A Review about Behavioural Indicators of Stress in Broilers: Insights from Digital Monitoring Technologies

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Abstract

Early detection and management of stress are very important to ensure welfare in broiler production systems and significantly influences poultry's health, behaviour, and productivity. Main stress-related behaviours, such as social interaction, excessive pecking, increased aggression, and reduced locomotion, are best analysed using smart video surveillance systems and machine learning algorithms capable of real-time data processing and pattern recognition. Also, the integration of wearable sensors (e.g., temperature and heart rate monitors) represents a complementary tool to enhance the precision and reliability of behavioural data. This review offers a comprehensive study of current digital solutions aimed to enhance animal welfare through automated, continuous, and non-invasive stress monitoring in broiler flocks. It discusses the use of video cameras equipped with computer vision and behavioural pattern recognition algorithms, presenting real-time applications for identifying signs of social isolation, aggression, and abnormal movement patterns. Additionally, the review emphasizes the role of machine learning algorithms in training neural networks to analyse large datasets generated from video recordings and behavioural reports. Finally, the review examines the wearable sensors tools like temperature and heart rate monitors, emphasizing how they enhance visual observations by providing valuable information about internal physiological states. Each of these technologies is evaluated in terms of accuracy, feasibility, and implementation challenges in commercial poultry systems. The integration of such tools can significantly enhance our ability to monitor broiler welfare dynamically, paving the way for predictive management strategies and improved animal care.

Keywords: broiler welfare, detection, pattern recognition, physiology, video recordings.

1. Introduction

Thermal stress in broiler chickens, particularly in high-density meat production systems, remains a major concern for animal welfare, physiological homeostasis, and overall productivity. Exposure to extreme temperatures, overcrowding, and social disruptions can lead to significant behavioural alterations in broiler chickens, including respiratory distress (panting), huddling, wing spreading for ventilation, and reduced mobility. These behavioural responses serve as compensatory mechanisms to cope with thermal and social stress but also act as early warning indicators of compromised welfare, discomfort and distress [1-2]. Thermal stress disrupts feed intake, compromises nutrient absorption, suppresses immune function, and increases oxidative stress, resulting in greater susceptibility to infections, poorer feed conversion, slower growth, and inferior meat quality [3]. Recent studies have consistently shown that thermal stress in broilers leads to reduced weight gain, elevated corticosterone levels, altered gut microbiota and intestinal barrier function, increased expression of heat shock proteins and pro-inflammatory cytokines, diminished feed intake, increased behavioural inactivity, and the suppression of key

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welfare-related behaviours such as dust bathing, preening, and social interactions [4-7].
Conventional methods for identifying stress in poultry—such as direct visual monitoring and behavioural scoring—are often too slow to capture the rapid physiological changes associated with stress. These methods are labour-intensive, susceptible to human bias, and generally unsuitable for large-scale commercial settings where thousands of birds are managed under intensive production systems [8]. In contrast, the integration of digital monitoring technologies—such as computer vision, thermal imaging, accelerometers, and wearable biosensors—offers a promising and scalable solution [9]. These modern technologies enable to monitor broiler chicken, automatically, continuous and without disturbance. By identifying signals like changes of body temperature, movement patterns, vocalizations, and heart rate fluctuations, they help identify signs of thermal stress early on. This early detection supports prompt action, whether through adjusting ventilation, modifying the diet, or activating cooling measures like misting systems [10]. For example, infrared thermography (IRT) has been effectively used to detect increases in peripheral temperature as a proxy for heat stress before observable behavioural signs manifest [11]. Using IRT offers advantages compared to the traditional rectal temperature (RT) method, as a non-invasive assessment method of peripheral vasomotor response, closely linked to core body temperature, particularly when the animal is healthy and within its thermal comfort zone [12]. Moreover, by analysing video recordings, machine learning models can detect subtle deviations from normal activity patterns (in movement or social interaction), helping predicting poultry welfare issues before they become serious issues [13]. Such advancements not only enhance welfare monitoring but also improve production efficiency by reducing the negative impact of prolonged stress on growth rate, feed conversion, and immune response [14]. These technologies are pivotal for transitioning toward precision livestock farming, where real-time data acquisition and automated decision-making optimize animal care and sustainability in poultry production systems [15-16].
This review synthesizes current research on digital technologies for detecting stress in broilers, focusing on behavioural indicators and the application of video surveillance, machine learning, and wearable sensors. By exploring the accuracy, feasibility, and challenges of these modern technologies, this review aims to highlight their potential to improve broiler welfare and to support the predictive management strategies of thermal stress mitigation.

2. Visible and impactful behavioural indicators of stress in broilers

Behavioural expressions in broiler chickens are sensitive markers of welfare status and can serve as early indicators of environmental or physiological stress. Under thermal, social, or nutritional stress, broilers exhibit measurable behavioural deviations from normal patterns [17]. Traditional observation methods are often limited or insufficient to capture imperceptible behavioural changes, especially in large flocks, therefore modern digital technologies enable objective and continuous monitoring of broiler behaviour [18].

