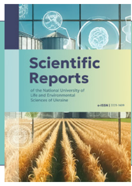
Received 12.01.2026 Revised 13.04.2026 Accepted 21.05.2026 Published: 27.05.2026

Vol. 22, No. 3
2026



Scientific Reports of the National University of Life and Environmental Sciences of Ukraine

Journal homepage: https://scireports.com.ua/en e-ISSN 2223-1609

UDC 636.5.033:612.176 DOI: 10.31548/dopovidi/3.2026.86

Factors of technological stress in broiler chickens and strategies for its prevention

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Abstract. In intensive poultry farming, a range of technological stress factors affect the growth and development of broiler chickens and the quality of poultry products. The impact of acute or chronic stress is reflected in poultry behavioural reactions, eating disorders, feed conversion, daily weight gain, and product quality. The purpose of the study was to critically review and systematise scientific knowledge about changes in the bird's body under the influence of technological stress factors. This paper analysed scientific literature on physiological and behavioural changes in poultry caused by stress-related disorders, identifies clinical and laboratory markers for their diagnosis, and outlines methods of prevention. The review helped to identify the main criteria that help differentiate the manifestations of stress in poultry. It was determined that the main technological stressors for poultry are a violation of the temperature regime of poultry rearing, an increase in the density of its content, regrouping, weighing, sorting, forming groups, trapping, moving, transporting, technological noise. Clinical manifestations in the development of stressful phenomena in poultry were a decrease in feed consumption, excitability, anxiety, fear, fatigue, rapid shallow breathing, premature maturation and impaired reproductive functions, a decrease in egg laying, a weakening of muscle tone, and a decrease in the quality of poultry products. The criteria for determining the manifestation of stressful phenomena in poultry were behavioural changes and clinical indicators, in the blood – the ratio of

Suggested Citation:
Tsvilikhovskiy, D., & Nemova, T. (2026). Factors of technological stress in broiler chickens and strategies for its prevention. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 22(3), 86-101. doi: 10.31548/dopovidi/3.2026.86.

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heterophiles to neutrophils, the content of corticosteroids. To investigate oxidative stress in greater depth, it would be useful to measure the levels of malondialdehyde and 8-hydroxy-2-deoxyguanosine in the birds' blood, and the activity of glutathione and superoxide dismutase, and the heat shock proteins HSP70 and HSP90. Strategies for preventing the development of technological stress factors include optimisation of keeping conditions, correction of the diet with the addition of biologically active compounds, macro- and microelements, organic acids, probiotics and prebiotics to build the birds' resistance to both production-related and other environmental factors. The results of the study will be useful for developing effective means of preventing technological stresses in poultry

Keywords: poultry; stress factors; heat exposure; density of keeping; lighting; physiological changes; preventive measures

Introduction

Poultry farming is a highly effective method of animal husbandry, which makes a significant contribution to ensuring the food safety of a significant part of the global population. Market demand and the use of contemporary intensive farming methods contributed to a significant increase in global poultry production, which reached 151.4 million tonnes in 2024/2025. Ukraine produces 1 million 390 thousand tonnes of poultry meat, which is 1.3% of the world market for poultry products (Poultry meat production..., 2025). In the face of changing consumer preferences and biosafety threats associated with outbreaks of highly contagious diseases, poultry sustainability and adaptability are crucial to ensuring global food security. Furthermore, climate change, intensification and automation of poultry rearing processes almost inevitably leads to the emergence of various stressful factors, which has a significant impact on the physiological status, growth, development of poultry, and the quality of poultry products.

R.M. Bilal *et al.* (2021) noted that environmental changes pose significant threats to agricultural activities and negatively affect poultry health and productivity in the face of current climate change. They also change the immunological status of poultry, make them susceptible to various diseases, contribute to a decrease in productivity (reduced feed consumption, growth, feed efficiency, immunity and egg production), and a decrease in the quality of poultry products. L.I. Podobied (2022) argued that the problem of increasing seasonal temperatures is becoming increasingly important in Ukraine. Periods of heat, when the outdoor temperature in summer exceeds 30°C, and in some regions – 40°C, are becoming longer, which negatively affects the main production indicators of poultry farms, as it leads to increased death of poultry due to heat stress. For most bird species, the thermoneutral zone (the ambient temperature range in which the body can maintain body temperature) is between 15.6 and 23.9°C. When the ambient temperature rises to 29.4°C, the bird changes its behaviour and reduces its feed intake to prevent an increase in body temperature. When the air temperature rises to 37.8°C, the bird's body temperature rises to lethal limits. S.F. Olayiwola & S.A. Adedokun (2025) reported that the poultry are very sensitive to light conditions, air quality, humidity, poor ventilation, transportation and veterinary manipulations, and violations of the feeding regime, nutrient deficiencies, feed contamination, diseases, an imbalance of the intestinal microbiota, etc. Most often, the poultry are exposed to elevated ambient temperatures, to which it is particularly vulnerable due to the lack of sweat glands and the presence of feathers. On the other hand, in some regions, cold stress is very harmful, which also causes serious economic damage on a global scale. In general, according to K. Deshmukh *et al.* (2024), there are four main types of stress in poultry farming: technological, environmental, food, and internal. Under the influence of these stresses, it leads to harmful changes at the molecular, cellular, and physiological levels of the bird's body, which ultimately reduces the productive and reproductive indicators of industrial poultry farming.

