

Alleviation of heat stress in broiler chicken using turmeric (*Curcuma longa*) - a short review

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Abstract

Heat stress is one of the most crucial issues in broiler production, particularly in tropical regions. Thermal stress may pose several problems related to growth, feed intake, nutrient utilization, physiological condition, immune function, intestinal ecology, and morphology as well as the antioxidant system in the body of chickens. Turmeric (*Curcuma longa*) is rich in curcumin, which can serve as an antioxidant. Being part of the nutritional interventions, treatment using turmeric has been documented to alleviate the negative impact of heat stress on broiler chickens, in terms of production, physiology, immunology, and antioxidant status of broilers. The present review elucidates the alleviation of heat stress in broiler chicken using turmeric based on the most recent literature.

Keywords: broilers, curcumin, health, thermal stress

Introduction

Heat stress has been an important factor that should greatly be considered in broiler production particularly in tropical regions (Sugiharto et al 2017a). The retarded growth rate increased disease outbreaks, and mortality is amongst the problems related to heat stress in broiler production (Sugiharto et al 2017b). The recent increase in global temperature due to climate change seems to further exacerbate the thermal effect on broiler production. Other than establishing the expensive thermal-controlled housing facilities, nutritional intervention such as dietary administration of turmeric has been practiced to alleviate the deleterious effect of heat stress on broiler production. Turmeric (*Curcuma longa*) belongs to the ginger family and

has long been known to be rich in curcumin, which is effective in ameliorating oxidative stress both in humans and animals (Hewlings and Kalman 2017). *In vivo* studies showed that turmeric treatment could restore the impaired growth performance, physiological alteration, weakened immune system and disrupted antioxidant system in heat-stressed broilers (Akhavan-Salamat and Ghasemi 2016; Sadeghi and Moghaddam 2018), and therefore could reduce or substitute the role of synthetic antioxidants that have recently been legislatively restricted (Sugiharto et al 2019). The ameliorating effect of and the mechanisms through which turmeric acts on heat-stressed broilers are critically discussed based on the most recent literature in the present review.

Heat stress in broiler chicken

Heat stress is a condition wherein animals are not capable of getting rid of excess heat in their bodies causing an increase in body temperature. Heat stress can occur when the heat load is greater than the animal's capacity to release the excess heat from the body. Thermal stress has been reported to cause several detrimental effects on broilers, including retarded growth rate, reduced feed intake, physiologic changes, gut microbial upset, compromised immune responses, and oxidative damage (Sugiharto et al 2017b). In agreement, Santos et al (2019) have recently reported that thermal stress caused mucosal and villus damage of the small intestine, which can be attributed to the compromised digestive and absorptive functions of chickens. The latter authors also revealed that heat stress modulated oxidative stress and inflammation as well as impaired intestinal integrity and nutrient transport of broilers. Likewise, Shi et al (2019) documented that heat stress-induced dysbiosis or altered composition of gut microbiota (both abundance and diversity of species). The latter condition consequently increased intestinal permeability and immune and metabolic dysfunctions. Concerning the immune defense of birds, Ohtsu et al (2015) previously reported that heat stress disturbed the immune system of broilers by modulating the gene expression of splenic cytokines (interleukin [IL]-4, interferon [IFN]- γ , and IL-12) and inducing spleen involution. Likewise, exposing birds to high environmental temperatures may implicate in the decreased numbers of lymphocytes and monocytes in the blood. Heat stress also reduced the number of CD3⁺ and CD8⁺ cells of broilers (Xu et al 2018). Moreover, Olfati et al (2018) exhibited that heat stress decreased antibody titer toward sheep red blood cells (SRBC), lymphocyte count and lymphoid organs

weights, and increased heterophil to lymphocyte ratio of broilers. Further, the concentrations of heat shock protein-70 (HSP70) and corticosterone in the serum of broilers were increased by heat stress (Olfati et al 2018; Shi et al 2019). In respect particularly to corticosterone, the rise in corticosterone levels may implicate in the impairment of intestinal ecology, morphology, and absorptive functions of broilers (Hu and Guo 2008). The elevated concentration of corticosterone may also negatively modulated metabolism and systemic immune response of broilers (Zaytsoff et al 2019). Moreover, heat stress has been reported to induce organ dysfunctions in broiler chickens. Huang et al (2018) noticed that acute thermal stress increased the levels of some blood biochemical parameters such as blood urea nitrogen (BUN), creatinine, alanine aminotransferase (ALT) and creatine kinase that may indicate the damage of vital organs such as kidney and liver.

