better animal health outcomes.

Similarly, Grandin (2015) ^[11, 23] emphasized that minimizing fear and stress during handling and transportation significantly improves welfare and productive efficiency in livestock systems. Grandin's work demonstrated that animals with reduced stress levels exhibit calmer behaviour, lower injury rates, and improved physiological functioning, thereby enhancing both welfare and economic returns.

Social Dynamics and Human-Animal Interactions in Livestock System

Livestock animals are inherently social beings that live within structured social systems where interactions among herd members and with humans significantly influence their behaviour, welfare, and productivity. Social behaviour in livestock includes group formation, dominance hierarchy, maternal bonding, communication, cooperative activities, and social learning. These social dynamics play a crucial role in maintaining behavioural stability and reducing stress within animal groups. Disruption of established social structures through improper handling, overcrowding, frequent regrouping, or isolation often results in aggression, fear, anxiety, and reduced productive performance.

Research conducted by Grandin (2015) ^[11, 23] demonstrated that calm, predictable, and welfare-oriented handling techniques substantially reduce fear and stress responses in livestock animals. Grandin observed that animals handled gently through low-stress management systems exhibited improved behavioural cooperation, reduced injury rates, and enhanced physiological stability compared to animals exposed to rough handling practices. Her findings further emphasized that livestock animals are highly sensitive to human behaviour, body language, noise, and environmental disturbances. Therefore, understanding animal perception and behavioural responses is essential for effective livestock management.

Similarly, Hemsworth and Coleman (2011) ^[13] reported that positive human-animal relationships significantly improve welfare and productivity in farm animals. Their studies showed that animals receiving regular positive interactions from caretakers displayed lower fear responses, reduced

cortisol concentrations, improved reproductive efficiency, and higher milk production. In contrast, negative or inconsistent handling practices increased stress-related behaviours and impaired productivity. The authors concluded that the attitude and behaviour of stockpersons directly influence the emotional state and behavioural adaptability of livestock.

Social relationships among animals themselves are equally important in determining welfare outcomes. Studies in dairy cattle, sheep, and goats have shown that stable social grouping promotes behavioural harmony, efficient feeding behaviour, and reduced aggression. Conversely, disruption of herd hierarchy or social isolation often causes behavioural disturbances and physiological stress. Research by Broom (2010) ^[6] further emphasized that animals use social learning to adapt to management conditions, feeding systems, and environmental challenges. Young animals frequently learn behavioural responses by observing experienced herd members, highlighting the cognitive importance of social interaction in livestock species.

Technological Innovations in Behavioural Monitoring of Livestock

Recent technological advancements have revolutionized livestock production systems by enabling more precise understanding and monitoring of animal behaviour, health, and welfare. The integration of artificial intelligence (AI), precision livestock farming (PLF), sensor technologies, machine learning, and automated video analysis has significantly improved the ability to continuously assess behavioural and physiological changes in farm animals. These innovations are transforming traditional livestock management into data-driven and welfare-oriented production systems.

According to Li *et al.* (2024) ^[15, 16], smart sensor technologies can continuously monitor animal movement, feeding behaviour, rumination activity, body temperature, and physiological indicators in real time. Their research demonstrated that wearable sensors and automated monitoring systems provide accurate information regarding behavioural changes associated with stress, illness, reproductive status, and environmental adaptation. Early identification of abnormal behaviour allows farmers to implement timely interventions, thereby improving animal health and reducing economic losses.

Similarly, studies published in Scientific Reports (2024) reported that AI-assisted video tracking systems are capable of detecting subtle behavioural changes in livestock animals with high precision. These systems analyze movement patterns, posture, feeding frequency, social interactions, and resting behaviour to identify indicators of stress, discomfort, lameness, or disease before clinical symptoms become visible. Such technologies enhance both welfare assessment and farm management efficiency by enabling continuous and non-invasive behavioural monitoring.

Advancements in machine learning and computer vision have also improved behavioural prediction and decision-making in livestock systems. Automated behavioural analysis can now identify emotional states, social interactions, and activity patterns that were previously difficult to measure accurately through manual observation. Precision technologies therefore provide valuable opportunities for improving welfare standards, optimizing

feeding management, reducing labour requirements, and enhancing productivity.

Furthermore, the integration of IoT-based monitoring systems and AI-driven analytics supports the concept of precision animal husbandry, where management decisions are tailored according to the behavioural and physiological status of individual animals. This individualized approach contributes to better disease prevention, stress reduction, reproductive management, and resource utilization.