The main technological stress factors affecting the physiological processes of poultry rearing are: deviations from the required temperature regime, increased stocking density, regrouping, weighing, sorting, grouping, catching, moving, transport, operational noise, prolonged storage of eggs, transport of eggs, inadequate storage conditions for eggs, and incorrect incubation regimes. Environmental stresses include temperature changes in the environment, insufficient ventilation, high levels of dust and ammonia in poultry premises, and insufficient lighting. Food stress is associated with impaired feed conversion, reduced average daily weight gain, immunosuppression, and increased mortality in growing poultry. In particular, these are the effects of mycotoxins, exposure to toxic metals (Pl, Kd, Hg), an imbalance of minerals (Se, Zn, Mn, Cu, etc.) and other nutrients, poor water quality, the use of coccidiostatics and other veterinary drugs. Internal stresses depend on the production cycle, including peak egg production and poultry vaccination, preventive treatments, microbial or viral diseases, and intestinal dysbiosis. Research, in particular by M. Shah Alam (2025), confirmed that most stresses in poultry farming occur at the cellular level. They are often linked to oxidative stress due to excessive production of free radicals or insufficient antioxidant protection. Furthermore, any stressful factors cause changes in regulatory mechanisms in the bird's body. This causes increased energy mobilisation and metabolic disorders that impair poultry productivity. Therefore, the development of effective ways to prevent stressful phenomena during intensive poultry rearing is an important task for researchers and practitioners.

The purpose of the study was to summarise and critically review existing scientific data on the occurrence of stresses in poultry during intensive farming, methods of diagnosis and strategies for preventing their occurrence. The focus of the research was on scientific data concerning the impact of various factors on poultry, the changes they induce, and their effect on growth, development, and the quality of poultry products, and a review of various strategies for preventing technological stress in poultry farming. The PubMed database, Elsiver, and specialised scientific journals were used to search for information. Descriptive, analytical, comparison, and synthesis methods were used. The comparison method was used to contrast different approaches to the diagnosis of stress conditions in poultry, described in scientific sources under the influence of various stress factors. This method helped to identify markers and criteria for the diagnosis of stress in poultry and approaches to prevention.

Characteristics of the main technological stress factors in poultry

In contemporary poultry farming, stress can be considered as an automatic reaction of the body caused by exposure to adverse environmental conditions. In poultry, stress manifests itself through a number of physiological responses, such as identification of a stress stimulus, activation of the sympathetic nervous system and adrenal medulla, and subsequent hormonal cascades, in particular, the production and release of corticosterone and catecholamines as a result of neuroendocrine-immune interaction. The secretion of epinephrine or norepinephrine increases respiratory and heart rate, blood pressure, and activates glycogenolysis and lipolysis. The release of corticosterone weakens the immune system, reduces feed intake, and impairs bowel function.

Y. Huang *et al*. (2024) highlighted that heat stress is becoming an increasingly serious problem for poultry. The degree of heat stress experienced by poultry is divided into mild, moderate, strong and depends mainly on heat radiation, humidity, thermoregulatory ability of the body, metabolic rate, age, intensity and duration of action of the heat factor. Due to the high metabolic rate that modern broiler chickens have, this leads to the production of more heat. When heat stress occurs, the neuroendocrine system in poultry is disrupted. It activates endocrine glands such as the pituitary gland, adrenal glands, thyroid gland, and sex glands through the action of the hypothalamus and sympathetic nerves. This causes changes in the level of hormones such as corticosterone, triiodothyronine, thyroxine, gonadotropin, decreased ovarian function, and promotes the release of catecholamines, which affects poultry productivity.

As indicated by S.F. Olayiwola & S.A. Adedokun (2025), in poultry, persistent corticosterone secretion is associated with cardiovascular disease, weakened immune systems, depression, muscle breakdown due to gluconeogenesis, and cognitive decline. This reaction can range from mild discomfort to serious consequences, including poultry mortality. Research data by C.M. Ncho (2025) indicated that heat stress significantly affects the digestive system of poultry. This leads to changes in the composition of microbial populations, disruption of specific functional pathways of microorganisms (tricarboxylic acid cycle, amino acid metabolism, antioxidant biosynthesis and fatty acid synthesis), disruption of intestinal barriers, which causes the appearance of increased intestinal permeability syndrome, which changes the pH of the intestinal environment, causes oxidative stress, and leads to inflammation. M.R. Farag & M. Alagawany (2018) indicated that acute or chronic heat stress negatively affects the well-being of poultry. In addition to inducing oxidative stress, heat stress can also cause cell damage. This, in turn, leads to endocrine disorders, immunosuppression, increased inflammatory processes, changes in the microbial population, deterioration of intestinal function, deterioration of meat quality, and the possible occurrence of intestinal diseases in poultry. Heat stress also causes hyperventilation, which disrupts the acid-base balance of the blood. This leads to respiratory alkalosis, the development of which interferes with the growth of chickens, egg production and eggshell quality of laying hens. Heat stress significantly reduces the egg production of laying hens and egg weight (Tesakul *et al.*, 2025).