To alleviate the deleterious effect of heat stress, several attempts have been executed, one of which is through dietary intervention. Administration of chemical-based or synthetic antioxidants have traditionally been practiced in broilers raised under high thermal conditions. Such an application may, however, be legislatively restricted as the excessive use of synthetic antioxidants may induce carcinogenic and mutagenic effects on humans as broiler consumers (Sugiharto et al 2019). For food safety reasons, there is now therefore a trend to use natural-based antioxidants for ameliorating the thermal stress impacts on broilers. Herbs are among the natural-based antioxidants that have recently been used to deal with heat-stressed broilers (Bagban et al 2016; Sadeghi and Moghaddam 2018).

Turmeric as a source of antioxidant

Turmeric is an herbaceous rhizomatous plant (*Curcuma longa*) belonging to the ginger family. Aside from being a cooking spice, turmeric has also been exploited as a feed additive in broiler production. We reported formerly that turmeric extract was able to improve the digestive process and physiological conditions of broiler chickens (Sugiharto et al 2011). Administration of decocted turmeric through drinking water was also reported to improve immune functions and stress responses of broilers (Isroli et al 2017). Turmeric has long been known as a source of curcumin, which has health properties. Curcumin is a natural polyphenol that has widely been known to ameliorate oxidative stress both in humans and animals. Hewlings and Kalman (2017) pointed out that curcumin is capable of scavenging free radicals

(such as reactive oxygen species [ROS] and reactive nitrogen species [RNS]), activating glutathione (GSH), catalase and superoxide dismutase (SOD) in neutralizing free radicals and also inhibiting ROS-generating enzymes for instances lipoxygenase/cyclooxygenase and xanthine hydrogenase/oxidase. Chemically, curcumin has a unique structure that is usually attributed to its antioxidant property. Curcumin has carbon-carbon double bonds, β -diketo group, and phenyl rings containing hydroxyl and methoxy substituents (Boroumand et al 2018). This structure allows curcumin to donate H-atom (from phenolic groups) to neutralize free radicals. In addition to curcumin (which is the primary polyphenols), turmeric powder also contains dimethoxycurcumin and bis-dimethoxycurcumin, 2,5-xyleneol (Brewer 2011), flavonoids, tannins, and ascorbic acid (Tanvir et al 2017) that can also exhibit neutralizing activity towards free radicals.

In Asian countries, there are several species and varieties of turmeric, which naturally possess different chemical features and biological activities (Akter et al 2019). In agreement with the latter authors, a study in Bangladesh by Tanvir et al (2018) also reported that different turmeric varieties may show different contents of polyphenols, flavonoids, ascorbic acids, and tannins. The different varieties of turmeric may also show different 2,2-diphenyl-1-picrylhydrazyl-hydrate (DPPH) free radical-scavenging activities and ferric reducing antioxidant power (FRAP) values. Owing to these facts, it is, therefore, necessary to be more selective in using turmeric as a source of antioxidants as different varieties may exert different antioxidative effects and therapeutic advantages on broilers.

Effect of turmeric on productive performance of heat-stressed broilers

Turmeric has recently been exploited to ameliorate the impaired growth performance in broilers exposed to thermal stress (Table 1). It appeared that turmeric was capable of improving nutrient digestibility and hence nutrient utilization by the chicks raised under high thermal condition (El-Maaty et al 2014). Formerly, Namagirilakshmi et al (2010) reported that turmeric powder improved the intestinal ecology and morphology by increasing the number of *Lactobacillus* and intestinal villi height of broiler chickens. In line with this, Rajput et al (2013) also revealed that feeding curcumin increased villus height, villus height to crypt depth ratio, and the absorptive area of villus of the small intestine of broilers. Taken together, the improving capacity of turmeric on gut ecology and morphology can, therefore, offset the decreased villus

