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Two incubation and two growing trials were carried out. A total of 1000 (Trial 1) and 1897 (Trial 2) eggs of the ROSS (308) strain were incubated from d 1 to 17 under normal conditions and from d 18 until hatch as follows: 37.2 to 37.4°C (control), 38.2 to 38.4°C for 24 h daily (chronic warm incubated) and 38.2 to 38.4°C for 2 h daily (short term warm stimulated). In incubation Trial 2, the chickens were sorted by sex. Chick quality was analysed by the Pasgar score. In the 35 day growing Trial 1, a total of 240 one day old chickens and in Trial 2 a total of 120 male and 120 female chickens from all incubation groups were kept at 34°C at d 1 and 2, and from d 3 up to the age of 35 days, at 32°C. The results of the two incubation trials showed that chronic or short-term increase in incubation temperature at the end of incubation did not diminish hatchability and chick quality. The data indicates different effects of chronic and short-term warm incubation as well as warm growing conditions on the performance of female and male broiler chickens. Female chickens seem to be better adapted to warm growing conditions and show a higher tendency in performance parameters (feed intake, body weight gain, and body weight) during the final growing period. In male chickens exclusively chronic warm-incubation leads to a lowered daily feed intake in the final growing period which results in the lowest fattening weight of 1332 g per animal (control: 1476 g, short term warm incubated: 1482 g). A lower feed intake decreases the bodily heat production and can help to minimize heat stress. At slaughtering (Trial 2), the percentages of breast meat, liver, heart, stomach, spleen and fat showed no statistical difference between the groups or sexes.

Key words: body weight gain, broiler chickens, hatchability, incubation temperature, high ambient temperature during growing period

Introduction

In meat-type fowl (e.g. broiler chickens, meat-type turkeys) during the last years there has been a strong genetic selection leading to a rapid growth and increased feed efficiency (Havenstein et al., 2003), but also increased metabolic heat production already during incubation (Janke et al., 2004). This results in a relatively low capability to balance energy expenditure under extreme conditions (e.g. heat spells) following by major economic losses (Yahav, 2000). Numerous methods were studied to reduce the negative effects of high ambient temperatures during the growing period. Fasting of broilers during heat stress, for instance, reduces the extra heat load by feed digestion and enhances survival (Abu-Dieyeh, 2006). Additions of nutritional supplements to feed or water can support maintenance of the electrolyte balance and increase water intake (Dai et al., 2009). Another method for reducing heat stress in poultry is an increase in air velocity in the poultry-keeping house. It results in an increase in the thermoneutral temperature and a decrease in body temperature (Tzschentke et al., 1996; Yahav et al., 2004a, 2008) via decreasing effective ambient temperature (Tzschentke and Nichelmann, 2000), but also improves production parameters, like growth rate, feed consumption and feed conversion (Dozier et al., 2005). During 'critical periods' of embryonic or early post-hatching development changes in climatic conditions (e.g. ambient temperature), may cause long-lasting changes in the epigenetic programming of respective body functions (‘imprinting of physiological control systems,’ Tzschentke and Plagemann, 2006). Thermal conditioning during the first days of post-hatching improved thermostolerance in later life (Yahav and Hurwitz, 1996; Yahav and Plavnik,
1999; Yahav and McMurtry, 2001). But from the practical point of view, thermal manipulations during incubation seem to be more easily applicable. Short-term thermal conditioning, preferably using short-term heat manipulation, during different times between day 8 and 18 of incubation, and using different duration and strength of temperature manipulation, show controversial results in relation to the improvement of post-hatching heat tolerance during different age periods (Moraes et al., 2003; Yahav et al., 2004b; Collin et al., 2005, 2007; Yalcin et al., 2005). The main problems seem to be the fine-tuning of temperature manipulation in poultry embryos and the poor knowledge on the ‘critical periods’ in the development of the thermoregulatory system. In our previous experiments and a few experiments from other investigators the last days of incubation were used for application of temperature manipulation, which seems to be beneficial. In poultry embryos at the end of incubation, peripheral and central nervous thermoregulatory mechanisms, as well as other body functions, are well developed (Tzschentke, 2007, 2008). Further, the end of incubation is characterized by dramatic changes in the quality of regulatory processes (Tzschentke and Plagemann, 2006), so that it is a ‘critical period’ in the development of body functions. During the last days of embryonic development changes in incubation temperature may induce epigenetic temperature adaptation, which results in a long-lasting cold or warm adaptation in poultry (Tzschentke, 2007). It could be shown in the chicken after cold-incubation (Decuyper, 1984, Minne and Decuyper, 1984), in turkeys after warm-incubation (Tzschentke and Nickelmann, 1999) and in the Muscovy duck after cold- and warm incubation (Tzschentke and Basta, 2002). But, these experiments were carried out with small numbers of animals, mostly observations of the postnatal development finished with day 10 of post-hatching and no data were obtained on the influence of prenatal cold- and warm incubation on hatchability, chick quality and productivity during later life.