Another factor that is important for ensuring the functioning, growth, and productivity of poultry is the lighting mode. As noted by C.M. Ncho *et al.* (2024), lighting plays a crucial role in triggering the secretion of various hormones that directly affect the growth, maturation, reproduction, and egg production of poultry. Therefore, to improve the production and efficiency of poultry farming, it is important to consider aspects of environmental management, such as regulating light intensity, duration, wavelength, and photoperiodic mode. Recent studies show that the wavelength of light affects a bird's ability to respond to stress, fear, and depression. In particular, exposure to green, red, and white light spectra can reduce fear and sensitivity in broilers, and irregular light exposure times can cause circadian rhythm disturbances that directly affect the bird's well-being and behavioural responses (El-Sabrout *et al.*, 2022). Currently, there is no conclusive data on the optimal lighting intensity to ensure the health and well-being of broiler chickens, which can be applied equally to all detention systems. With the exception of the first and last weeks of rearing, birds provide at least four hours of darkness every 24 hours. Four hours of darkness can be provided at one, two, or four-hour intervals.

Light intensity in poultry houses and other artificial environments is measured in lux or cd/m^2 and has a significant impact on the behaviour of chickens. According to the standard lighting mode for broiler chickens, a constant light intensity of 20 lux is maintained for the first 7 days (the early period after hatching), after which it is adjusted to a low intensity of 3-5 lux for the rest of the poultry rearing period. In addition, the density of poultry content is of great importance, which, if increased, can also cause violations of physiological and productive indicators, and affect the quality of the resulting products. As noted by E.T. Gül *et al.* (2022), the ideal keeping density for broilers should be 35 kg/m^2. Otherwise, there may be problems associated with reduced availability of feed and water in poultry, abnormal behaviour, lack of air, and poor flooring quality. In addition, the high density of poultry content can create a mild stress shock, increasing the temperature in the microenvironment around the bird and reducing heat transfer from the body. This leads to pathological reactions that may be associated with a violation of the function of the intestinal barrier.

Simultaneously, K. von Eugen *et al*. (2019) found that when the poultry content density is increased during the first 6 weeks, chickens have more anxious behaviour than when the poultry content density is low. Simultaneously, both high and insufficient keeping densities of chickens recorded a higher level of corticosterone in their blood, compared to those chickens that were kept in conditions of optimal density. At 10 weeks of age, plasma corticosterone levels in chickens decreased to optimal density levels in both groups, while feather corticosterone levels remained high only in the high density group. The researchers concluded that a threefold increase or decrease in broiler chicken keeping density affects corticosterone levels and anxiety behaviour in poultry, but within the adaptive capabilities of chickens. The increase in keeping density has led to a slowdown in their adaptation and an increase in the cost of its provision.

T. Shynkaruk *et al*. (2022) also evaluated the effect of poultry keeping densities at the rates of 31, 34.5, 38, and 41.5 kg/m^2 on the wellbeing and productivity of broiler chickens. They found that with a decrease in the density of content, the humidity of the litter, cases of dermatitis of the paw pads, poultry mortality from infections, fear, and stress decreased. The ratio of heterophiles/lymphocytes in the blood of poultry was the highest in the density variants of 31 and 41.5 kg/m^2. This suggests that the bird experienced more chronic stress at both low and high planting densities. The optimal body weight of poultry was highest in the density variants of 31 and 34.5 kg/m^2. The increase in body weight of the bird increased with a decrease in the keeping density, and feed consumption was greatest in the variant with a density of 34.5 kg/m^2. M.G. Anderson *et al*. (2021) in another experiment investigated the effect of environmental complexity and keeping density on determining broiler anxiety and tonic immobility (a measure of fear). The results of the study showed that the bird at the age of 3 weeks was less timid in high-density conditions than in low-density conditions. In addition, the results showed that a more challenging detention environment improved the well-being of broiler chickens by reducing anxiety. Thus, through behavioural testing, the researchers found that broiler chickens kept in higher-density environments reacted less fearfully than those kept in lower-density environments, contrary to the expectations and findings of other researchers.

Additionally, J. Son *et al*. (2022) indicated that the effect of high temperatures (33°C for 24 hours for 7 days and high content densities (23 and 26 birds/m^2) led to a significant decrease in the body weight and superoxide dismutase (SOD) activity in its blood, and an increase in rectal temperature and corticosterone levels. In addition, concentrations of the heat shock protein HSP 70 and malondialdehyde in the liver were higher in the group with 26 birds/m^2. Similarly, the uptake activity of 2,2-diphenyl-1-picrylhydrazyl radicals in breast tissue increased linearly with increasing bird landing density. Therefore, a lower planting density in broiler chickens can reduce oxidative stress caused by high temperatures and improve the antioxidant capacity of the bird's body and the quality of poultry products during the hot seasons of the year. Thus, technological stress factors such as temperature disturbances, lighting, and changes in content density lead to significant changes in the bird's body and affect metabolic processes on its growth and productivity.