height and villus height to crypt depth ratio by heat stress (He et al 2018). Turmeric treatment has also been noticed to increase the weight of the pancreas and length of bile duct epithelial fold and thereby improved the digestive process of broilers (Namagirilakshmi et al 2010). One of the reasons for which heat stress attenuates the growth performance is that heat stress impaired the appetite resulting in reduced feed intake of broilers (He et al 2018). Dietary inclusion of turmeric powder has been reported to increase feed intake in broilers during heat stress (Akhavan-Salamat and Ghasemi 2016; Bagban et al 2016). In this case, the appetite stimulant and stomachic and carminative properties of turmeric (Chakraborty et al 2011) seem to account for the increased feed consumption in heat-stressed broiler chickens. Heat stress has been associated with reduced erythrocytes and hemoglobin concentrations in blood (Xu et al 2018). The decreased levels of these blood components can detrimentally affect the growth performance given that erythrocytes and hemoglobin are crucial in transporting and supplying oxygens for cellular respiration. Dietary supplementation of turmeric extract has been reported to increase the concentration of hemoglobin of broilers in the study of Sugiharto et al (2011). The latter author further suggested that the increased hemoglobin value was associated with the increased metabolic rate, and may, therefore, counter the retarded growth rate in heat-stressed broilers. In the previous study, we also reported that the administration of turmeric extract improved stress response in broilers as indicated by the lowered heterophil to lymphocyte (H/L) ratio (Sugiharto et al 2011). Considering that heat stress may enhance the energy expenditure for maintenances rather than for production, the improved stress response with feeding turmeric may therefore partially save the energy for growth in heat-stressed broilers. Thermal stress has been attributed to the attenuated activity of thyroid hormones (triiodothyronine [T_3] and thyroxine [T_4]) and thereby lower metabolic rate and energy production (Sugiharto et al 2017b). Given that curcumin may elevate plasma concentrations of thyroid hormones (Xie et al 2019), feeding turmeric may, therefore, compensate for the reduced activity of thyroid hormones due to heat stress. Moreover, the potentials of turmeric in improving the immune and oxidative system (Swathi et al 2016; Sadeghi and Moghaddam 2018) and thus health are most also likely to save the energy for broiler growth during heat stress.

Effect of turmeric on physiological conditions of heat-stressed broilers

Raising broiler chickens under high thermal conditions is associated with physiological alterations, which may in turn lead to pathophysiological conditions (Sugiharto et al 2017b). Dietary administration of turmeric has been reported to ameliorate the physiological changes in broiler chickens raised under heat stress conditions. The increased concentration of corticosterone is commonly found in the serum of broilers experiencing heat stress (Olfati et al 2018; Shi et al 2019). Considering the catabolic activity of this stress hormone, the increased level of serum corticosterone in broilers during heat stress may implicate in muscle protein break down (Xu et al 2018) and diversion of energy from muscle biosynthesis to maintenance (Zaytsoff et al 2019). Feeding turmeric has been noticed to alleviate the increased corticosterone in broilers due to heat stress (Swathi et al 2016). Formerly, Amr et al (2017) reported the efficacy of turmeric powder in restoring the detrimental effect of corticosterone administration on the physiological conditions of broilers. Turmeric is rich in curcumin, which has recently been reported to alleviate the increased corticosterone concentration in broiler chickens (Zhang et al 2019). The latter investigators suggested that the strong antioxidant (anti-stress activity) and hepato-protective capacities of curcumin were attributed to the alleviating effect of curcumin (turmeric) on the increased stress hormone levels due to heat stress. Thermal stress condition has been associated with the reduced thyroid hormones activity and hence reduced energy supply for growth (Sugiharto et al 2017b). Indeed, Zeinali et al (2011) and Sadeghi and Moghaddam (2018) documented that turmeric powder could restore the activities of triiodothyronine and thyroxine in heat-stressed broilers. This may consequently correct the compromised growth rate in broilers due to heat stress. It seems that curcumin in turmeric acted a significant role in stimulating the biosynthetic activity of the thyroid gland (Papież et al 2008). In line with the previous study, Rajput et al (2013) and Xie et al (2019) also reported that curcumin was able to increase the activity of thyroid hormones in broilers.