With the following study we will fill in this lacuna. The goal of the study is to investigate the influence of short-term and chronic moderate increase in incubation temperature during the last 4 days of incubation on hatchability, chick quality and performance until slaughter age in broiler chicks kept under constant warm conditions. Further, in one trial chicks were sorted by sex, to show if male and female broiler chicks are differently sensitive to prenatal temperature manipulations as well as post-hatching temperature conditions.

Materials and Methods

A total of 1000 eggs (Trial 1) and 1897 eggs (Trial 2) of the ROSS (308) strain from breeders aged between 30 and 50 weeks were incubated from Day 1 to 17 at normal incubation temperature (37.2–37.4°C). For this incubation period in each trial one incubator with 15 trays for a maximum of 110 eggs was used. From d 18 until hatching the eggs were sorted in hatch incubators with different temperature programmes. In one hatch incubator the temperature was 37.2–37.4°C (control). The temperature was continuously increased by 1°C over standard (38.2–38.4°C) in the second hatch incubator (chronic warm incubation), and 1°C over standard for 2 hours daily in the third hatch incubator (short-term warm stimulation) from d 18 of incubation until hatching. In Trial 2, the 1-day old chickens were sorted by sex. Random sampling of chicks (50 of all incubators in Trial 1 and 30 males and 30 females of all incubators in Trial 2) were analysed by the Pasgar™ score (vitality, navel, legs, beak, and belly). The highest chick quality has a score of 10 and one point is subtracted for each abnormality recorded in one of the above-mentioned five criteria (www.pasreform.com).

The one-day-old chicks from the two incubation trials were used in subsequent growing trials. Treatments and procedures were performed according to the European Community regulations concerning the protection of experimental animals and the guidelines of the Lower Saxony State Office for Consumer Protection and Food Safety (LAVES), Germany. In Trial 1, a total of 240 one-day-old chickens (mixed male and female chickens) from all incubators, and in Trial 2, a total of 120 male chickens and 120 female chickens from all incubators, were randomly distributed in treatments with 12 chicks per pen and 20 pens (10 males/10 females) per group. The duration of the trials was 35 days. In both trials, temperature was 34 degrees at Day 1 and 2, and from Day 3 to the age of 35 days, temperature was 32 degrees in the treatment facility. Feed (Table 1) and water were provided for ad libitum consumption. Body weight and feed intake were recorded at Days 1, 14, 21 and 35 of age. Body weight was recorded for each broiler individually and analysed on pen-basis. Feed was weighed back on a pen-basis weekly. One bird per pen representing the mean body weight of broilers of this pen was slaughtered at the end of Trial 2 (10 male/10 female per group) to determine carcass composition. Weights of total breast meat (without skin), complete right leg, liver, heart, gizzard, spleen and sum of abdominal and viscera fat were individually recorded. All parts were expressed as percentage of body weight.

