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Improvement of robustness and performance in meat-type chickens and ducks by short-term temperature training in the hatcher

Abstract

The thermoregulatory system plays a central role in various body functions of the organism. It not only keeps the body temperature on an optimum level but also interacts with feed intake, growth rate, immune and stress responses. Perinatal temperature training (PTT) with short-term warm loads (+ 1°C, maximum 2 hrs/day) from day 18 until hatching, has shown long lasting effects on different traits. PTT decreased oxygen consumption during final embryonic development, improved hatching performance, changed the secondary sex ratio in favor to male chickens, and improved performance during the post-hatching growing phase by better weight gain and feed conversion. Improvement of hatching results and post-hatching performance was found in small and large scale experiments. Further, long-lasting changes in physiological parameters (HLR, metabolic hormones T3/T4) indicate better stress response through PTT. Similar results have been found in ducks with short-term cold training. It is assumed that PTT during the last days of hatching reduces the metabolic rate. Hence, the birds have more energy available for performance as well as for adaptation, immune and stress responses during environmental challenges. In conclusion, PTT improves robustness and production efficiency. It is a practicable epigenetic tool, in chickens and ducks which enables realization of the genetic determined performance. Through better adaptation to changing environmental conditions PTT also contributes to the bird`s welfare.

Keywords

Incubation, broilers, ducks, perinatal temperature, adaptation, performance

Introduction

According to the Agricultural Outlook 2020 poultry meat will be the largest meat sector in the world (OECD/FAO, 2014). Continuous genetic improvement in poultry breeds led to a fast development in performance of commercial poultry lines. Broilers in particular are characterized by high growth and metabolic rate already during embryonic development (Janke et al.; 2004, Druyan, 2010; Buzala et al., 2015). High performance and increased metabolic heat production result in relative low capacity of heat dissipation and increased susceptibility to stress under changing environmental conditions (Havenstein et al., 2003; Schmidt et al., 2009; Kalmar et al., 2013; Loyau, 2015). The higher risk of high yielding poultry lines for behavioural, physiological and immunological problems is an important animal welfare issue. Improvement of robustness alongside with high production efficiency has top priority. Recent studies using short-term temperature stimulation during critical developmental periods in the hatching phase (perinatal temperature training, PTT) have shown positive effects on robustness, health and performance in fast growing chickens and ducks.

In the following we review the physiological background of this method and present results of small-scale and large-scale experiments.

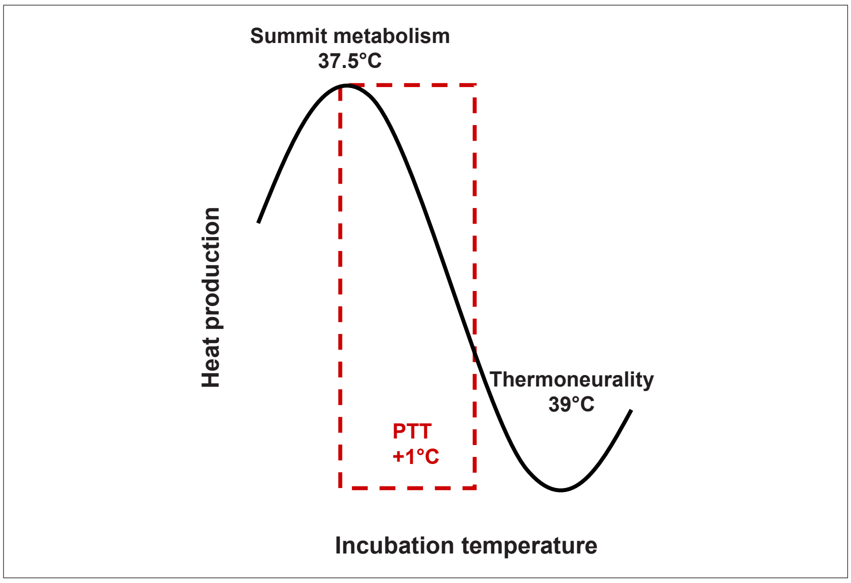

Figure 1: Schematic diagram of the relationship between oxygen consumption and incubation temperature of late term poultry embryos (PTT: perinatal short-term temperature training, temperature range)

Physiological background of PTT

How does temperature training improve robustness and production efficiency?