During stress conditions, such as heat stress, the increased level of corticosterone usually implicate increased muscle protein catabolism and thus elevated levels of uric acid and creatinine in the circulation of broilers (Liu et al 2016). Feeding turmeric powder was able to lower the plasma concentrations of uric acid and creatinine in heat-stressed broilers as reported by El-Maaty et al (2014) and Bagban et al (2016). It was possible that the reduced concentration of corticosterone due to turmeric administration (Swathi et al 2016) may lower the catabolic activity of muscle protein and thus reduce the content of uric acid and creatinine in the circulation. Turmeric may also improve feed intake and digestibility (El-Maaty et al 2014;

Sadeghi and Moghaddam 2018) and thereby improve the energy supply for the chickens during thermal stress. The latter condition eventually reduced muscle protein catabolism and hence uric acid and creatinine in the plasma of heat-stress chicks. Literature documented that turmeric could ameliorate the negative effect of heat stress on lipid and cholesterol profile in broilers (Hosseini-Vashan et al 2012). It seemed that curcumin in turmeric helped the liver in taking low-density lipoprotein (LDL) out of circulation. Curcumin also increased the production of bile salts by the liver to carry the excess LDL out of the body of chicks (Adegoke et al 2018). In line with this, Xie et al (2019) reported that curcumin may modulate the expression of genes related to lipogenesis and lipolysis resulting in reduced LDL and triglycerides concentrations in the plasma and liver of broilers. Organ dysfunction has been attributed to heat stress in broilers (Huang et al 2018). Interestingly, turmeric may ameliorate such tissue damage as indicated by the reduced levels of ALT, aspartate aminotransferase (AST), alkaline phosphatase (ALP), creatinine, uric acid, creatine kinase in the bloodstream (El-Maaty et al 2014; Hosseini-Vashan et al 2012; Hosseini-Vashan et al 2015). The antioxidant and anti-inflammatory activities of curcumin have been attributed to the ameliorating effect of turmeric or curcumin on the liver and kidney damage in broilers under toxicity and stress conditions (Sayrafi et al 2017). Overall, the alleviating effect of turmeric on the physiological condition in heat-stress broilers may consequently restore the growth rate of the chicks during the thermal stress conditions.

Effect of turmeric on the immune response of heat-stressed broilers

The high thermal condition has been associated with the immune depression in broilers (Ohtsu et al 2015; Sugiharto et al 2017b). This may consequently increase the susceptibility of chickens to infectious diseases. Turmeric rhizome powder has previously been demonstrated to improve the heterophil/lymphocyte ratio and immunoglobulin (Ig) G antibody titers against SRBC in broiler study conducted by Akhavan-Salamat and Ghasemi (2016). In line with the latter report, Swathi et al (2016) reported that turmeric powder (0.4% of diets) increased cell-mediated immune response against phytohaemagglutinin and humoral immune response against Newcastle disease vaccine (NDV) in broilers exposed to heat stress. The increased corticosterone and decreased antioxidant enzyme activities have been associated with the immune depression in broilers maintained under high thermal conditions (Sugiharto et al

2017b). Turmeric was previously reported to prevent the increased corticosterone level in the bloodstream (Swathi et al 2016) while increasing the antioxidant enzyme activities in heat-stressed broilers (El-Maaty et al 2014; Swathi et al 2016). Such conditions may, therefore, alleviate the impairing effect of heat stress on the immune system of broilers. A study by Al-Sultan et al (2003) showed that turmeric increased lymphoid organs (spleen, Bursa of Fabricius, and thymus) weight index, which can, therefore, compensate for the lymphoid organ involution in broiler during thermal stress (Ohtsu et al 2015). Given the crucial role of lymphoid organs in producing and maturing immune cells, the capacity of turmeric in maintaining the development of these organs is therefore essential to keep the chicks healthy during thermal stress conditions.