Influence of Climate Change on Livestock Behaviour and Welfare

Climate change has emerged as one of the most significant global challenges affecting livestock production systems, animal welfare, and behavioural adaptability. Rising environmental temperatures, increased humidity, irregular rainfall patterns, water scarcity, and extreme climatic events directly influence the cognitive behaviour, physiological responses, and productivity of livestock animals. These environmental stressors disrupt normal behavioural patterns and reduce the ability of animals to maintain physiological balance under changing climatic conditions.

Studies published in Applied Animal Behaviour Science (2024) demonstrated that heat stress significantly alters grazing behaviour, feeding patterns, resting activity, and social interactions in cattle. Animals exposed to high environmental temperatures exhibited reduced grazing time, lower feed intake, increased water consumption, and prolonged resting behaviour in shaded areas. The researchers further observed that heat stress increased behavioural signs of discomfort, irritability, and fatigue, ultimately leading to decreased milk production, reduced growth performance, and impaired reproductive efficiency.

Research by Broom (2019) emphasized that climate-related stress negatively affects both the physical and mental well-being of livestock animals. According to Broom, prolonged exposure to heat stress compromises immune function, increases susceptibility to diseases, and reduces the capacity of animals to cope effectively with environmental challenges. Such stress conditions also impair cognitive functioning, learning ability, and behavioural adaptability.

In dairy cattle, buffaloes, sheep, and goats, climate-induced stress has been associated with altered rumination behaviour, increased respiratory rate, reduced social interaction, and behavioural depression. Similarly, water scarcity and poor-quality feed resources during extreme climatic conditions negatively affect feeding behaviour and animal welfare. These changes not only compromise productivity but also threaten the sustainability of livestock farming systems globally.

Consequently, climate-resilient livestock management practices have become essential for maintaining animal welfare and productive efficiency under changing environmental conditions. Strategies such as improved housing design, ventilation systems, shade provision, cooling technologies, nutritional supplementation, and behavioural monitoring are increasingly being adopted to minimize climate-related stress in livestock systems.

Future Perspectives: Precision Technologies and Cognitive Livestock Farming

The future of livestock farming is increasingly moving toward smart, precision-based, and welfare-oriented production systems in which cognitive behaviour and

artificial intelligence will play a central role. Advances in behavioural science, machine learning, robotics, biosensors, and automated monitoring technologies are transforming conventional livestock management into highly integrated systems capable of continuously assessing the physical, behavioural, and emotional condition of animals.

Recent research published on arXiv (2025) ^[2] suggested that artificial intelligence models can predict livestock behaviour with high accuracy by analyzing behavioural patterns, movement data, feeding activity, vocalization, and environmental conditions. These predictive models enable proactive management strategies that can identify stress, disease risk, reproductive changes, or abnormal behaviour before severe health problems occur. Such early prediction systems have the potential to significantly improve welfare, reduce production losses, and optimize farm efficiency.

Emerging technologies such as emotion-detection systems, facial recognition software, wearable biosensors, IoT-based monitoring devices, and automated decision-support systems are expected to further revolutionize livestock management. These technologies can continuously evaluate behavioural indicators associated with stress, fear, pain, comfort, and social interaction, thereby allowing farmers to better understand not only the physical condition but also the mental and emotional state of animals. Similarly, precision livestock farming systems integrated with AI and cloud-based analytics are expected to provide individualized management solutions based on behavioural and physiological data from each animal. Such systems will facilitate precision feeding, disease prevention, reproductive monitoring, and welfare assessment while reducing labour dependency and improving resource efficiency. Researchers such as Grandin (2015) ^[11, 23] have emphasized that combining behavioural science with modern technology can greatly enhance humane livestock management practices. Future systems are therefore likely to focus not only on maximizing productivity but also on promoting animal welfare, emotional well-being and sustainable farming practices.

Conclusion

In conclusion, cognitive behaviour has emerged as a crucial component of modern livestock science, providing deeper insight into the mental abilities, emotional responses, and adaptive capacities of farm animals. Livestock species demonstrate learning ability, memory, social interaction, problem-solving behaviour, and environmental awareness, all of which influence their welfare, health, and productive efficiency. Scientific studies have shown that stress, improper handling, adverse environmental conditions, and social disruption negatively affect behavioural stability and physiological performance, whereas positive management practices improve adaptability and overall well-being. Recent advances in artificial intelligence, precision livestock farming, sensor technologies, and automated behavioural monitoring have further enhanced the understanding of animal behaviour and enabled more accurate, welfare-oriented management strategies. In the context of climate change and increasing demands for sustainable agriculture, integrating cognitive and behavioural knowledge into livestock production systems will be essential for developing ethical, resilient, and scientifically efficient animal husbandry practices in the future.

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