2.1 Social behaviour modifications

Broilers exposed to thermal stress often exhibit decreased social interaction, manifested through behaviours such as flock dispersion, social withdrawal, and reduced activities [19]. These behavioural changes indicate compromised and suggest impaired welfare [20-21]. Post et al., (2003) [21] reported that broilers experiencing thermal and social stress showed reduced group cohesion and increased individual isolation, accompanied by elevated corticosterone levels. Other authors [22] demonstrated that video surveillance and movement analysis could predict behavioural deviations linked to environmental stressors. Similarly, Banhazi et al., [23] highlighted the importance of real-time location systems for assessing flock dynamics in precision livestock farming.

2.2 Excessive pecking

Stress can lead to redirected behaviours such as excessive pecking at conspecifics, objects, or environmental structures. This includes both gentle and severe feather pecking and may escalate to cannibalism if left unaddressed. Nasirahmadi et al., [24] developed a computer vision system capable of detecting pecking and clustering events in commercial broiler houses. Bright and Joret (2012) [25] reviewed pecking control strategies and emphasized early detection as a key intervention. Also, Zeltner and Hirt, [26] found that environmental enrichment reduced stress-induced pecking and improved plumage condition.

2.3 Increased aggression

Broiler aggression, expressed through chasing, biting, or threatening postures, often intensifies under conditions of heat stress, high stocking density, or insufficient resource availability [27]. These aggressive episodes disrupt poultry social stability and contribute to injury and reduced productivity, therefore showed that video systems could detect aggressive episodes under thermal stress [13]. Estevez [28] noticed that also the space allowance and environmental complexity influence aggression in dense broiler populations, on the other hand, Bokkers and Koene [29] linked increased aggressive behaviours to poor leg health and restricted mobility.

2.4 Reduced locomotion

Low activity levels, including persistent lying, decreased exploration, or movement decreasing are often signs of underlying discomfort or thermal stress in broilers [30]. Heat-stressed birds minimize activity to reduce endogenous heat production, whereas cold-stressed birds may huddle and remain inactive [31]. Aydin [32] employed wearable sensors to successfully track inactivity and detect lethargy in heat-stressed broilers. Other researchers [33] found that both cold and heat exposure altered walking behaviour and standing time. Thermal stress significantly impaired broiler locomotion. Using inertial measurement units (IMUs), researchers reported that broilers exposed to heat stress remained inactive for up to 76.22% of the time, highlighting lethargy [34]. Similarly, cold stress reduced neuromuscular activity, leading to muscle stiffness and reduced movement, further compromising welfare and performance.

3. Digital monitoring technologies

Advancements in precision livestock farming have enabled the smart digital systems utilization that automatically monitor broiler chickens in real-time. These technologies allow researchers and farmers to supervise poultry and helps reveal key insights into their behaviour, health, and diet, supporting better welfare and improved production efficiency [35]. Poultry were the first livestock species to commercially adopt automated monitoring systems for behaviour, health, and welfare—driven by their intensive production, high stocking density, and sensitivity to management-related stress, highlighting the industry's early adoption of precision livestock farming tools [36]. Several studies emphasize that the poultry sector serves as a model for integrating automated welfare assessment tools [37] including video surveillance, sound analysis, and wearable sensors, due to the birds' high sensitivity to environmental fluctuations and their rapid growth life cycles. Banhazi et al. [23] emphasized that poultry houses offer a more controlled environment, which allows earlier and more effective application of real-time digital monitoring compared to ruminants or swine.

3.1 Video surveillance and computer vision

Video surveillance systems integrated with computer vision algorithms have greatly advanced broiler behaviour evaluation by providing accurate data concerning animal welfare, also detecting subtle behavioural changes indicative of stress [38-39]. For sound analysis, modern microphone arrays can capture and analyse vocalizations, pecking, and environmental sounds. Deep learning models have been trained to detect acoustic changes associated with heat stress, fear, and isolation. Li et al. [40] noted that tracking broilers with video analytics is challenging due to their similar appearance, unpredictable movements, and variations in age and stocking density. On the other hands, other studies [41] achieved over 96% accuracy in identifying stress conditions from broiler vocal patterns using a spectrogram-based convolutional neural network. According to Yang et al. [42] image-based locomotion tracking identified pathological movement up to 10 days before clinical diagnosis, offering strong potential for pre-emptive welfare interventions.

Convolutional Neural Networks (CNNs) are a type of deep learning model specifically designed to process data (images or videos), especially designed to automatically learn patterns like shapes, textures, or movements from visual inputs [43]. The software track efficiently individuals, especially when combined with object detection frameworks like YOLO (You Only Look Once) in real-time, facilitating accurate behaviour mapping [44]. These tools are critical in detecting behavioural changes linked to thermal stress especially.