Changes that occur in the bird's body under the influence of stressful factors

As noted by D. Diaz *et al*. (2022), prolonged heat exposure changes the course of anabolic processes in the poultry body to catabolic ones, which leads to a violation of the growth, muscle development, and quality of poultry meat. In addition, heat stress changes the composition of the gut microbiota, which leads to a decrease in microbial diversity and preference for opportunistic microorganisms. These changes impair the absorption of nutrients, disrupt energy metabolism, and impair immune system function, increasing physiological stress. In addition, significant haematological and biochemical changes occur in the bird's body, in particular, a decrease in the number of red blood cells, a decrease in the haemoglobin content and haematocrit value, which impairs oxygen transport and energy metabolism. An increase in the content of non-esterified fatty acids (NEFA) and β-hydroxybutyrate in the blood plasma of poultry indicates the development of catabolism, when lipids are mobilised for energy due to poor feed intake and increased metabolic needs.

L. Yang *et al*. (2010) experimentally proved that acute heat stress in the body of broiler chickens increases the production of reactive oxygen species (ROS), the activity of antioxidant enzymes (SOD, catalase (CAT), and glutathione peroxidase (GSH-Px)), and the synthesis of malonedialaldehyde (MDA). These parameters, which are caused by heat stress, gradually decrease during the first 12 hours after exposure to high temperatures. Therefore, acute exposure to high temperatures can inhibit the activity of the mitochondrial respiratory chain, which leads to excessive ROS production and, as a result, to lipid peroxide oxidation and oxidative stress. Therefore, an important consequence of heat stress is the development of oxidative stress. J.A.M. Prates (2025) also reported that prolonged exposure to heat leads to excessive production of ROS, including superoxide anions (O_2^-), hydroxyl radicals (OH-) and hydrogen peroxide (H_2O_2), which exceeds the capabilities of endogenous antioxidant systems of the bird's body. In addition, R. Farag & M. Alagawany (2018) argued that exposure to heat stress can increase salmonella colonisation in the gut and increase poultry susceptibility to *E. coli*, and alter the microbial background of the ileum.

According to M. Shah Alam (2025), oxidative stress is the driving force behind the development of mycotoxicosis in poultry, in which a cascade of pro-inflammatory cytokines is triggered by the activation of numerous cellular signalling pathways, such as nuclear transcription factor κβ and mitogen-activated protein kinase. It promotes apoptosis and dysfunction of tissues and organs, such as immunosuppression, hepatotoxicity, nephrotoxicity, neurotoxicity, and gastrointestinal toxicity. The effects of this toxicity lead to poor feed conversion, feed rejection, low growth rates, reduced fertility, and reduced poultry hatchability.

Heat stress also has a negative impact on the mineral balance of the bird's body, and the degree of this effect depends on the type of mineral and the severity of heat stress. Exposure to high temperatures on broilers negatively affects the metabolism of minerals and their elimination routes, and also reduces the delay in the bird's organism of certain mineral elements, such as P, Na, K, S, Mg, Mn, Zn, and Cu. It is known that heat stress worsens the productive parameters of broiler chickens. But there is no clear definition in the literature of neuroimmune involvement observed during heat stress in infectious processes. Furthermore, permanent damage or the presence of pathogenic agents causes a stressful process in the gastrointestinal tract of poultry, increasing inflammation and oxidative stress.

One of the critical functions of the poultry gastrointestinal tract is to prevent harmful substances from entering the body from the intestinal lumen, which is called the intestinal barrier function. The function of the intestinal barrier is often determined by intestinal permeability and is closely related to the integrity of the dense junction of mucosal enterocytes, which is a sealed protein complex between enterocytes in the gastrointestinal tract. They serve as the body's first line of defence against the penetration of microorganisms and antigens from the intestinal lumen. If the function of tight intestinal contacts is disrupted, then both local and systemic inflammation in the body increases.

This leads to a decrease in the health and productivity of the bird.

As noted by J.E. Shin *et al*. (2018), reduced expression of genes and proteins associated with tight contacts in the gastrointestinal tract often correlates with reduced intestinal barrier function under the influence of heat stress factors. Damage to the intestinal epithelial barrier increases permeability, promotes inflammation, and reduces the surface area available for nutrient absorption. The brain-gut-microbiota system is responsible for maturing and maintaining the balance of the immune and nervous systems, which improves poultry productivity and resistance to diseases. J.M. Lyte (2024) indicates that there is a close relationship between gastrointestinal neurophysiology and the gut microbiome, highlighting the intersection of neurochemistry and microbiome along the respiratory and reproductive pathways of poultry. It is known that thermal or cold stressors alter neurochemical concentrations in poultry intestines. In particular, heat stress modulates the expression of neurochemical enzymes in the gut, including monoamine oxidase. Transport stress, during 2-3-hour exposure, causes rapid changes in the number of microbiota strains, which affects the susceptibility to intestinal carriers of food pathogens in poultry.

Diagnostic markers of stress in poultry

Stress in poultry can be caused either by one factor or by a complex combination of several factors. In the occurrence of stress factors, local climatic conditions (sunlight, heat exposure, humidity, temperature and air movement), animal production systems (free range or intensive rearing), conditions of keeping (manual or automatic temperature control, ventilation systems), methods of keeping (planting density, feeding time, drinking water temperature), and breed characteristics of poultry (genetic background, gender, age, metabolic rate, and thermoregulatory ability) are important.

