Review
Challenges to poultry production in tropical or subtropical climate conditions [1]

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ABSTRACT

Harsh climatic conditions are limiting and detrimental parameters for poultry production in tropical countries. Numerous studies have demonstrated that heat stress negatively effects the productively and welfare of poultry. There is no doubt that these unfavorable effects can also be economically significant, particularly in hot areas. This review focuses on the causes and the harmful influences of heat stress, whereas the coping strategies are summarized from related published papers. Future studies are required to increase the limited knowledge in the genetic aspect or its interactions to cellular and physiological level for improved heat tolerance. Breeding and selection for heat adapted poultry lines is becoming another popular research for the issue.

(Key Words: Poultry, Heat stress, Tropical or subtropical climate, Coping strategy)

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INTRODUCTION

Animal producers have to face some unavoidable challenges such as disease infections, environmental stress, problems of feed quality and availability, etc. Harsh climatic conditions are the most limiting parameter for livestock production, particularly in tropical and sub-tropical countries (Renaudeau *et al.*, 2011). The optimum temperature for poultry performance is considered to lay from 18ºC to 22ºC for broilers and from 19 to 22ºC for layers (Charles, 2002). Temperate conditions encountered in America or Europe generally allow for a better animal performance as compared to those in Asia. However, as global warming, heat waves may occur more frequently and last longer than before in America and Southern Europe. Heat stress is caused by a combination of high temperature humidity, and low air velocity and thus exert intensive detrimental effects on animal production (Balnave and Brake, 2005; Yahav *et al.*, 2004). In America, heat stress has been estimated to decrease egg production by 0.5 to 7.2%, and to increase mortality by 0.03 to 0.96%, leading to a global economic loss of 98.1 million per year (St-Pierre *et al.*, 2003). There is no doubt that effects of heat stress can also be economically significant for tropical and sub-tropical areas, where average ambient temperature frequently exceed 30ºC with high humidity (Tan *et al.*, 2010). Thus, hot environments (e.g. heat stress) are the critical stressor in poultry production and heat adaptation in poultry breeding is becoming a worldwide issue.

EFFECTS OF HIGH AMBIENT TEMBERATURE ON CHICKENS

Chickens have to grow and lay while exerting an effort to sustain their body temperature within a normal range, and have to cope with stress responses in order to ensure their organs function under a severe heat insult (Lin *et al.*, 2006). Many studies have pointed out the adverse effects of heat stress, such as poor growth rate and meat quality, high mortality, and poor laying rate and egg quality (Marsden and Morris, 1987; Shane, 1988; Howlider and Rose, 1989). The physiological mechanism for birds to maintain their body temperature within the normal range relies upon a balance between internal heat production and heat dissipation. Many studies showed that feed intake of laying hens was one of most negative effects by a rise in ambient temperature (Mignon-Grasteau *et al.*, 2015). At temperature above 30ºC, laying hens decrease their feed intake due to the stress response in the appetite regulation circuit in the hypothalamus. Furthermore, fuel metabolism is shifted to cool body temperature instead of towards production. Moreover, heat stress also decreases egg quality and efficiency of immune response (Novero *et al.*, 1991; Al-Saffar and Rose, 2002). Similar situations in feed intake and growth rate were also observed in growing broilers (Yalcin *et al.*, 1997; Settar *et al.*, 1999; Akşit *et al.*, 2006). Several evidences demonstrated that high ambient temperature is a major parameter hindering poultry meat production, including meat yield, meat quality, and carcass composition and often leading to pale, soft, and exudative (PSE) meat (Barbut, 1997; Woelfel *et al.*, 2002). To deal with heat adaptation, livestock farmers in

Asian countries were advised to use expensive management equipment to control environmental temperatures in order to maximize productivity of their animals. Many useful methods were suggested in order to maintain feed intake under hot conditions while maintain normal metabolic heat production.

Behavioral and physiological responses under feed deprivation and heat acclimation have been investigated in order to propose effective practices to improve chicken thermotolerance (Ait-Boulahsen *et al.*, 1993; De Basilio *et al.*, 2003). A study showed that several specific behaviors of birds such as less time feeding and moving, more time resting, drinking, and panting, and elevated wings were observed when birds are exposed under heat stress conditions (Mack *et al.*, 2013). Also, air sacs play a key role for promoting heat exchange between bird's body and environment. However, a higher level of blood pH and carbon dioxide hamper blood bicarbonate availability for eggshell mineralization in accompany with increased panting under heat stress environments. Furthermore, female's reproductive function (e.g. the normal status of reproductive hormones at the hypothalamus and ovary) was found to be disturbed by heat stress (Rozenboim *et al.*, 2007; Elnagar *et al.*, 2010). Thermal stress also impacts males such as decreased sperm concentration, semen volume, number of live sperm cells, and the increased sperm motility (McDaniel *et al.*, 1995; McDaniel *et al.*, 2004). Recent studies were focused on the identification of QTL for some traits easily measured under heat stress conditions to identify genes or genomic regions associated with a favorable response to high ambient temperatures to facilitate genetic selection of heat-resistance chickens. An advanced intercross chicken line (heat-susceptible broiler × heat-resistant Fayoumi) was used for the identification of QTL for some traits (blood chemistry components; BCC, body temperature, body weight, breast yield, and digestibility) which are potential indicators for adaption under heat stress conditions (Van Goor *et al.*, 2015 and 2016). However, results showed a very low heritability (0.00 to 0.10) for BCC and a low to moderate value (0.03 to 0.35) for other traits. Recently, a genome wide associated study (GWAS) identified 120 significant QTL for chicken body temperature, body weight, breast yield, and digestibility measured under heat stress conditions (Van Goor *et al.*, 2015). Besides, a recent QTL detection study under the real condition of the humid sub-tropical climate in Taiwan was carried out, in which an F2 population of 743 individuals produced by crossing the Taiwan Country chicken L2 line with an experimental line of Rhode Island Red layer R- provided by INRA (Lien *et al.*, 2017). Both QTL mapping and GWAS were used to assess adaption to sub-optimal climate conditions in the study. In both studies by Van Goors' and Liens', totally 22 QTL regions (5 QTL for growth related traits and 17 for blood chemistry traits) were commonly detected. Three out of 22 common QTL on GGA14 were detected in association with body temperature in Van Goors' study, and for body weight and shank length in Liens' study. The mapped QTLs may be used for genomic selection to improve performance and heat tolerance in chickens, particularly in tropical and sub-tropical climate conditions.

