Optimizing animal productivity during heat stress

Tips and tricks on how to manage heat stress in poultry

Content

What is heat stress?

Heat stress is an annual reoccurring problem that continues to challenge the poultry industry worldwide. Improvements in poultry genetics for higher production performance and increased lean meat have led to higher metabolic rates: birds consequently produce more body heat, making them increasingly prone to heat stress. Increased ambient temperatures and longer duration of hot seasons, as one of the most immediate and obvious effects of global warming, along with higher stocking densities, contribute strongly to the frequent occurrence of heat stress in birds.

Birds are subjected to heat stress when the air temperature and humidity uncontrollably increases their core body temperature and they cannot balance body heat production and body heat loss. The absence of sweat glands and presence of feathers in poultry makes the process of thermoregulation as an adaptive response to heat stress quite complex. Heat stress can occur irrespective of age and type of bird.

The optimum environmental temperature for performance is likely to be 19 to 22°C for laying hens and 18 to 22°C for growing broilers (Charles, 2002). In this 'thermoneutral zone' there is no heat stress, and body temperature remains constant. When the 'upper critical temperature' is exceeded, birds pant to actively lose heat and increase their water intake. In the area between 'upper critical temperature' and 'maximum heat loss', bird welfare, performance and health can be affected. When 'maximum heat loss' is exceeded, mortality can occur.

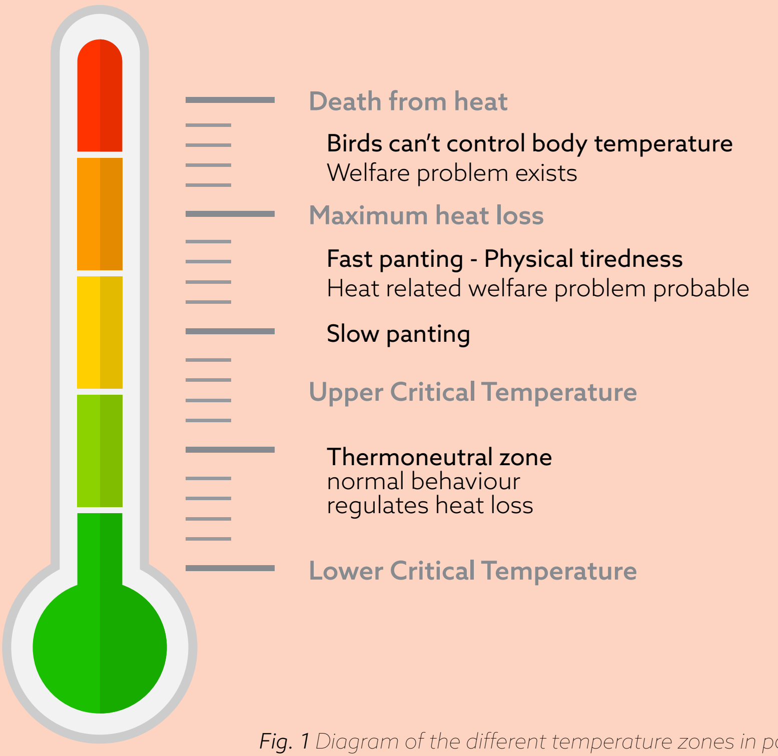
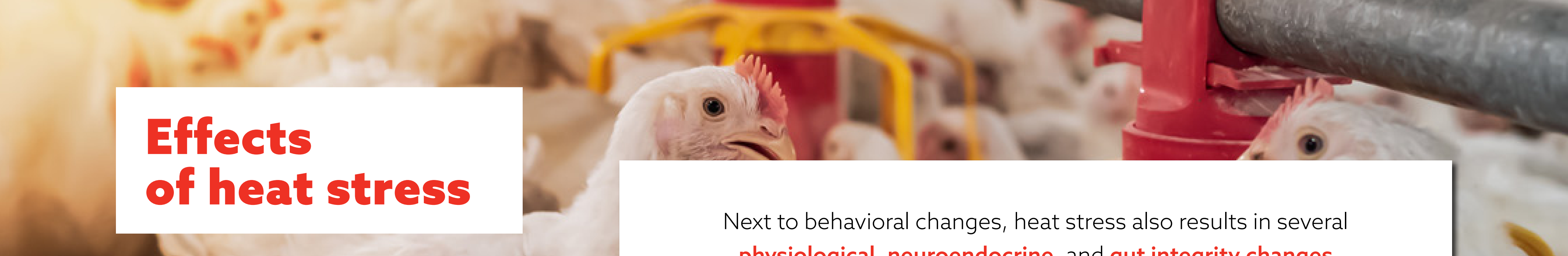


Fig. 1 *Diagram of the different temperature zones in poultry*

How do birds react in behavior to heat stress?