Understanding the biological mechanisms underlying the occurrence of stress in poultry, and using reliable biological markers (or biomarkers) are central to developing new approaches to mitigating the effects of stress on animals. Due to the lack of sweat glands, the bird cannot cool its body. To regulate their body temperature, chickens spread their wings, keep them away from their bodies by ruffling their feathers, collecting dust, and moving less. Poultry tends to drink more and increase their rest time, while reducing their feed intake. Based on the unique respiratory system, which includes air bags connected to the lungs, a continuous and unidirectional flow of air through the respiratory system is ensured, promoting efficient gas exchange and maintaining the high metabolic needs of poultry. It is important to note that increased peripheral blood flow reduces excessive heat production, and increased shortness of breath helps to cool the body by evaporation (Onagbesan *et al.*, 2023).

As noted by M.D. Kucheruk & D.A. Zasekin (2018), under the influence of heat stress factors, the bird moves little, sits with its beak open, and has shallow and rapid breathing (thermal respiration). Blood tests reveal reduced total protein levels, elevated haemoglobin levels against a background of dehydration, and an increased mean corpuscular haemoglobin (MCH) level. High levels of excitability in poultry have been observed in response to various technological stress factors, along with anxiety, fear, aggressive behaviour, loss of appetite, fatigue and behavioural disturbances in young chickens, quails, and ducks. Common signs of stress in mature chickens, quails, and ducks during the development of technological stress are premature mass maturation, decreased and complete cessation of egg laying, impaired reproductive function, and weakened muscle tone. In addition, young poultry have a slowdown in feather growth and tousling, depression of the clinical and physiological state, tachycardia, arrhythmia, slowing or increasing intestinal motility. In an adult bird, "pecking" or cannibalism, premature mass moulting is observed.

In poultry, as in animals of other species, a reliable indicator of stress is the content of corticosterone in the blood plasma. Corticosterone, which circulates in the blood, is extensively metabolised by the liver with a half-life of 10-15 minutes in chickens. Elevated levels of corticosterone in the blood plasma have been observed in poultry during the night. Restraining birds for blood sampling can also cause additional stress and, consequently, a surge in corticosterone levels within a few minutes. Thus, M. Dehnhard *et al*. (2003) suggested using the analysis of steroid metabolites in poultry faeces. They developed and validated a method for non-invasive measurement of glucocorticoid metabolites in chicken faeces. Non-invasive measurements of faecal metabolites are promising for monitoring stress in poultry.

In addition, the ratio of heterophiles to lymphocytes (H/L ratio) is considered an indicator of physiological stress in poultry. Heat stress in poultry significantly increases the ratio of heterophiles to lymphocytes (H/L), which is a standard indicator of physiological stress. During heat stress, the level of corticosteroids in the bird's blood increases, which leads to an increase in the number of heterophiles and a decrease in the number of lymphocytes. In the blood of poultry exposed to heat stress, a reduced number of lymphocytes is often found, which may correlate with a decrease in antibody production and immune suppression. Simultaneously, this ratio may change with the age of the bird, which is associated with the development of the immune system in broiler chickens, and may also differ between breeds. In particular, J.J. Danzaria *et al*. (2025) indicated that Cobb 500 cross chickens have the lowest H:L values both under natural heat stress and under experimental conditions, which indicates their thermal tolerance compared to Ross 308 cross.

Key indicators of oxidative stress in poultry include high blood levels of MDA, 8-hydroxy-2-deoxyguanosine (8-OHdG) and heterophyll/lymphocyte ratio, and reduced glutathione (GSH) and SOD activity (Weidong *et al*., 2023). M. Shanmugam *et al*. (2017) indicated that all living organisms respond to various stressors by synthesising a group of evolutionarily conserved polypeptides called heat shock proteins (HSP). Most HSPs serve as molecular chaperones, helping organisms overcome internal and external stresses. Changes in HSP expression after harmful stimuli suggest that these proteins can be used to assess physiological stress in birds of various species. Heat shock proteins, particularly HSP70 and HSP90, serve as critical, sensitive biomarkers for monitoring stress in chickens, especially under heat stress and high population densities.

Strategy for preventing technological stress in poultry farming

The strategy for preventing technological stress in poultry farming includes advanced methods of poultry management, including optimised feeding and control of environmental factors. Simultaneously, there is a constant search for ways to reduce the effects of stress in poultry and maintain the bird's vital activity at a high level. The main methods of combating stress in poultry include: cooling the premises with sprinklers, cooling water to 12-13°C with a constant flow from wells, changing the feeding regime of poultry (early in the morning and late in the afternoon), moistening the feed, rapid biocorrection of osmotic pressure in the cells of the protoplasm of the body with feed and water, etc.