Data from growing trials of broilers were evaluated by one-way ANOVA: \[ y_i = \mu + a_i + e_{ij} \] where \( y_i \) = performance parameters of broilers, \( \mu \) = mean, \( a_i \) = group (hatch incubator, temperature regime), \( e_{ij} \) = error term. Means differences were evaluated by the Student-Newman-Keuls Test (\( P < 0.05 \)). All statistics were carried out using SAS operating system (SAS Version 9.1, 2002/03).

Results

The results of the two incubation trials (Tables 2 and 3) showed that a chronic increase in temperature by 1°C, did not influence the percentage of hatched chicks (Trial 1 93.2%, Trial 2 96.4%) in comparison to the control (Trial 1 94.5%, Trial 2 96.2%). Interestingly, short-term warm
stimulation even improved the hatching results by more than $1.5\%$ in both incubation trials. Further, in Trial 2 the percentage of male chicks was higher in comparison with the hatched female chicks after short-term warm stimulation in comparison with the other tested incubation conditions. The factor to evaluate the vitality of the hatched chicks (Pasgar$^*$-score) was above 9 in all trials and only slight differences were seen between the incubating groups.

In growing Trial 1, the feed intake of the chronic warm incubated broilers (Group 2) was always lower than the feed intake of the control (Groups 1) and the short-term warm incubated broilers (Group 3), which could be statistically established for the first phase of life (d 1–14) (Table 4). The daily body weight gain and the feed consumption did not differ between the groups. The mean body weight in broilers in Group 2 was statistically lower than in the other two groups until day 21. At the end of fattening (d 35) a difference was only seen between Groups 1 and 2.

For a differentiated statement on the influence of changes in the temperature regime in the hatch incubator and the subsequent high surrounding temperature in the treatment facility on the growth of chicks of both sexes, the broilers in growing Trial 2 were sorted on the day that they hatched. Daily feed intake was the same for all groups until Day 21 (Table 5). In the third week of

### Table 1. Ingredient composition and analysed and calculated nutrients of the diet (g/kg)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Trial 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>200.0</td>
</tr>
<tr>
<td>Corn</td>
<td>353.0</td>
</tr>
<tr>
<td>Soya bean meal</td>
<td>372.5</td>
</tr>
<tr>
<td>Soya oil</td>
<td>29.0</td>
</tr>
<tr>
<td>Di-calcium-phosphate</td>
<td>18.5</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>10.4</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>2.5</td>
</tr>
<tr>
<td>DL-methionine</td>
<td>2.5</td>
</tr>
<tr>
<td>L-lysine-HCl</td>
<td>1.6</td>
</tr>
<tr>
<td>Premix</td>
<td>10.0</td>
</tr>
</tbody>
</table>

1) Vitamin-mineral premix provided per kg of diet: Fe, 32 mg; Cu, 12 mg; Zn, 80 mg; Mn, 100 mg; Se, 0.4 mg; I, 1.6 mg; Co, 0.64 mg; retinol, 3.6 mg; cholecalciferol 0.088 mg; tocopherol, 40 mg; vitamin K$_{3}$, 4.5 mg; thiamine, 2.5 mg; riboflavin, 8 mg; pyridoxine, 6 mg; cobalamin, 32 $\mu$g; nicotinic acid, 45 mg; pantothenic acid, 15 mg; folic acid, 1.2 mg; biotin, 50 $\mu$g; choline chloride, 550 mg.

2) Analysed values.

3) Calculated values (WPSA; 1985).

4) Calculated values.

### Table 2. Result of incubation — Trial 1 (1000 hatched eggs; 52 unfertilised eggs = 5.2%; two times to candle eggs - 13 embryos died off)

<table>
<thead>
<tr>
<th>Group</th>
<th>1 Control</th>
<th>2 4d, 24h, +1°C</th>
<th>3 4d, 2h, +1°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs per hatch incubator</td>
<td>312</td>
<td>311</td>
<td>312</td>
</tr>
<tr>
<td>Hatched living chickens, %</td>
<td>94.5</td>
<td>93.2</td>
<td>96.5</td>
</tr>
<tr>
<td>Pasgar$^*$-score</td>
<td>9.6</td>
<td>9.5</td>
<td>9.4</td>
</tr>
</tbody>
</table>