- Birds will start to drop their wings to increase their surface area for heat loss and they will start to pant.
- Energy will be redirected away from growth and/or production in favor of maintaining thermoregulatory homeostasis.
- Less feed will be consumed to decrease endogenous heat production via a reduced metabolic activity.
- Birds lose a high amount of water through the respiratory tract causing them to significantly drink more to restore the thermoregulatory balance. The increase of respiration rate is also the cause of acid-base imbalance (respiratory alkalosis).
- Redistribution of the blood flow to the skin and respiratory tract may occur.



Effects of heat stress

Next to behavioral changes, heat stress also results in several **physiological**, **neuroendocrine**, and **gut integrity changes**

❶ Physiological changes

OXIDATIVE STRESS

Oxidative stress is a major detrimental consequence of the most common commercial stressors in poultry production, including heat stress as demonstrated in previous research (Surai *et al*. 2019, Estévez *et al*. 2015). In thermoneutral circumstances an optimal redox balance in the cell/body is maintained (balance between oxidants and antioxidants). However during heat stress an imbalance occurs, either by higher production of reactive oxygen species or by a decrease in the effectiveness of the antioxidant defense system. Excess free radicals produced during oxidative stress damage various cell components including proteins, lipids, and DNA.

ACID-BASE IMBALANCE

During panting, excretion of CO_2 occurs at a greater rate than the cellular production of CO_2, which leads to reduced carbon dioxide levels in the blood altering the standard bicarbonate buffer system. The lower levels of CO_2 result in a decrease in concentration of carbonic acids (H_2CO_3) and hydrogen ions (H^+) whereas the amount of bicarbonate ions (HCO_3^-) raises thus, raising the blood pH, making it alkaline. To cope with this situation and maintain the normal blood pH, birds will start excreting more amount of HCO_3^- and retain H^+ from the kidney. The elevated H^+ alters the acid-base balance.

Panting thus ultimately induces respiratory alkalosis. When coupled with reduced feed intake, respiratory alkalosis can have detrimental effects on the host's mineral balance and potassium levels.

SUPPRESSED IMMUNOCOMPETENCE

The immune system can be profoundly compromised by heat stress. Secretion of antibodies typically falls, and T cell, and lymphocyte proliferation as well as immunoglobulin concentrations may be deleteriously affected. Heat stress can also lead to inflammation (higher expression of IFN-γ, TNF-α), which may contribute to further tissue damage through inflammatory processes and oxidative stress. Because of these deleterious effects, heat stress also leads to immunosuppression which predisposes the host to more severe infectious and contagious diseases.

Effects of heat stress

2 Neuroendocrine changes

The neuroendocrine system plays a crucial role in maintaining homeostasis and normal physiological functioning of birds during heat stress.

Both the hypothalamic-pituitary-adrenal axis and the orthosympathetic nervous system are activated in response to heat stress, which further aggravates the harmful effect of a high body temperature (Lin *et al*., 2006).

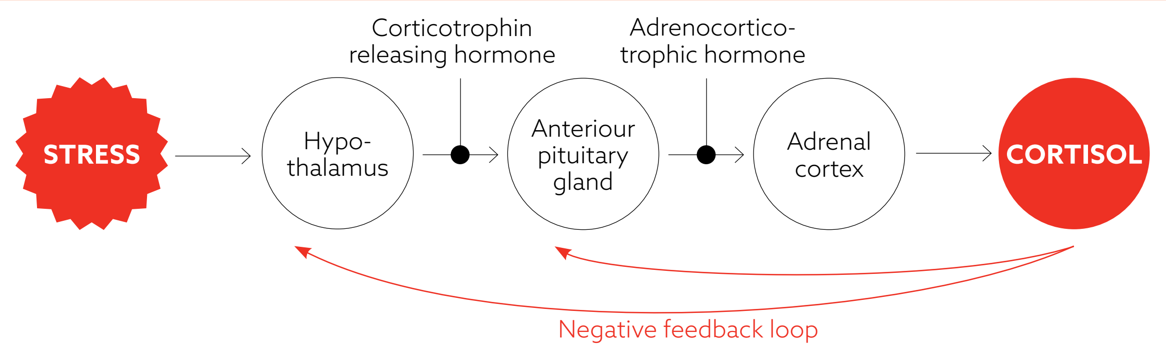


Fig. 2 The hypothalamic-pituitary-adrenal axis: the common mechanism for interactions among glands, hormones, and parts of the midbrain that mediate the body's responses to stress.