S. Bhawa *et al*. (2023) argued that the negative effects of heat stress can be addressed through strategic management improvements, including the selection of poultry rearing systems with better ventilation, suitable conditions, and recommended proper planting densities. This is crucial for improving poultry productivity when exposed to high temperatures. The use of closed poultry keeping systems ensured optimal conditions for raising poultry, the ability to regulate temperature, humidity and lighting, which helped to reduce stress and promote egg production, minimising the influence of external factors. Instead, poultry raised in open systems is more exposed to environmental factors (Tesakul *et al*., 2025).

The use of ultraviolet (UV) light is also widely used in poultry farming. Since the bird can see in the UV spectrum with wavelengths of 320-400 nm, the inclusion of shorter wavelengths can be considered as more natural illumination. In addition, illumination with a wavelength of 280-310 nm has a physiological effect by stimulating the synthesis of vitamin D, which affects the skeletal development. As indicated by S.M. Rana & D.L.M Campbell (2021), UV light has a positive effect on reducing fear responses and stress responses, but it significantly increases the risk of feather biting with age. The addition of UV radiation may have a more pronounced effect on egg production and shell quality when hens are deficient in vitamin D_3 in their diet or if they are in the final stage of production. In addition, changes in the colour of light lead to changes in stress levels, which is manifested in a lower ratio of neutrophils to lymphocytes (H:L) in the blood of broiler chickens raised under blue light, compared to those raised under white light. Using blue light during the hatching and rearing phase of the bird leads to reduced stress and reduced fear. This suggests that blue light can improve emotional states of fear and stress, thereby improving the bird's well-being. However, the most powerful and cost-effective method of compensating for the negative effects of heat stress, as indicated by L.I. Podobied (2023), is the use of the effect of biocorrection of poultry body metabolism with the help of special feed additives and complete feeding of poultry.

A current trend in research is the optimisation of the gut microbial balance, metabolism, and intestinal integrity through the use of alternative products such as prebiotics, organic acids, plant extracts, essential oils, and trace elements, due to their anti-inflammatory, antioxidant and immunomodulatory effects. This is aimed at reducing the colonisation of various pathogens associated with the induction of inflammatory processes in the gastrointestinal tract. The complex interaction of intestinal microflora and these drugs plays a crucial role in their use and proper effect on the modulation of natural host microflora (Tellez-Isaias *et al.*, 2023).

Poultry's energy and amino acid needs during heat stress are the most studied, while vitamins and trace elements remain among the least studied nutrient groups. Therefore, knowing the nutritional needs of poultry for specific farming options under heat stress is of great importance and requires careful assessment of the nutrients in the diet. Feeding should include balancing the diet and providing the necessary trace elements to improve the productive and reproductive performance of poultry. Supplementation with fats, antioxidants, yeast, and electrolytes is one of the most common feeding strategies to ensure optimal poultry production. Replacing antibiotics in production systems with alternative products, improved management practices, strict biosafety, quality ingredients, the absence of diseases (mycoplasma/salmonellosis), and effective immunisation programs are effective strategies for achieving poultry health and productivity goals. Probiotics can improve the physiology, gut health, and immune system of poultry under heat stress. Therefore, it is believed that the use of probiotics together with proper management potentially helps to eliminate some of the negative effects of heat stress on poultry (Hernández-Coronado *et al.*, 2025).

Approaches to reducing the level of oxidative stress in poultry, according to O.E. Oke *et al.* (2024), include management techniques to reduce stress in the production environment, antioxidant supplements, and dietary supplements. Natural antioxidants, including plant extracts, minerals and vitamins, are effective in increasing the bird's resistance to oxidative effects. To improve antioxidant defence in poultry under stressful conditions, it is necessary to activate cellular homeostatic networks (vitagens/several key proteins encoded by genes that regulate a complex network of processes involved in longevity), to synthesise protective factors that can counteract the increased production of ROS and oxygen-saturated proteins. According to V. Calabrese *et al.* (2014) vitagens include heat shock proteins: HSP70 and hemoxygesnase-1 (HO-1); SOD; thioredoxin system (Trx, Trx peroxidase (peroxiredoxins), sulphiredoxin and TrxR); glutathione system (GSH, glutathione reductase (GR), glutaredoxin (Grx), GPx); sirtuins.

K. Deshmukh (2024) noted the role of antioxidants in reducing oxidative stress and the ability to maintain effective antioxidant protection and redox balance in the body. Antioxidants such as vitamin E or trace elements (such as Se, Mn, Cu, and Zn) are essential components of poultry premixes and, in most cases, provide the bird's physiological need for these elements. However, under stress, there is a need for additional support of the antioxidant system in poultry. Based on the activation of a number of vitagens (through mechanisms associated with Nrf2: SOD; haemoxygenase-1, HO-1; GSH and thioredoxin, or other mechanisms: heat shock proteins (HSP)/heat shock factors (HSF), sirtuins, etc.), the internal protection of the antioxidant system, and the maintenance of redox balance was carried out.

Vitamin E is the main antioxidant in biological systems. It has been found that the optimal addition of vitamin E to poultry feed improves feed conversion efficiency, body weight gain, productivity and egg quality, nutrient absorption, immune response, and antioxidant status in poultry (Khan *et al.*, 2011). Vitamin C can also prevent oxidative stress by scavenging ROS. Although poultry can synthesise vitamin C, its amount is limited under heat stress. Vitamin C supplements (250 mg/kg of feed) improved growth rate, nutrient utilisation, egg production and egg quality, immune response, and antioxidant status in poultry exposed to heat stress.