### Table 3. Result of incubation — Trial 2 (1897 hatched eggs; egg weight = 60.7 g; 90 unfertilized eggs = 4.7%; two times to candle eggs - 57 embryos died off)

<table>
<thead>
<tr>
<th>Group</th>
<th>1 Control</th>
<th>2 4d, 24h, +1°C</th>
<th>3 4d, 2h, +1°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs per hatch incubator</td>
<td>583</td>
<td>583</td>
<td>584</td>
</tr>
<tr>
<td>Hatched living chickens, %</td>
<td>96.2</td>
<td>96.4</td>
<td>97.8</td>
</tr>
<tr>
<td>Male chicks, %</td>
<td>49.7</td>
<td>50.5</td>
<td>51.5</td>
</tr>
<tr>
<td>Female chickens</td>
<td>50.3</td>
<td>49.5</td>
<td>48.5</td>
</tr>
<tr>
<td>Pasgar$^*$-score</td>
<td>9.4</td>
<td>9.7</td>
<td>9.7</td>
</tr>
<tr>
<td>Male chicks</td>
<td>9.3</td>
<td>9.5</td>
<td>9.8</td>
</tr>
</tbody>
</table>
### Table 4. Performance of broilers — Incubation trial 1 (Mean, SD)

<table>
<thead>
<tr>
<th>Group Age, d</th>
<th>Feed intake, g/broiler/d</th>
<th>Body weight gain, g/broiler/d</th>
<th>Feed conversion, kg/kg</th>
<th>Body weight in g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1–14</td>
<td>32.9 ± 1.3</td>
<td>32.1 ± 1.3</td>
<td>33.0 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>15–21</td>
<td>72.5 ± 3.1</td>
<td>70.8 ± 3.7</td>
<td>72.4 ± 2.9</td>
<td></td>
</tr>
<tr>
<td>22–35</td>
<td>100.6 ± 14.1</td>
<td>94.7 ± 14.0</td>
<td>97.0 ± 12.9</td>
<td></td>
</tr>
<tr>
<td>1–35</td>
<td>67.8 ± 6.2</td>
<td>64.7 ± 6.3</td>
<td>66.4 ± 5.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–14</td>
<td>26.8 ± 1.2</td>
<td>26.3 ± 1.1</td>
<td>26.9 ± 0.7</td>
<td></td>
</tr>
<tr>
<td>15–21</td>
<td>51.8 ± 1.9</td>
<td>50.4 ± 3.1</td>
<td>51.7 ± 2.6</td>
<td></td>
</tr>
<tr>
<td>22–35</td>
<td>51.2 ± 11.7</td>
<td>47.0 ± 12.9</td>
<td>48.7 ± 11.7</td>
<td></td>
</tr>
<tr>
<td>1–35</td>
<td>41.6 ± 5.0</td>
<td>39.4 ± 5.4</td>
<td>40.6 ± 4.8</td>
<td></td>
</tr>
</tbody>
</table>

^a,b^ Means with different letters differ significantly.

1, control; 2, chronic warm incubated (4 d, 24 h, ±1°C); 3, short-term warm stimulated (4 d, 2 h, ±1°C).

### Table 5. Performance of broilers — Incubation trial 2 (Mean, SD)

<table>
<thead>
<tr>
<th>Group Age, d</th>
<th>Feed intake, g/broiler/d</th>
<th>Body weight gain, g/broiler/d</th>
<th>Feed conversion, kg/kg</th>
<th>Body weight in g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1–14</td>
<td>33.4 ± 1.4</td>
<td>32.9 ± 1.2</td>
<td>33.0 ± 1.1</td>
<td>32.1 ± 1.1</td>
</tr>
<tr>
<td>15–21</td>
<td>78.7 ± 4.3</td>
<td>79.4 ± 3.1</td>
<td>78.2 ± 4.5</td>
<td>72.5 ± 2.9</td>
</tr>
<tr>
<td>22–35</td>
<td>101.0 ± 15.4</td>
<td>87.7 ± 8.1</td>
<td>100.7 ± 12.3</td>
<td>105.0 ± 7.4</td>
</tr>
<tr>
<td>1–35</td>
<td>69.3 ± 6.4</td>
<td>63.9 ± 4.0</td>
<td>68.9 ± 5.0</td>
<td>68.8 ± 3.6</td>
</tr>
</tbody>
</table>

^a,b^ Means with different letters differ significantly.