Temperature regulation plays a central role in the hierarchy of regulatory systems in homoeothermic (warm-blooded) animals. The goal of temperature regulation is the maintenance of a constant body core temperature under most conditions. It is the prerequisite for optimum development and performance. The thermoregulatory system integrates different body functions. The close relationship between thermoregulation and other homeostatic physiological functions occur already on cellular level in the regulatory center of the brain, the hypothalamus. Hypothalamic neurons receive and process temperature, metabolic, osmotic and hormonal signals (Boulant and Silva, 1989; Hori, 1991). Hence, adaptation to temperature may also influence feed intake, body weight development, metabolism, immune and stress response, and reproduction (DuRant et al., 2012; Horowitz, 2014; Nassar et al., 2014). Finally, PTT may improve robustness in poultry (Boerjan, 2010; Tzschentke and Tatge, 2012).

Why is the hatching phase optimum for application PTT?

During the last days before hatching the embryo is prepared to respond to environmental stimuli. Physiological mechanisms have evolved from open loop to closed feedback control systems (Tzschentke and Plagemann, 2006, Tzschentke, 2007; Tzschentke and Rumpf, 2011). Closed feedback systems are a prerequisite of efficient PTT. During the perinatal period environmental influences can have long-lasting and obviously transgenerational effects (Tzschentke and Plagemann, 2006, Tzschentke et al., 2014, 2015a). Improvement of temperature adaptation and growth in relation to perinatally experienced chronic temperature changes were already demonstrated in chickens about 30 years ago from Minne and Decuypere (1984) and Decuypere (1984). In our own research in Muscovy ducks we found long-lasting effects of changes in incubation temperature during final embryonic development on post-hatching sensitivity of hypothalamic neuronal mechanisms, which were related to improved temperature adaptation and stress response (Tzschentke and Basta, 2002; Janke and Tzschentke, 2010).

Why is heat production declined by short-term mild warm PTT?

Mild short-term warm stimulation during final embryonic development decreased oxygen consumption and heat production in layer- and meat-type chicken as well as in Muscovy duck embryos (Nichelmann et al., 1994; Janke et al., 2002; El-Sabry and Tzschentke, 2010). Birds are naturally incubated under conditions of 'summit metabolism' (Nichelmann et al., 1994; Tzschentke and Rumpf, 2011). Heat production decreases with increasing incubation from the natural incubation temperature of about 37.5°C towards thermoneutral conditions of about 39°C **(Figure 1)**. Above thermoneutrality heat production increases again. This shows that the response of heat production to changes in the ambient (incubation) temperature of the embryo is similar to that observed in the post-hatching and adult state (Tzschentke and Nichelmann, 1999; Nichelmann and Tzschentke, 2002).

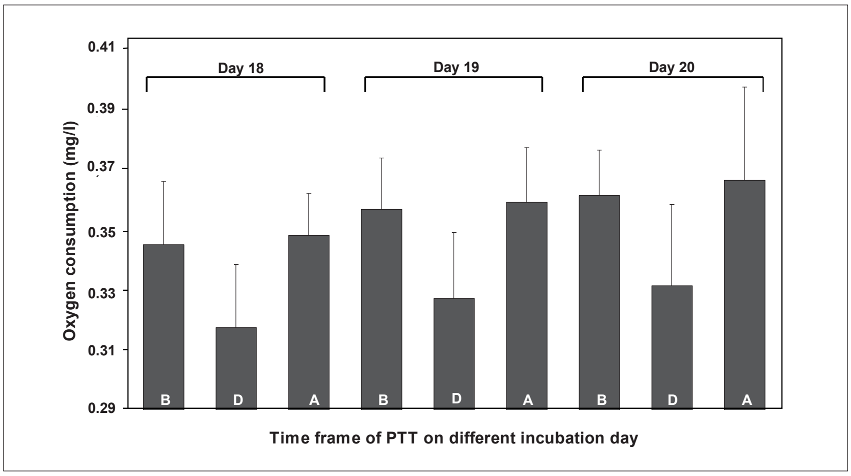

Figure 2: Influence of perinatal short-term temperature training (PTT, + 1°C for 2 hrs daily) on oxygen consumption of Cobb broiler embryos on incubation days 18, 19 and 20 (N=7). Columns represent mean values of oxygen consumption measured for 60 sec. before (B), during (D) and after (A) PTT (El Sabry, M.I., B. Tzschentke, 2010)

During a mild increase in hatching temperature heat loss mechanisms (e.g. respiration, blood circulation) are effective to keep deep body temperature constant (Holland et al., 1998; Nichelmann and Tzschentke, 2002, 2003; Tzschentke 2007). This could be demonstrated in experiments where deep body temperature was measured in the colon of the embryo (Holland et al., 1998; Tzschentke 2007). We concluded that mild warm PTT decreased oxygen consumption and heat production in embryos of high yielding broilers **(Figure 2)**. The daily PTT training during 'critical period' in the development of thermoregulation might programme the thermoregulatory system and homeostatic functions. The long-lasting result would be a lower basic metabolism, which enables better weight gain and feed conversion rate. Under these conditions there is energy available to cope with stress and immune challenges. Thus, PTT improves robustness and performance.