3 Gut integrity changes

ALTERATION OF THE INTESTINAL BARRIER AND THE COMMENSAL INTESTINAL MICROBIOTA

Heat stress can also negatively affect intestinal mucosa and microbiota. This can have an important physiological and pathological effect on the host.

Consequences of heat stress

1 Immune consequences

- In laying hens:
  - lower T and B cell activity
  - inhibition of white blood cell and antibody production
- In broilers:
  - atrophy of immune organs including the spleen
  - increased IL-2, IL-4 and IL-12 production
  - reduced IFN-γ production

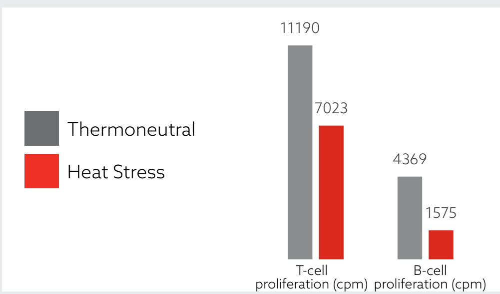


Fig. 3 *Mashaly et al. 2004. Poult Sci. 83:889-894*

2 Systemic consequences

- Increased production of "stress markers" including cortisol, glucocorticoids and catecholamines. The release of cortisol alters how nutrients are utilized by the bird. These will be re-allocated from growth toward minimizing the stress being experienced by the bird. When nutrients are siphoned away from growth in this way, performance can be negatively impacted.
- Mucosal leaking leading to enteric inflammation, tissue damage and increased intestinal permeability
- Reduced secretion of reproductive hormones like estradiol, LH and FSH, leading to poorer yolk quality and fertility
- Reduced activity, respiratory alkalosis
- Reduced feed intake and growth

3 Microbiological consequences

- Destabilization of the gut microbiome
- Reduction of "good" bacteria like Lactobacillus and Bifido bacteria
- Increased amount of potential pathogens in the gut
- Stimulates intestinal colonization by
- Salmonella (Burkholder *et al.*, 2008)

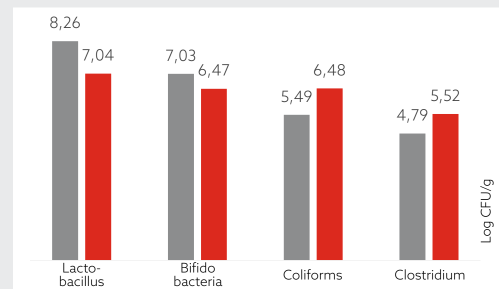


Fig. 3 *Mashaly et al. 2004. Poult Sci. 83:889-894*

These major consequences will significantly impact bird performance as seen in:

- Decreased feed intake and, consequently, poor growth & feed efficiency
- Increased mortality
- Digestive disorders
- Reduced fertility in breeders
- Lower laying rates
- Lower meat and egg quality
- Poorer eggshells

KEMIN

Mitigation strategies

Environmental measurements

1| Reducing the temperature inside the houses to increase animal welfare. Cooling through ventilation or evaporative cooling can help to keep birds closer to their thermo-neutrality and to disperse endogenous heat production.

2| Reducing stocking density during hot periods can be beneficial however, this is not always viable for producers.

3| Adjusting the lighting regimen to encourage increased feed intake overnight and in the early morning, when ambient temperature is lower, can help to reduce the performance effects of decreased feed intake.

4| Managing water intake; providing sufficient water space and fresh, cool water will encourage birds to drink. Water intake during heat stress will increase by 2 to 4 times over the normal intake.

Nutritional strategies

Feed quality

1| **Preventing oxidation**
Preventing feed rancidity due to oxidation ensures high feed palatability and consequently encourages an optimal feed intake by the bird. Antioxidants in the premix and feed will safeguard their full nutritional value and tastiness. Additionally, various antioxidant solutions have been shown to also have potential in vivo effects, helping to reduce formation of radicals in feed and therefore reducing its detrimental effects of heat stress on bird health.