1, control; 2, chronic warm incubated (4 d, 24 h, ±1°C); 3, short-term warm stimulated (4 d, 2 h, ±1°C).
was not different from the control, showing controversial results related to hatchability and the males of the control group (g) and the from different investigators, where a short-term temperature investigation led to the statistically significant lowest final weight of this group by g compared with studies (Tzschentke and Halle, ). Different studies incubated group led to the statistically significant lowest were observed, which could be approved in another of our studies.

The final fattening phase exclusively by the chronic warm significantly higher percentage of hatched male chicks was distinctly, but not statistically significantly, higher which incubation temperature was over standard for our trial. At slaughter age, the body weight of female broilers for all groups until the st day of the growing negative effect on hatchability. In both incubation trials male broilers in all groups was guaranteed higher than for incubation during the last days of incubation had no effect on hatchability. In our studies found that a chronic as well as short-term increase in body weight gain in the final phase of fattening proved to be more positive for female broilers, as did the feed intake of the female broilers at g per day ). But the effect of an increase in incubation temperature on hatchability depends on the duration and strength of warming as well as the embryonic development of which the temperature increase occurs. In our studies we found that a chronic as well as short-term increase in incubation during the last 4 days of incubation had no negative effect on hatchability. In both incubation trials the highest hatchability could be found in the Group 3, in which incubation temperature was 1°C over standard for 2 hours daily. Further, under these incubation conditions a significantly higher percentage of hatched male chicks were observed, which could be approved in another of our studies (Tzschentke and Halle, 2009). Different studies from different investigators, where a short-term temperature increase was used during various times of incubation, showing controversial results related to hatchability and hatching time. Yahav et al. (2004b), for instance, reported a significant increase in hatchability, but no effect on the timing of hatchability peak after thermal manipulation between day 16 and 18 of incubation for 3 h at 39.5°C in broiler chicks. Also Collin et al. (2005, 2007) observed no depressing effect on hatchability if either different duration (3 to 24 h) of thermal manipulation (39.5°C) between embryonic day 16 and 18 or the same thermal manipulation for 3 h per day between embryonic day 8 and 10 and 16 and 18 was used. On the other hand, Moraes et al. (2003) found decreased hatchability and delayed hatching process after heat conditioning of 39°C 2 h per day from day 13 until 17 of embryonic development. A possible explanation was the depressed corticosterone levels in the thermal manipulated embryos at internal pipping. Heat manipulation (39.5°C) of broiler embryos decreased hatchability and later performance when applied for 24 h between day 7 and 16 of incubation, but had no effect on both parameters if applied for 12 h per day, only, during the same embryonic period (Piestun et al.,