Changes in the acid-base balance in blood plasma and the development of respiratory alkalosis can be prevented by adding electrolytes such as NH_4Cl, $NaHCO_3$, and KCl. During respiratory alkalosis, the bird releases more bicarbonate ions with the kidneys to restore normal blood pH. A high level of electrolyte balance in the diet, 200-300 meq/kg, is considered effective in mitigating the adverse effects of heat stress in poultry (Mangan & Siwek, 2024). Selenium is widely recognised as an essential trace element for humans and animals of various species, including poultry. Adding selenium to the diet in appropriate doses plays a crucial role in promoting the growth and reproduction of poultry. A sufficient amount of selenium is necessary to ensure that selenium performs its biological functions. It is worth noting that both a deficiency and an excess of selenium in the diet can seriously threaten the health of poultry. As noted by X. Zi-Jian *et al.* (2025), for broiler chickens during the growth period, the required amount of selenium in the diet should be 0.15 mg/kg.

Effects of stress caused by high poultry keeping density, according to E.T. Gül *et al.* (2022), it is possible to correct for an increase in dietary concentrations of amino acids such as lysine, methionine, tryptophan, and arginine, minerals such as selenium and chromium, and vitamins such as C and E. The addition of supplements such as probiotics, humates, phytophenolic compounds and propolis to the diet effectively reduces or eliminates the negative effects caused by high livestock density. As a result, regulating animal feeding effectively reduces or prevents negative consequences, thereby improving animal welfare and ensuring a better food yield. In addition, there is a positive effect of organic acids (citric, formic, fumaric, sorbic, butyric, propionic) against pathogenic bacteria, due to their antimicrobial activity, reducing the pH in the gastrointestinal tract by acidification, which leads to an increase in the use of feed nutrients and, thus, affects the growth and development of broiler chickens (Kim *et al.*, 2015). P.M. Karkach & Y.L. Obraztsova (2019) highlighted the positive effect of drinking solutions of ascorbic acid (vitamin C) and potassium chloride (KCl) on reducing the effect of heat stress during fattening broiler chickens. J.L. Campo & S.G. Dávila (2002) showed that tocopherol and niacin effectively reduce the effects of heat stress, while lactic acid increases stress in poultry caused by high fever.

Trace elements, in particular zinc (Zn), selenium (Se), copper (Cu), manganese (Mn) and chromium (Cr), act as essential cofactors for antioxidant enzymes, significantly reducing physiological and heat stress in broiler chickens. Organic chelated forms are more bioavailable than inorganic sources. They effectively reduce HSP70 expression, reduce pro-inflammatory cytokine levels, and improve immune function. T. Mohammadizad *et al*. (2025) noted that the addition of oorganic trace elements in the diet of poultry exposed to heat stress have a positive effect on growth, intestinal structure, and physiological responses associated with stress. In particular, poultry fed with chelated forms of trace elements showed significantly higher body weight gain, production efficiency index, serum T_4 concentration and duodenal villus height compared with poultry fed a basic diet. In addition, poultry fed micronutrients had a lower feed conversion rate, mortality rate, blood heterophyll/lymphocyte ratio, alkaline phosphatase activity, and corticosterone concentration, and heat shock protein HSP-70 expression levels in the liver and hypothalamus, indicating better resistance to stress.

Technological innovations

K. Olejnik *et al*. (2022) argued that the use of technological solutions in various livestock systems that can help to better control environmental conditions and poultry health is a prospect for poultry farming. Various types of technologies allow collecting data about poultry in real time, which can help to prevent a decline in animal welfare by identifying the early stages of diseases in stressful situations, and also allows quickly taking measures to limit the negative consequences. I. Fontana *et al*. (2015) noted that a combination of audio and video information in automated herd management systems can be used in early warning systems to detect health or well-being problems in poultry. Due to the use of audio and video information in the technological process in online mode, it is possible to monitor and model the behaviour, health, and productivity of poultry. According to the researchers, the frequency of sounds made by a bird is inversely proportional to its age and body weight. Thus, the more they gain body weight, the lower the frequency of sounds. The non-invasive nature of audio and video equipment allows it to be used for long-term monitoring without disturbing the bird. The bird's body weight provides information about feed growth and conversion in the herd.

A. Goel (2021) pointed out that an important innovative development is technologies for influencing embryos for breeding heat-resistant poultry crosses. During incubation, various nutrients such as carbohydrates, trace elements, and amino acids are added to the developing embryos *in ovo*, or the embryos are subjected to heat treatment involving slight changes in incubation temperature. This increases thermal tolerance in hatched chickens, increases feed intake, and affects the resistance and adaptation of poultry immunity. G.D. Vandana *et al*. (2021) noted that the use of advanced biotechnological tools helps to identify relevant genetic markers in poultry. In the future, this will help in the development of new strains with higher thermal tolerance by developing an appropriate breeding programme that includes selection using markers. Thus, such strategies can help to optimise and support poultry production in the face of climate change.