2| **Optimizing physical properties of the ration**
Feed that is easier for the bird to digest requires less energy consumption, thereby reducing both heat production and the magnitude of performance loss from reduced feed intake. Likewise, ensuring that feed particle size is optimal, not too dusty, and that feed is fresh will have similar effects.

Feed formulation and feeding strategies

1 | Increasing the proportion of fat/oil in the diet while maintaining the total dietary energy content constant

It is well known that during metabolism fat produces lower heat increment compared to protein and carbohydrates (Musharaf *et al*., 1999).

ENERGY VALUES KCAL/KG	STARCH	CRUDE PROTEIN	CRUDE FAT
Digestible Energy	*4,183 (100)*	*4,924 (118)*	*8,437 (202)*
Metabolizable Energy	*4,183 (100)*	*4,302 (103)*	*8,437 (202)*
Net Energy	*3,442 (100)*	*2,437 (71)*	*7529 (219)*
Heat Production	*741*	*1864*	*908*
In Parenthesis, energy values as percentage of starch; crude protein and crude fat are assumed to be 90 % digestible; starch is 100 % digestible			

Therefore, additional fat supplementation to broiler diets is a commonly practiced protocol in warm climates to reach high energy levels while diminishing the negative effects of heat stress.

Moreover, fats have the capacity to slow down the passage rate of feed through the GIT, which may allow a more complete digestion and absorption of nutrients (Mateos *et al*, 1982), being that crucial in a reduced feed intake scenario.

2 | Formulating the diets by digestible amino acids rather than crude protein.

A high protein diet can have a harmful effect on growing performance, especially in modern fast-growing broiler genetics, where growth rate and meat yield are impaired by high dietary protein levels at high environmental temperature (Cahaner *et al*., 1995). On the other hand, monitoring of feed intake is of paramount importance, as nutritional interventions to decrease dietary protein level can also have a deleterious effect on growth performance. Buyse *et al*. (1992) reported higher feed intake of chickens fed with low-protein diets compared to those fed with isoenergetic high protein diets, which resulted in higher heat production and fat deposition. In a diet with a deficient balance of amino acids, the formulation following the right ideal amino acid profile with the use of synthetic amino acids will be of help to reduce the heat increment and consequently the harmful effects of high environmental temperature. If a non-accurately balanced diet in amino acids is supplied, more nitrogen will be excreted, which consequently shall result in higher ammonia release into the air, being further aggravated with higher temperatures (Lin *et al*., 2006). Moreover, high levels of atmospheric ammonia can affect the ability of broilers chickens to effectively control their body temperature (Yahav, 2004).

3 Promoting optimal nutrient digestion and absorption

As essential nutrients are being relocated to cope with heat stress, it's key to ensure all feed intake is as much efficiently used by the bird as possible to maintain an optimal growth and feed efficiency. For instance, Haetinger *et al*. (2021) found that the use of a bio-emulsifier based on lysophospolipids improved performance as well as crude fat and protein digestibility when applied to high energy diets containing 3 to 5% added oil. Therefore, the use of tools and strategies to maximize nutrient digestibility and absorption are of paramount importance in a context of a reduced feed and therefore nutrient intake.

4 Feed restriction, dual feeding and wet feeding

Applying feed restriction during the hotter periods can enhance the thermal resistance of broiler chickens. It reduces heat production as well as the body temperature, consequently impacting survivability positively (Yalçin *et al*., 2001, Uzum *et al*., 2013). However, this strategy leads to reduced growth rates and is only advisable in extreme situations. Moreover, special attention must be taken when re-feeding feed restricted broilers as the feed restriction can results in overcrowding and high mortality rates as a result (Wasti *et al*, 2020). To avoid this, dual feeding can ensure constant feed supply to the broilers while still minimizing negative consequences of heat stress. The base of this strategy is the higher heat increment generated by proteins compared to fats and carbohydrates (Uzum *et al*., 2013). So, a protein-rich diet is supplied during the cooler period (during night hours) and an energy-rich diet is supplied during the hot period (during day hours). This is still not a strategy that will improve growth performance (Lozano *et al*., 2006) but has proven to reduce body temperature (Basilio *et al*., 2001 and Lozano *et al*., 2006) and mortality of heat stress broilers (Basilio *et al*, 2001). Although less common, a wet feeding strategy could also be used to increase water intake and help coping with thermoregulation. To be carefully considered is the potential problems associated with mold growth, which is favored by high temperatures and humidity.