### Table 6. Slaughter performance of broilers (% of live weight)—Incubation trial 2 (Mean, SD)

<table>
<thead>
<tr>
<th>Group</th>
<th>Parameter</th>
<th>1 Male</th>
<th>2 Male</th>
<th>3 Male</th>
<th>1 Female</th>
<th>2 Female</th>
<th>3 Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressing</td>
<td>72.7±2.5</td>
<td>74.2±1.2</td>
<td>72.4±0.9</td>
<td>72.4±1.3</td>
<td>72.6±1.5</td>
<td>71.0±3.8</td>
<td></td>
</tr>
<tr>
<td>Breast meat</td>
<td>14.9±1.2</td>
<td>15.1±0.6</td>
<td>14.1±0.8</td>
<td>15.2±1.2</td>
<td>15.1±1.1</td>
<td>15.2±1.3</td>
<td></td>
</tr>
<tr>
<td>Legs</td>
<td>21.7±1.0</td>
<td>22.4±1.1</td>
<td>21.2±1.1</td>
<td>21.1±0.8</td>
<td>20.4±1.5</td>
<td>20.7±0.6</td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td>2.2±0.3</td>
<td>2.0±0.1</td>
<td>2.5±0.4</td>
<td>2.4±0.4</td>
<td>2.5±0.4</td>
<td>2.5±0.3</td>
<td></td>
</tr>
<tr>
<td>Heart</td>
<td>0.4±0.0</td>
<td>0.4±0.0</td>
<td>0.4±0.0</td>
<td>0.4±0.1</td>
<td>0.4±0.0</td>
<td>0.4±0.0</td>
<td></td>
</tr>
<tr>
<td>Gizzard</td>
<td>1.0±0.2</td>
<td>1.1±0.2</td>
<td>1.1±0.3</td>
<td>1.1±0.1</td>
<td>1.0±0.1</td>
<td>1.0±0.1</td>
<td></td>
</tr>
<tr>
<td>Spleen</td>
<td>0.03±0.02</td>
<td>0.03±0.02</td>
<td>0.03±0.02</td>
<td>0.04±0.02</td>
<td>0.03±0.03</td>
<td>0.04±0.03</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1.9±0.3</td>
<td>2.1±0.3</td>
<td>2.2±0.3</td>
<td>1.9±0.3</td>
<td>2.1±0.4</td>
<td>2.3±0.3</td>
<td></td>
</tr>
</tbody>
</table>

*a,b* Means with different letters differ significantly.

### Discussion

**Influence of Increase in Incubation Temperature on Hatchability, Hatching Time and Chick Quality**

It is well known that overheating poultry embryos results in lower hatchability (Wilson, 1991; French, 2000). But the effect of an increase in incubation temperature on hatchability depends on the duration and strength of warming as well as the embryonic development at which the temperature increase occurs. In our studies we found that a chronic as well as short-term increase in incubation during the last 4 days of incubation had no negative effect on hatchability. In both incubation trials the highest hatchability could be found in the Group 3, in which incubation temperature was 1°C over standard for 2 hours daily. Further, under these incubation conditions a significantly higher percentage of hatched male chicks were observed, which could be approved in another of our studies (Tzschentke and Halle, 2009). Different studies from different investigators, where a short-term temperature increase was used during various times of incubation, showing controversial results related to hatchability and hatching time. Yahav et al. (2004b), for instance, reported a significant increase in hatchability, but no effect on the timing of hatchability peak after thermal manipulation between day 16 and 18 of incubation for 3 h at 39.5°C in broiler chicks. Also Collin et al. (2005, 2007) observed no depressing effect on hatchability if either different duration (3 to 24 h) of thermal manipulation (39.5°C) between embryonic day 16 and 18 or the same thermal manipulation for 3 h per day between embryonic day 8 and 10 and 16 and 18 was used. On the other hand, Moraes et al. (2003) found decreased hatchability and delayed hatching process after heat conditioning of 39°C 2 h per day from day 13 until 17 of embryonic development. A possible explanation was the depressed corticosterone levels in the thermal manipulated embryos at internal pipping. Heat manipulation (39.5°C) of broiler embryos decreased hatchability and later performance when applied for 24 h between day 7 and 16 of incubation, but had no effect on both parameters if applied for 12 h per day, only, during the same embryonic period (Piestun et al.,

fattening, the chronic warm incubated male broilers consumed statistically more feed (79.2 g/animal/d) than the female animals in all groups. However in the final growing phase (d 22–35), the feed intake in Group 2 was only 88 g per animal and day, while in all other groups, more than 101 g feed per animal and day were consumed, and the feed intake of the female broilers at 105–107 g per day was about 5 g more than for the male animals. The daily body weight gain in the final phase of fattening proved to be more positive for female broilers, as did the feed conversion (1.88–1.94 kg/kg). The body weight for the male broilers in all groups was guaranteed higher than for females for all groups until the 21st day of the growing trial. At slaughter age, the body weight of female broilers was distinctly, but not statistically significantly, higher than in males. In male broilers the reduced feed intake in the final fattening phase exclusively by the chronic warm incubated group led to the statistically significant lowest final weight of this group by 1332±188 g compared with the males of the control group (1476±236 g) and the short-term warm stimulated group (1482±225 g), which was not different from the control.