STRATEGIES TO COPE WITH HEAT STRESS IN POULTRY

Simultaneously to the rising awareness of animal welfare, controlling environmental conditions to provide a comfortable environment is important for successful poultry production. Since new management practices were generally not sufficient to maintain maximal production, the combination of nutritional, environmental, and genetic strategies has been recommended (Lin *et al.*, 2006; Renaudeau *et al.*, 2011). Lin *et al.* (2006) reviewed current methods and proposed some strategies to cope with heat stress and to maintain thermoregulation and homeostasis in poultry:

1. Environmental strategies: including intermittent light regimes, early heat conditioning, early feed restriction, and controlled humidity, etc. to avoid additional stress and stress-related mortality such as shipping or handling during the hottest periods.

2. Feeding strategies: temporary feed restriction, changing the feeding time from once to twice daily (including feeding at night), giving wet diet (containing 50% moisture) to increase the dry matter intake for layers, etc. Most feeding strategies are aimed at preventing the metabolic peak of heat production and environmental heat loads from occurring simultaneously (Renaudeau *et al.*, 2011). Feed restriction before or during heat exposure is found to be an effective approach to improve heat resistance (Balnave, 2004). Several cases were observed in turkey and layers. Özkan *et al.* (2003) showed that feed withdrawal during the hottest period of the day reduced mortality without any negative effects on growth performance. Şahin and Küçük (2001) found a simple way that feed withdrawal in the hottest period of the day (14 to 18 h) during the summer months was a good practical management to reduce heat stress related depression in feed intake and egg production in laying hens.

3. Nutritional strategies: reduction of excess protein, addition of fat, supplementation of vitamins and electrolytes, and water balance, etc. Under high ambient temperature (up to 35ºC), broiler producers were recommended to give extra fat supplement to overcome the adverse impact of heat stress (Dale and Fuller, 1980). Comparing with different percentage of fat used in the diet, broilers gained more body weight when high fat diet (5 to 10%) was given (Dale and Fuller, 1980; Ghazalah *et al.*, 2008). It should pay more attention that an increased mortality rate was observed in heavy broilers which fed high-fat diet during heat stress (Zulkifli *et al.*, 2007). Moreover, less protein with increased levels of synthetic amino acids was suggested to give better results than only providing high protein diets. Dietary supplementation with vitamins and minerals were beneficial for performance and immune function (Ferket and Qureshi, 1992).

4. Genetic strategies: selection for heat tolerance and the usage of major genes. In tropical and sub-tropical regions, animal survival often relies on extra management costs like cooling methods or other strategies mentioned above, which lead to a decline of farmers' income. Animal breeding for heat tolerance would be one of cost-effective approaches against harsh environments. Improving the ability of animal heat resistance could be achieved by selection or the introgression of heat adaptation genes. Crossbreeding is a usual way in animal breeding to combine the advantages of both parents. In poultry, several breeds exhibit traits favoring heat tolerance. For example, two major genes: the naked-neck gene and frizzle gene were found to regulate bird's feather characteristics and improve heat tolerance (Bordas and Mérat, 1984; Zerjal *et al.*, 2010). Another case reported by Cahaner *et al.* (2008) is the scaleless mutation which results in featherless chicken.

This discovery was currently introgressed in a fast-growing line to improve bird's thermotolerance. Considering the global warming and animal welfare, it is important to select animals for thermotolerance. Suitable selection criteria or specialized lines should be identified to set up a breeding program to avoid the adverse impact of hot conditions on poultry welfare and production.

CONCLUSION

Heat stress has detrimental effects on poultry production. The management approaches to cope with harsh climate including environmental, feeding, nutritional, and genetic strategies to minimize the adverse effects of heat stress in poultry production were summarized in current review. This is all the more justified that increasing evidences indicate that much of the variations of domestic fowls in response to heat stress may be genetically-based (Soleimani *et al.*, 2011; Felver-Gant *et al.*, 2012; Mack *et al.*, 2013). A meta-analysis on heat stress in laying hens showed that eggshell strength, egg mass, hen-day egg production, and daily feed intake, were the most sensitive traits to heat stress (Mignon-Grasteau *et al.*, 2015) which should be targeted by selection. Thus, further studies are required to increase the currently limited knowledge in genetic aspect and in its interactions to cellular and physiological level for improved heat tolerance.

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綜論報告

熱帶及亞熱帶氣候條件下家禽產業的挑戰 (1)

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摘要：惡劣的氣候條件是熱帶國家家禽產業的限制與不利因子。許多研究已證實熱緊迫對家禽生產與福祉帶來負面影響。毫無疑問地，這些不利影響在經濟上具顯著意義，尤其是在炎熱的地區。本文綜述了熱緊迫的成因及其不利影響，並從相關發表文獻中摘錄了應對策略。進一步的研究仍需持續進行，以增長對耐熱基因或遺傳組合有限的知識。熱適應性家禽品系的育成將成為另一項熱門的研究。

（關鍵語：家禽、熱緊迫、熱帶及亞熱帶氣候、因應對策）

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