The disruption of the gut microbial ecosystem and, hence, compromised immune system has been related to heat stress conditions in broiler chickens (Sugiharto et al 2017b). Considering the efficacy of turmeric in decreasing coliform and increasing *Lactobacillus* counts in the intestine (Samarasinghe et al 2003; Ahlawat et al 2018), gut microbial ecology improvement by turmeric may, therefore, improve the immune status of broiler during heat stress. Yet, the data regarding the ameliorating effect of turmeric on the gut microbial ecology of broilers during heat stress are still scarce. The improvement of immune responses in heat-stressed broilers seemed to also be contributed by the anti-inflammatory effect of turmeric and curcumin (Samarasinghe et al 2003; Hewlings and Kalman 2017). Indeed, the anti-inflammatory activity of turmeric or curcumin may be responsible for the modulation of the immune cell functions of animals (Kakhkhaie et al 2019). Dyslipidemia, which is the enhanced levels of blood cholesterol, triglycerides, LDL, and decreased HDL, has been related to heat stress in broiler chickens exposed to high thermal conditions (Sugiharto et al 2017b). The latter authors as well as study in humans by Madenspacher et al (2010) suggested that dyslipidemia may compromise the immune responses and thus impairs host defense against infectious agents. Since turmeric could avoid broiler from dyslipidemia (Hosseini-Vashan et al 2012), it could, therefore, be reasonable that turmeric improves the immune defense of heat-stressed broilers. A study by Kamel et al (2017) noticed that heat stress implied in decreased numbers of leukocytes and lymphocytes, which are important components of the immune system. Previously, Isroli et al (2017) documented that the administration of decocted turmeric through drinking water increased the numbers of leukocytes and the proportion of lymphocytes in blood as well as the concentration of globulin (precursor of immunoglobulin) in the serum of broilers.

On this basis, it could, therefore, be expected that turmeric could compensate for the impairing effect of heat stress on the broiler's immune defenses.

Effect of turmeric on antioxidant status of heat-stressed broilers

Heat stress has been characterized by the impaired antioxidant system in the body of broilers, such as the reduced activities of glutathione peroxidase (GPx), SOD and catalase, and increased lipid peroxidation (Hosseini-Vashan et al 2016). Indeed the impaired antioxidant enzyme activities may implicate in the increase in free radicals leading to pathophysiological conditions, compromised immune competence, increased lipid peroxidation, and DNA disruption (Devi et al 2000). Feeding turmeric has been reported to ameliorate the impaired antioxidant system in broilers exposed to thermal stress conditions (Table 3). In general, the mechanisms by which turmeric improves the antioxidant system of broiler could be through promoting the activities of antioxidant enzymes as well as alleviating the lipid peroxidation (Akhavan-Salamat and Ghasemi 2016). Curcumin is the active compound in turmeric that serves a crucial role in improving the antioxidant status in broilers. Besides direct scavenging of free radicals, curcumin may increase the synthesis and activate antioxidant enzymes such as GSH, catalase, and SOD and also inhibit ROS-inducing enzymes (Hewlings and Kalman 2017). Note that the increased antioxidant enzyme activities can further implicate lowered lipid peroxidation (Reddy and Lokesh 1994).

Constraints of turmeric in alleviating heat stress effect on broilers

The potentials of turmeric in ameliorating the negative effect of heat stress in broilers have been described. Different from these positive findings, some investigators reported no effect of dietary supplementation of turmeric on the conditions of broilers when exposed to heat stress. For instance, Hosseini-Vashan et al (2012) administrated turmeric powder at the levels of 0.4% and 0.8%, but they did not find any substantial impact on body weight gain, feed intake, FCR, and production index of broilers raised under heat stress conditions. In concurrence with this report, Candra and Putri (2020) recently reported that turmeric powder (500 mg per kg body weight of broiler) did not have any influence on the growth rate of broilers maintained in thermal stress conditions. In the case of growth rate, feeding turmeric may not

improve the weight gain, but rather improve the carcass traits of broilers as indicated by the lower content of abdominal fat (Samarasinghe et al 2003; Sugiharto et al 2011). It is therefore possible that turmeric may increase the deposit of body protein instead of body fat (Samarasinghe et al 2003). The absent effect of turmeric on the physiological condition was also noticed by Zeinali et al (2011), at which administration of turmeric powder (10 g/kg diets) did not affect plasma concentrations of T₃, triglycerides, and cholesterol of heat-stressed broilers. In respect to immune function, Hosseini-Vashan et al (2012) did not find any effect of turmeric powder (0.4% and 0.8% of diets) on antibody response of broilers against SRBC, IgM, IgG and antibody titers against NDV. Some reasons may explain the possible absent effect of feeding turmeric on heat-stressed broilers, one of which is the low solubility, which consequently low bioavailability of turmeric and curcumin for broilers. Hewlings and Kalman (2017) formerly suggested that one of the main problems with turmeric and curcumin is their poor bioavailability due to low solubility, low absorption, rapid metabolism, and elimination. Combining curcumin with other herbs has been suggested to improve the bioavailability of curcumin (Hewlings and Kalman 2017). In agreement with this, Al-Sultan et al (2019) combined turmeric powder and cumin to improve the efficacy of turmeric in alleviating the detrimental effect of heat stress on broilers.