During the first trial between 2.5 to 4.0% of the animals died in each group. In the second trial 8% of the chronic warm incubated male broiler chickens died, and in the remaining groups between 3 and 6% of the animals did not survive. In the two trials only one animal died respectively during the first 14 days. All further losses appeared between the 21st and 35th days of age.

At slaughter, the percentages of breast meat, liver, heart, gizzard, spleen and abdominal fat yield were not statistically different between the groups or sexes (Table 6). Statistically firmed difference in the percentage of dressing was calculated between the chronic warm incubated male broilers (group 2) and the short-term warm incubated female animals (group 3) and in the percentage of legs between male (group 2) and female broilers (group 2 and 3).
Influence of Increase in Incubation Temperature on Performance Until Slaughter Age at High Temperatures (32°C)

In comparison to broiler chickens kept according to the temperature-regime of the broiler (Days 1 and 2: 35-34°C, 3 and 4: 33-32°C, 5 to 7: 30°C, 2nd week: 29°C, 3rd week: 26°C, 4th week: 22°C, 5th week: 20°C; Tzschentke and Halle, 2009) permanent warm temperatures (32°C) during growing period caused in both Trials each incubation group a strong decrease in all performance parameters investigated. This result is not surprising, because the depressive effect of high ambient temperature on poultry performance is well known. For instance, the effect of feed on maintaining the balance between heat production and heat loss is probably the most direct effect of high ambient temperature on poultry. This means, that a decrease in growth or egg production in a hot environment is mainly caused by a reduction of feed intake (MacLeod, 1981; Waibel and MacLeod, 1993; Mujahid et al., 2009) in order to reduce heat production.

The results of the second growing trial show clear differences between male and female broiler chickens regarding the influence of the manipulations in incubation temperature on the post-hatching performance as well as the adaptability to warm growing conditions. The data indicates different effects of short-term and chronic warm incubation for the development under warm growing conditions between female and male broiler chicks. Female broilers of all incubation groups reached a distinctly higher final body weight compared to male broilers, especially those of the chronic warm incubated group. But, the differences between both sexes were not statistically significant because of the high individual variation in heat tolerance. In females no significant differences could be found between the different incubated groups in relation to all investigated parameters. Differences in performance were only found in different incubated males. It is interesting that in males, the only significant difference was obtained in the group which was chronic warm incubated during the last 4 days of incubation. At the end of the growing period (days 22–35) in this group, feed intake was significantly lower than in the control and short-term warm stimulated group. Moreover, the final body weight (d 35) was significant lower, too. Finally, in male broiler chickens chronic warm incubation during the last 4 days of incubation seems to have a long-lasting effect on body functions, which is related to the adaptation to hot climatic conditions. The chronic warm incubated male chickens showed a stronger reduction of feed intake, which leads to a stronger decrease in body heat production under permanent hot ambient temperatures. Finally, it can minimize the thermal strain of these birds. Improved heat tolerance in broilers during heat challenge on slaughter age was also found after thermal conditioning on day 3 of post-hatching (Yahav and Hurwitz, 1996; Yahav et al., 2005). During acute heat challenge, the temperature manipulated broiler chicks had a significantly reduced
heat production (Yahav and Hurwitz, 1996), showed alterations in sensible heat loss by convection and radiation (Yahav et al., 2005) and a reduced stress level (lower plasma corticosterone concentration) as well as a lower body temperature, which finally results in dramatically reduced mortality.