Studies on PTT in broilers in small and large scale tests

In small scale experiments (about 1000 eggs per treatment) with Ross 308 broilers (Tzschentke and Halle, 2009) we demonstrated for the first time that PTT (maximum + 1°C, 2 hrs/day) increased hatching rate and body weight of hatched chicks, and changed the secondary sex ratio (percentage of vital male and female chicks hatched in relation to total chicks hatched) **(Figure 3)**. Short-term warm stimulation improved hatchability by more than 1.5% and was associated with a significantly higher proportion of hatched male chickens. In subsequent growth trials a better feed conversion mostly along with better body weight gain up to the slaughter age (35 days) were observed (Tzschentke and Halle, 2009). The positive effects were preferentially found in males **(Table 1)**. Similar effects have been reported by Elmehdawi et al. (2015) in a large scale experiment (incubators for 42,240 eggs) using a stimulation of + 0.5°C for 2 hrs per day from 18th day of incubation until hatching. The proportion of vital hatched male chickens was significantly increased by 2.2 to 3.5% in response to PTT. Examination of the unhatched eggs confirmed the hypothesis that PTT improves the robustness already of the embryos, and especially in the males. The percentage of unhatched male embryos was significantly higher in the control group. Similar effects were found if PTT of +1°C was applied, even the increased percentage in male hatched chickens was not statistically significant higher (Elmehdawi et al., 2016). However, long-term effect of

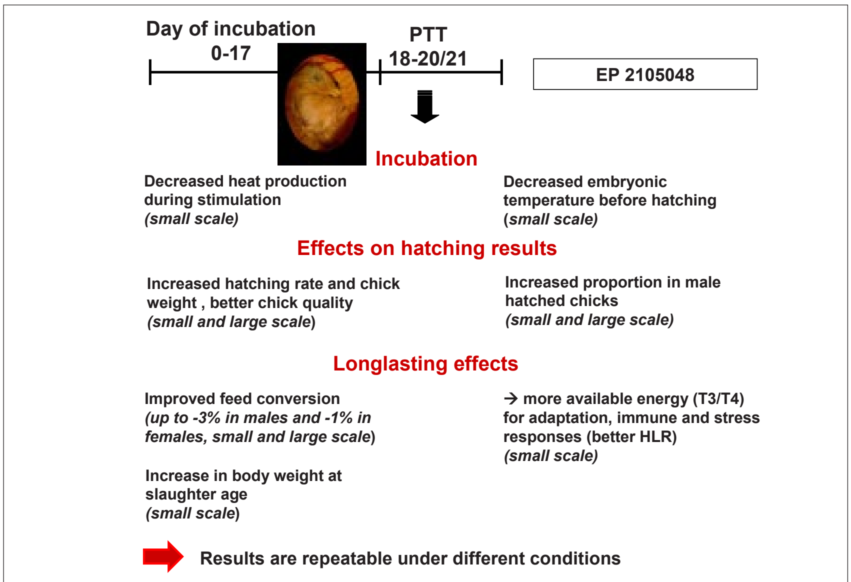

Figure 3: Summary of the results of perinatal short-term temperature training (PTT) on robustness and performance in broiler chickens from small and large scale experiments (results from large scale experiments, Elmehdawi et al., 2015, 2016; image ©Pasreform Hatchery Technologies)

Table 1: Performance of normally incubated (Control) and perinatal temperature stimulated (4 days, 2 h per day, + 1°C) broiler chickens (n=120/group/sex; Tzschentke and Halle, 2009)