Conclusions

Intensive conditions for raising poultry are inevitably associated with the occurrence of technological stress factors, such as temperature violations, insufficient lighting, changes in the density of keeping, regrouping, sorting, and transportation of poultry. Such factors have a significant impact on the growth, productivity, and metabolic processes in the bird's body due to hormonal imbalance, changes in the functioning of the cardiovascular and respiratory systems, immune response, and weakening of resistance to infectious agents, which increases the risk of poultry morbidity and causes significant economic damage to poultry farms.

Despite the growing amount of knowledge about the effects of technological stressors on the body, the literature lacks a comprehensive review of biomarkers that comprehensively characterise changes in the poultry. Currently, the diagnosis of stress in poultry is based on physiological and behavioural indicators. In particular, these are changes in behaviour, apathy, disorders of sleep, breathing, and heartbeat, reduced feed intake, aggressive behaviour, excessive pecking and cannibalism. In the blood of poultry, the content of glucocorticoids changes, the activity of white blood cells decreases, the ratio of heterophiles to lymphocytes changes, which is an important indicator of the physiological state and stress level in poultry. More thorough studies need to determine the indicators of oxidative stress – the activity of SOD, CAT and GSH-Px, MDA, and heat shock proteins HSP70 and HSP 90. Simultaneously, there is no clear substantiation for the indicators of the neuroimmune system, especially when exposed to pathogens against the background of stressful factors.

Developing strategies to reduce the impact of stress factors on the bird's body during intensive rearing is an important task for researchers and practitioners. Effective prevention of technological stress in poultry involves a comprehensive approach, which includes optimisation of the conditions of its maintenance, including ensuring a proper microclimate in poultry houses, ventilation and lighting systems, rational balanced feeding of feed in accordance with the regulatory age needs of poultry, the use of vitamins, trace elements, antioxidants that reduce the response to adverse stimuli or increase the resistance of the bird's body. In strategies for the prevention and mitigation of technological stress, it is advisable to thoroughly study the molecular changes caused by the use of probiotics, prebiotics, adaptogens, organic acids, vitamins, minerals, and their impact on the gut microbiota both under the influence of stress factors and pathogens.

Important for the study are advanced innovative implementations, research on which is still ongoing, such as gene mapping and genetic breeding during breeding to breed heat-resistant breeds, the use of thermal conditioning during embryonic development, which increases the ability of birds to tolerate high temperatures. And technologies for introducing nutrients *in ovo,* which contributes to the thermal tolerance of poultry, increasing its feed consumption, and increasing adaptogenicity. The use of advanced monitoring systems allows detecting stress manifestations in poultry in time and effectively correcting them. The timely diagnosis of stress in poultry ensures their welfare, guarantees high-quality poultry products, determines operational efficiency and minimises economic losses in the poultry industry.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Фактори виникнення технологічного стресу у курчат бройлерів та стратегії його профілактики

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Анотація. За інтенсивного вирощування птиці на ріст, розвиток птиці бройлерів та якість продукції птахівництва впливає цілий ряд технологічних стресових факторів. Вплив гострого чи хронічного стресу відображається на поведінкових реаціях птиці, розладах харчової поведінки, конверсії корму, добових приростах та якості отриманої продукції. Метою роботи був критичний огляд та систематизації наукових знань, щодо змін в організмі птиці за впливу технологічних стресових факторів. У статті проаналізовано наукові публікації щодо змін в організмі птиці на фізіологічному та поведінковому рівні за стресових розладів, визначені клінічні та лабораторні маркери їх діагностики та методи профілактики. Огляд допоміг виокремити основні критерії, які допомагають диференціювати прояви стресу у птиці. Визначено, що основними технологічними стресорами для птиці є порушення температурного режиму вирощування птиці, збільшення щільності її утримання, перегрупування, зважування, сортування, формування груп, відлов, переміщення, транспортування, технологічні шуми. Клінічними проявами за розвитку стресових явищ у птиці були зменшення споживання нею корму, збудливість, тривожність, страх, втома, прискорене поверхневе дихання, передчасне дозрівання та порушення репродуктивних функцій, зниження яйцекладки, ослаблення м'язового тонусу та зниження якості продукції птахівництва. Критеріями встановлення прояву стресових явищ у птиці є зміни поведінки та клінічні показники, у крові – співвідношення гетерофілів до нейтрофілів, вміст кортикостероїдів. Для більш глибокого дослідження оксидативного стресу корисним буде визначення вмісту в крові птиці малонового діальдегіду, 8-гідрокси-2-дезоксигуанозину, активності глутатіону та супероксиддисмутази, білків теплового шоку HSP70 і HSP90. Стратегії профілактики розвитку технологічних стресових факторів включають оптимізацію умов утримання, корекцію раціону із додаванням до його складу біологічно активних сполук макро – мікроелементів, органічних кислот, пробіотиків, пребіотиків для формування стійкості організму птиці до дії як технологічних, так і інших факторів зовнішнього середовища. Результати дослідження будуть корисними для розробки дієвих засобів профілактики технологічних стресів у птиці

Ключові слова: птиця; стресові фактори; тепловий вплив; щільність утримання; освітлення; фізіологічні зміни; превентивні заходи