Final considerations

Heat stress is attributed to impaired productive performance and health in broiler chickens. As a part of the nutritional interventions, most of the literature convincingly showed the efficacy of turmeric in alleviating the negative effect of heat stress on broilers in terms of production, physiological conditions, immune responses, and antioxidant system.

Conflict of interest

The author had no conflict of interest.

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Table 1 Effect of turmeric on performances of heat-stressed broilers.

References	Findings
Akhavan-Salamat and Ghasemi (2016)	Turmeric rhizome powder partially restored the decreased body weight gain, feed intake and mortality of heat-stressed broilers
Bagban et al (2016)	Turmeric powder (0.5% of diets) increased body weight gain and feed intake of broilers exposed to thermal stress
El-Maaty et al (2014)	Turmeric powder (0.5 g/kg diets) improved final body weight, feed conversion ratio (FCR) and digestibility of crude protein and ether extract of broilers exposed to heat stress
Sadeghi and Moghaddam (2018)	Turmeric powder (0.5% of diets) increased average daily gain, feed intake, and decreased FCR of broiler exposed to heat stress

Table 2 Effect of turmeric on physiological conditions of heat-stressed broilers.

References	Findings
Bagban et al (2016)	Turmeric powder (0.5% of diets) decreased plasma levels of ALT, lactate dehydrogenase (LDH) and uric acid of heat-stressed broilers
Hosseini-Vashan et al (2012)	Turmeric powder (0.4% and 0.8%) increased HDL level and decreased total cholesterol, LDL, LDH, AST, ALT and ALP levels in the plasma of heat-stressed broilers
El-Maaty et al (2014)	Turmeric powder (0.5 g/kg diet) decreased plasma levels of AST, ALT, creatinine, triglycerides, cholesterol, LDL and very-low-density lipoprotein (VLDL), and an increased HDL level of heat-stressed broilers
Sadeghi and Moghaddam (2018)	Turmeric powder (0.5% of diets) increased serum concentrations of T ₃ and T ₄ in thermal-stressed broilers
Hosseini-Vashan et al (2015)	Turmeric rhizome powder (0.4 and 0.8%) decreased plasma concentrations of cholesterol, LDL, creatine kinase, AST, ALT and ALP of broiler chickens exposed to thermal stress
Swathi et al (2016)	Turmeric powder (0.4% of diets) decreased serum concentration of corticosterone of broilers exposed to heat stress
Zeinali et al (2011)	Turmeric powder (10 g/kg diets) increased plasma concentration of T ₄ in heat-stressed broiler chickens

481 **Table 3** Effect of turmeric on the antioxidant status of heat-stressed broilers.

References	Findings
Akhavan-Salamat and Ghasemi (2016)	Turmeric rhizome powder increased GPx and SOD activities and alleviated the increased levels of malondialdehyde (MDA) in serum due to heat stress
Bagban et al (2016)	Turmeric powder (0.5% of diets) decreased plasma levels of MDA of heat-stressed broilers
Hosseini-Vashan et al (2012)	Turmeric powder (0.4% and 0.8%) increased GPx, decreased thiobarbituric acid reactive substances (TBARS) levels in plasma and H/L ratio of heat-stressed broilers
El-Maaty et al (2014)	Turmeric powder (0.5 g/kg diet) decreased plasma MDA and increased SOD and GSH levels in heat-stressed broiler
Sadeghi and Moghaddam (2018)	Turmeric powder (0.5% of diets) increased serum levels of SOD but did not affect GPx, catalase, MDA and total antioxidant capacity (TAC) of broiler stressed by high ambient temperature
Hosseini-Vashan et al (2015)	Turmeric rhizome powder (0.4 and 0.8%) increased plasma concentrations of GPx and SOD and decreased TBARS of broilers maintained in heat stress condition
Swathi et al (2016)	Turmeric powder (0.4% of diets) increased SOD, GPx, catalase and glutathione activities in plasma of broilers exposed to heat stress

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