Group Age, days	1[1)] Control		2[1)] Short-term warm stimulated	
	Male	Female	Male	Female
Feed intake, g/broiler/day				
1 – 14	35.0 a	33.9 b	35.9 a	33.9 b
15 - 21	89.9 a	81.1 b	92.5 a	81.4 b
22 – 35	155.3 a	128.4 b	156.3 a	127.3 b
1 - 35	93.3 a	80.8 b	95.2 a	80.7 b
Feed to gain ratio, kg/kg				
1 – 14	1.22	1.24	1.22	1.24
15 - 21	1.35	1.39	1.33	1.37
22 – 35	1.65 ab	1.66 a	1.60 c	1.62 bc
1 – 35	1.50 ab	1.51 a	1.47 c	1.49 bc
Body weight, g/broiler				
14	445	428	455	426
21	919 a	845 b	942 a	841 b
35	2270 b	1927 c	2336 a	1938 c

a; b; c; – Means within rows with one common letter do not differ significantly (P> 0.05)

Table 2: Performance of normal incubated and perinatal temperature stimulated (6 days, 2 h per day; -10C) Pekin ducks (n=72/group/sex; Halle et al., 2012)

Group Age, days	1[1)] Control		2[1)] Short-term cold stimulated	
	Male	Female	Male	Female
Feed intake, g/duck/day				
1 – 21	110.9 a	102.5 c	105.bc	108.9 ab
22 – 49	262.0	243.9	241.6	258.7
1 - 49	197.2 a	183.3 b	183.1 b	194.5 ab
Feed to gain ratio, kg/kg				
1 – 21	1.61 a	1.62 a	1.55 b	1.64 a
22 – 49	3.23 a	3.32 a	2.88 b	3.49 a
1 - 49	2.60 b	2.65 ab	2.38 c	2.74 a
Body weight, g/duck				
1	54 b	55 b	58 a	56 b
21	1498 a	1386 b	1476 a	1448 a
49	3773 a	3449 b	3832 a	3526 b

a; b; c; – Means within rows with one common letter do not differ significantly (P> 0.05)
[1)] 1- Control, 2- short-term cold stimulated

PTT on performance was only found after PTT of + 1°C (Elmehdawi et al., 2016). In this experiment feed conversion was improved by about -2% which was similar to results from the small scale experiment (Tzschentke and Halle, 2009).

First experiments on stress response showed that PTT treated chickens had a significantly lower heterophil to lymphocyte ratio (HLR) in comparison with the normally incubated control birds. During severe stress male broilers showed significantly higher thyroid hormone levels (T3/T4) in the blood, which demonstrate higher ability to mobilize energy for the stress response (Tzschentke et al., 2015b).

Perspectives of PTT application in other poultry species

In other poultry species as Pekin ducks short-term temperature training in the hatching phase was also tested. Whereas short-term mild warm stimulation as in the broiler chickens depressed hatching results in ducks, short-term cold stimulation (1°C below standard incubation temperature for 2 hrs per day) had long-lasting effects on the ducks performance (Halle et al., 2012). Short-term mild cold stimulation during the last days before hatching improved body weight gain and feed conversion during the growing period exclusively in male ducks. Further, at slaughter age male and female ducks from the short-term stimulated group reached statistically higher crude protein content in the breast meat compare to ducks of the control group **(Table 2 and 3)**. Obviously, ducks need different temperature stimulation than chickens, because of their better cold tolerance and higher maturity of body functions as termoregulatory heat production already during final incubation (Sallagundala et al., 2006).

Table 3: Content (%) of water, protein and fat in the fresh matter of the breast meat of normally incubated and perinatally temperature stimulated (6 days, 2h per day; -10C) Pekin ducks (n=6/group/sex; Halle et al., 2012)

Group	1[1)] Control		2[1)] Short-term cold stimulated	
	Male	Female	Male	Female
Water	76.9 a	76.6 a	76.0 a	75.1 b
Crude fat	1.2 ab	1.0 b	1.3 ab	1.5 a
Crude Protein	21.9 c	22.4 bc	22.7 ab	23.3 a

a; b; c; – Means within rows with one common letter do not differ significantly (P> 0.05)

Conclusions

In conclusion, in broiler chickens robustness alongside with production efficiency can be improved by PTT as a practicable epigenetic tool. Advantages of an epigenetic method would be the relatively simple application of nature like changes in environmental factors during incubation as well as the short-term achievement of practice relevant results (already in the first generation). In chickens, short-term mild warm stimulation during a critical period of body temperature control development may program the basic metabolism on a lower level. This would enable better activation of environmental adaption processes, stress- and immune responses as well as better realization of the genetic determined performance potential. To improve the PTT protocols for other poultry species, more research on embryonic physiology as well as on its long-term effects is necessary.

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