Support of bird health

1 | Electrolytic balance

Panting disturbs the blood acid/base balance and results in respiratory alkalosis, which suppresses the growth of broiler chicken and impairs eggshell quality of laying hens. Electrolytes therefore should be added to the drinking water (2 to 3 days) to recover the acid-base imbalance. Phosphorus, sodium, potassium supplementation is preferred as well as sodium bicarbonate via feed or with carbonated water. A higher range of dietary electrolyte balance (dEB) is advisable to ameliorate the harmful effects of heat stress (Mushtaq *et al*., 2013). Supplementation of sodium bicarbonate can increase dEB and seems the best candidate to tackle detrimental effects of heat stress, since it contains both sodium and bicarbonate. Moreover, sodium bicarbonate is also found to improve eggshell formation (Lin *et al*. 2016)

2 | Vitamins

Vitamin E has been found to prevent liver damage, help in the synthesis and release of vitellogenin (Yardibi *et al*., 2008). It improves egg production, egg weight, eggshell thickness, specific gravity and Haugh units when administered to heat stressed laying hens (Khan *et al*., 2011).

Vitamin A is essential for an adequate level of antibody production. So higher levels are required to cope with heat stress. Higher levels of vitamin A supplementation can help to increase egg weight in laying hens (Lin *et al*., 2002) and improve live weight gain, FCR and serum MDA concentration in broilers (Kucuk *et al*., 2003).

Vitamin C dietary supplementation is a very common strategy during heat stress. Supplementation of vitamin C (250 mg/kg of feed) can improve growth rate, nutrient digestibility, egg production, immune response and antioxidant status of heat stress birds (Khan *et al*., 2012).

3 | Enhancing the immune system

The damages caused by heat stress to the immune system range from detrimental effects at the level of the main immune organs in terms of size and weight (Jahanian and Rasouli 2015), to a reduced production and activity of immune cells. It therefore becomes **more difficult for heat stressed birds to be resilient to disease**. Many of the nutritional strategies mentioned above can contribute to support birds immunity during heat stress challenges (e.g. vitamin E, Vitamin C, or Chromium supplementation). In addition, the use of immune modulators like β-glucans can strengthen birds adaptation to heat stress by reducing the production of proinflammatory cytokines like TNF-α. Enhancing the immune system with β-glucans has been shown to improve the growth performance and meat quality of birds subjected to heat stress (Zhang et al., 2020).

4 Minerals

Zinc is associated with the antioxidant defense system and immune function. Zinc participates in the synthesis of antioxidant enzymes and is crucial for normal development and function of various immune cells.

Chromium supplementation has been shown to decrease the levels of corticosterone in the blood, thereby alleviating the negative effects of stress on growth and performance to allow the bird to reach its full genetic potential. Chromium is also an integral component of chromodulin, necessary for insulin functioning.

In heat-stressed broilers, adding chromium to the diet has been associated with an improved humoral and cellular immune response, an increase in body weight, feed intake, and carcass quality (Vignale *et al*. 2017, Lester *et al*. 2018). Reducing insulin resistance, chromium favors blood microcirculation and, consequently, heat dissipation (Erik H. Serne *et al*., 1998)

Selenium supplementation to several poultry species during heat stress can improve antioxidant and immune status. It can also reduce the negative impact of heat stress on egg quality parameters (Habibian *et al*., 2015).

5 Promoting a healthy digestive tract

It has been well documented that the consequences of heat stress in birds include the loss of the intestinal barrier function (Quinteiro-Filho *et al*., 2010, Alhenaky *et al*., 2017), which eventually leads to increased permeability (to bacteria and toxins) and intestinal inflammatory responses. In this sense, heat stress has been described as a predisposing factor of enteritis in birds. Injury resulting from heat stress can occur in different segments of the digestive tract and the intestinal morphology can be negatively altered (via changes in villus height, crypt depth and overall surface area). Decreased production of digestive enzymes can further compromise nutrient utilization and growth during heat stress. Butyrate has been shown to exert protective effects against intestinal damage induced by heat stress (Abdelqader *et al*., 2017).