In our previous experiments in chronic warm incubated chicken (Layer line), turkey and Muscovy duck embryos (38.5°C, last days of incubation), changes in different physiological parameters were observed until day 10 of post-hatching, which are related to warm adaptation. In warm incubated poultry embryos a higher body temperatures was determined (Loh et al., 2004, Tzschentke, 2007), which could be a prerequisite of higher thermo-regulatory set-point during post-hatching development. This was found in warm incubated turkeys, which preferred a higher ambient temperature during the first 10 days post-hatching (Tzschentke and Nichelmann, 1999). Further, on day 10 post-hatching chronic warm or cold load changed the neuronal thermosensitivity in the hypothalamus, the brain area that includes the thermo-regulatory centre in birds and mammals. In Muscovy ducklings, for instance, prenatal warm load elevated the neuronal hypothalamic cold-sensitivity where an increased proportion of cold and a reduced proportion of warm sensitive neurones in comparison with the control group were observed (Tzschentke and Basta, 2002). Prenatal cold load induced the opposite effect. This change in the hypothalamic neuronal thermosensitivity may be the result of a downward or upward shift of the threshold in which the respective neurones are temperature sensitive as a long-lasting effect of prenatal warm- or cold adaptation. Further, after a short-term heat load significant differences in the c-fos expression of hypothalamic neurons were found between adult chickens (8 weeks of post-hatching), which were chronic warm- and cold incubated (Janke and Tzschentke, 2010). This immediate early gene plays a major role as stress marker but also in consolidation of long-term memories (Rose, 1991; Hildebrandt et al., 1998; Tischmeyer and Grimm, 1999). These examples show that in poultry chronic warm (or cold) incubation during the last days of incubation can induce long-lasting physiological changes, which are related to warm or cold adaptation.

On the other hand, in the actual study both types of temperature manipulation at the end of incubation did not improve the performance of male and female broilers under constant warm growing conditions. Under the normal growing conditions for broilers a significantly lower feed conversion and a significant increase in body weight at slaughter age was exclusively found in male broiler chickens after short-term warm stimulation (2h daily, +1°C over standard) during the last 4 days of incubation (Tzschentke and Halle, 2009).

From our study it can be concluded that female and male broiler chicks develop different tolerance to high ambient temperature. In male broiler chickens, exclusively chronic warm incubation (1°C over standard) during the last 4 days of incubation obviously induced long-term changes in body functions, which are related to warm-adaptation. The chronic warm incubated male chickens show a significantly lower feed intake at the end of the growing period, which leads to a decrease in body heat production. Finally, it can minimize the thermal stress of these birds and could be a sign of improved heat adaptation. During perinatal critical developmental periods applied environmental variations might induce long-lasting effects, which often will be expressed not before the later development or adult age. Examples are the development of the Ascites syndrome in poultry, which can be already originated by suboptimum incubation conditions (Buys et al., 1998), and the development of diabetes, which may be originated by prenatal malprogramming of metabolism, food intake and body weight (Plagemann, 2004). Further, cross adaptation to the actual postnatal environment influences the perinatally determined developmental trajectory (Janke and Tzschentke, 2010).

Chronic (24 h), as well as short-term (2h daily), increases in incubation temperature by 1°C over standard during the last 4 days of incubation have no negative effect on hatchability and chick quality. The time-window for thermal manipulation used in this study is situated at the end of incubation. In this period the thermoregulatory system and related adaptive systems are well developed and side effects by temperature manipulations could be minimized. On the other hand, both types of prenatal temperature manipulation did not improve the post-hatching performance of the broilers of both sexes under constant warm growing conditions. The question is open, if at the end of embryonic development chronic warm incubated male broilers can better tolerate acute heat challenge under the normal mild ambient temperatures. To clarify this, further studies are necessary. In prenatal short-term warm stimulated broilers kept under normal growing conditions we found a significant improved performance in male broiler chicks until age of slaughter (Tzschentke and Halle, 2009). Finally, from this and our actual studies we can conclude that possibly different goals (improvement of heat adaptation or performance) needs different manipulation in incubation temperature (chronic changes to improve heat adaptation and short-term changes to improve performance). Further, this manipulation has to be specific for female and male broilers.

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