3.2 Machine learning algorithms

Machine learning is central to interpreting the vast datasets generated by digital monitoring systems. Both supervised and unsupervised learning techniques are employed to classify behaviours, detect stress patterns, and predict welfare issues [45]. Models such as the Improved Feature Fusion Single Shot MultiBox Detector (IFSSD) have achieved remarkable accuracy in identifying health-related behaviours. According to Qi et al. [46], FCBD-DETR (Faster Chicken Behavior Detection Transformer) this models improved detection speed and accuracy, facilitating real-time monitoring of broiler activities. Other systems like unsupervised learning methods like K-means clustering help categorize broiler activity into high, medium, and low. Branco et al. [19], reported that during cyclic heat stress, broilers clustered into low-activity groups significantly more often, showing a strong correlation with increased thermal stress levels. In contrast, processing video data in real time ensures prompt detection and notification of behavioural irregularities. Other researchers [47] demonstrated that using lightweight CNN enables real-time detection of broiler distress behaviours, triggering automated interventions within seconds.

3.3 Wearable sensors

Wearable sensor technologies enhance visual monitoring systems by delivering both physiological and movement-related data from individual birds. They are essential tools for personalized tracking, especially in large-scale poultry operations [48].
The physiological sensors, implantable or surface-mounted micro-sensors measure metrics such as heart rate, body temperature, and respiration rate. These parameters correlate strongly with environmental stressors. Studies [49] demonstrated the use of integrated physiological sensors to monitor circadian heart rate fluctuations as early indicators of thermal discomfort in broilers. Sensor retention and bird welfare are critical. Various methods—ranging from sutures (with 19.5-day retention time) to fabric harnesses—have been tested. It is widely recommended that sensor systems remain under 5% of body weight to avoid welfare compromise [38].

Figure 1. Machine learning technologies for early stress detection in broiler farms

4. Integration and implementation challenges

The integration of video surveillance, machine learning algorithms, and wearable sensors presents a robust framework for monitoring broilers' behavioural indicators of stress in real time. Together, these technologies offer a deeper insight into behavioural and physiological responses to stressors, although challenges remain for their effective use in commercial poultry systems [50].

4.1 Comprehensive monitoring

Marques et al. [49] also emphasized that wearable sensors—such as accelerometers, thermistors, and heart rate monitors—can detect subtle physiological deviations that precede visible stress-related behaviours. These data streams, when synchronized with video analytics, provide a richer behavioural context and support more nuanced welfare assessments. In addition, other studies [51] reported that infrared thermography, when integrated with computer vision and sensor-based movement tracking, effectively identified early thermal discomfort before it was behaviourally expressed. This highlights the utility of hybrid monitoring platforms in precision livestock farming. Furthermore, cloud-based data integration platforms allow real-time processing and alert systems. According to Van Hertem et al. [22] the use of decision-support systems based on integrated data streams significantly reduced stress episodes and improved production outcomes in broiler farms. This integrated monitoring approach supports the goals of precision livestock farming by combining data-driven insights with smart decision-making to improve welfare, productivity, and sustainability, for prompt responses and customized care, advancing automation in livestock welfare [52].

4.2 Feasibility in commercial farms

Although behavioural and physiological monitoring systems have shown high accuracy under controlled experimental and semi-commercial conditions, their adoption at full commercial scale remains relatively limited [50]. A major obstacle is represented by the economic feasibility, as the high initial costs of equipment and additional expenses for maintenance and data management challenge long-term sustainability for producers [53]. Another critical barrier is system scalability and logistics. Commercial broiler farms often manage tens of thousands of birds spread across multiple houses. Implementing a consistent monitoring infrastructure across such large populations demands robust networking solutions, advanced data processing capabilities, and trained personnel to interpret the data in real time [22]. Wearable sensor technologies—although promising for individualized data collection—pose ergonomic and behavioural concerns when applied on a large scale. Other studies [38] reported that improperly fitted devices can negatively impact broiler mobility, induce discomfort, and suppress natural behaviours such as pecking or dustbathing. Similarly, Nasirahmadi et al., [24] observed that visible or obtrusive sensors increased bird alertness and disrupted normal flock behaviour, introducing confounding variables that may bias data accuracy. Additionally, biosecurity risks associated with equipment reuse and inter-house transfers must be considered, especially in regions prone to disease outbreaks such as avian influenza [54]. Digital monitoring tools show promise for poultry farming, but their success depends on affordability, scalability, animal comfort, and reliability in real conditions [55]. Another major issue in implementing integrated monitoring systems is big data handling. These technologies generate high-frequency data streams—including video, audio, thermal, and biosensor inputs—that require substantial storage, high processing power, and sophisticated algorithms for interpretation. Cruz et al. [56] highlighted the necessity of commercial poultry systems to integrate real-time analytics capable of handling terabytes of data daily to identify welfare issues and generate timely alerts.

5. Conclusion

Digital monitoring technologies represent a innovative and useful approach to managing broiler welfare. Video surveillance and computer vision provide real-time insights into behavioural changes, while machine learning algorithms enable the analysis of large datasets to identify stress patterns. Wearable sensors offer complementary physiological data, enhancing the accuracy of stress detection. These technologies can significantly improve early stress detection and welfare problems in broilers. These technologies enable the poultry industry to adopt predictive management, improving both animal welfare and productivity

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