Another important consequence of heat stress in birds is the change that occurs in the gut microbiome (Shi *et al*., 2019). The commensal microflora can be modified and become less protective against colonization by pathogenic bacteria such as Salmonella (Burkholder *et al*. 2008). It is therefore advisable to promote intestinal barrier function and a healthy digestive tract during heat stress challenges. For example, the supplementation of effective *Bacillus Subtilis* based probiotic is advisable to support gut morphology, maintain microbiome balance and support growth performance (Abdelqader *et al*., 2020).

Main take-aways

- Heat stress remains a major challenge for many poultry producers with extensive potential negative effects on bird health, performance, and production profitability.
- Being a complex process for the bird to cope and with a wide range of consequences on the metabolism, it is important to implement a multi-factorial preventive approach to safeguard business viability.
- Various interventions have been shown to be effective in mitigating heat stress and reducing the associated detrimental effects. In addition to management measures e.g. reduction of stocking density and adjusting lighting regimes, a well-designed, and targeted dietary strategy is key for maximum support of your birds to ensure minimal economical losses.

> Kemin offers a unique cost-efficient program, promoting intestinal health combined with optimal nutrient supply.

For more information on Kemin's Heat Stress programme please contact us

A publication of KEMIN EUROPA nv

Toekomstlaan 42,
2200 Herentals
Belgium

T.+32 14 28 62 00

www.kemin.com/emena
www.kemin.com/heat-stress-poultry

KEMIN®

Resource list

1. **Abdelqader, A. M., Abuajamieh, M., Hammad, H. M., & Al-Fataftah, A. R. (2017).** Effects of dietary butyrate supplementation on intestinal integrity of heat-stressed cockerels. Journal of animal physiology and animal nutrition, 101(6), 1115-1121.
2. **Abdelqader, A., Abuajamieh, M., Hayajneh, F., & Al-Fataftah, A. R. (2020).** Probiotic bacteria maintain normal growth mechanisms of heat stressed broiler chickens. Journal of Thermal Biology, 92, 102654.
3. **Alhenaky, A., Abdelqader, A., Abuajamieh, M., & Al-Fataftah, A. R. (2017).** The effect of heat stress on intestinal integrity and Salmonella invasion in broiler birds. Journal of Thermal Biology, 70, 9-14.
4. **Basilio, V., M. De Vilarin, S. Yahav, M. Picard (2001).** Early Age Thermal Conditioning and a Dual Feeding Program for Male Broilers Challenged by Heat Stress. Poultry Science, 80: 29–36.
5. **Burkholder, K. M., Thompson, K. L., Einstein, M. E., Applegate, T. J., & Patterson, J. A. (2008).** Influence of stressors on normal intestinal microbiota, intestinal morphology, and susceptibility to Salmonella enteritidis colonization in broilers. Poultry Science, 87(9), 1734-1741.
6. **Buyse, J., E. Decuypere, L. Berghman, E.R. Kühn, F. and Vandesande (1992).** Effect of dietary protein content on episodic growth hormone secretion and on heat production of male broiler chickens. British Poultry Science, 33: 1101-1109.
7. **Cahaner, A., Y. Pinchasov, and I. Nir (1995).** Effects of dietary protein under high temperature on body weight, breast meat yield, and abdominal fat deposition of broiler stocks differing in growth rate and fatness. Poultry Science, 74: 968-975.
8. **Habibian M, G. Sadeghi , S. Ghazi, M.M. Moeini (2015).** Selenium as a feed supplement for heat-stressed poultry: a review. Biolological Trace Elements Research, 165(2):183-93.
9. **Haetinger, V.S., Y.K. Dalmoro, G.L. Godoy, M.B. Lang, O.F. de Souza, P. Aristimunha, and C. Stefanello (2021).** Optimizing cost, growth performance and nutrient absorption with a bio-emulsifier based on lysophospholipids for broiler chickens. Poultry Science, 100 (4).
10. **Khan, R.U., S. Naz, Z. Nikousefat, M. Selvaggi, V. Laudadio, and V. Tufarelli (2012).** Effect of ascorbic acid in heat-stressed poultry. World's Poultry Science Journal, 68: 477–490.
11. **Khan, R.U., S. Naz, Z. Nikousefat, V. Tufarelli, M. Javdani, N. Rana, V. Laudadio (2011).** Effect of vitamin E in heat-stressed poultry. World's Poultry Science Journal, 2011, 67: 469–478.
12. **Kucuk, O., N. Sahin, K. Sahin (2003).** Supplemental zinc and vitamin A can alleviate negative effects of heat stress in broiler chickens. Biolological Trace Elements Research, 94: 225–235.
13. **Lester, T., K. Brown, C. Eagleson, V. Iseri, J. Lee (2017).** Evaluation of chromium propionate on broiler growth performance and processing yields. Journal of Poultry Science 96 (E-suppl. 1): 188.
14. **Lin, H., H.C. Jiao, J. Buyse, and E. Decuypere (2006).** Strategies for preventing heat stress in poultry, World's Poultry Science Journal, 62 (1): 71-86.
15. **Lin, H., L.F. Wang, J.L. Song, Y.M. Xie, Q.M. Yang (2002)** Effect of dietary supplemental levels of vitamin A on the egg production and immune responses of heat-stressed laying hens. Poultry Science, 81: 458–465.
16. **Lozano, C., V. De Basilio, I. Oliveros, R. Alvarez, I. Colina, D. Bastianelli, S. Yahav, M. Picard (2006).** Is sequential feeding a suitable technique to compensate for the negative effects of a tropical climate in finishing broilers? Anim. Res. 2006, 55: 71–76.
17. **Mateos, G.G., J.L. Sell, and J.A. Eastwood (1992).** Rate of food passage (transit time) as influenced by level of supplemental fat. Poultry Science, 61: 94–100
18. **Musharaf, N.A., and J.D. Latshaw (1999).** Heat increment as affected by protein and amino acid nutrition. World's Poultry Science Journal, 55: 233–240.
19. **Mushtaq, M.M.H., T.N. Pasha, T. Mushtaq, R. Parvin (2013).** Electrolytes, dietary electrolyte balance and salts in broilers: An updated review on growth performance, water intake and litter quality. World's Poultry Science Journal, 69: 789–802.
20. **Quinteiro-Filho, W. M., Ribeiro, A., Ferraz-de-Paula, V., Pinheiro, M. L., Sakai, M., Sá, L. R. M. D., ... & Palermo-Neto, J. (2010).** Heat stress impairs performance parameters, induces intestinal injury, and decreases macrophage activity in broiler chickens. Poultry science, 89(9), 1905-1914.
21. **Erik H. Serne´, MD; Coen D.A. Stehouwer, MD, PhD; Jan C. ter Maaten, MD; Piet M. ter Wee, MD, PhD; Jan A. Rauwerda, MD, PhD; Ab J.M. Donker, MD, PhD; Reinold O.B. Gans, MD, PhD (1998).** Microvascular Function Relates to Insulin Sensitivity and Blood Pressure in Normal Subjects. Circulation, 1999;99:896-902.
22. **Shi, D., Bai, L., Qu, Q., Zhou, S., Yang, M., Guo, S., ... & Liu, C. (2019).** Impact of gut microbiota structure in heat-stressed broilers. Poultry science, 98(6), 2405-2413.
23. **Uzum, M.H., and H.D.O. Toplu (2013)**. Effects of stocking density and feed restriction on performance, carcass, meat quality characteristics and some stress parameters in broilers under heat stress. Rev. Med. Vet. (Toulouse), 164: 546–554.
24. **Vignale, K., D. Koltes, J. Weil, S. West, S.L. Weimer, V. Iseri, and K.D. Christensen (2017).** The effect of chromium propionate on performance responses in heat stressed male broiler chickens. International Poultry Scientific Forum. Atlanta, GA. Abstract T181, page 53.
25. **Wasti, S., N. Sah, B. Mishra (2020).** Impact of Heat Stress on Poultry Health and Performances, and Potential Mitigation Strategies. Animals, 10: 1266.
26. **Yahav, S. (2004)** Ammonia affects performance and thermoregulation of male broiler chickens. Animal Research, 53: 289-293.
27. **Yalçin, S., S. Özkan, L. Türkmut, and P.B. Siegel (2001).** Responses to heat stress in commercial and local broiler stocks. 1. Performance traits. British Poultry Science, 42: 149-152.
28. **Yardibi, H., and G.T. Hoştürk (2008).** The effects of vitamin E on the antioxidant system, egg production, and egg quality in heat stressed laying hens. Turk. J. Vet. Anim. Sci., 32: 319–325.
29. **Zhang *et al*. (2020)** effect of dietary beta-1.3-glucan supplementation and heat stress on growth performance, nutrient digestibility, meat quality organ weight, ileum microbiota and immunity in broilers. Poultry science 99; 4969-4977