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Effect of Environmental Temperature During the First Week of Brooding Period on Broiler Chick Body Weight, Viscera and Bone Development

Efeito da Temperatura Ambiente Durante a Primeira Semana de Vida de Frangos Sobre o Peso Vivo, Desenvolvimento de Vísceras e Crescimento Ósseo

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■ **Observações / Notes**

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ABSTRACT

The objective of the present study was to assess the development of broiler chicks during the first week post-hatching when reared at three different environmental temperatures. A total of 480 day-old chicks were placed in three environmentally controlled rooms (20, 25 and 35°C) from 1 to 7 days of age. Body weight gain, feed and water intake, as well as liver, gizzard, heart, yolk sac and bursa of Fabricius weights were measured daily. Tibia and femur bones were weighed and their length and width (medial diameter) were also obtained. The chicks reared at 20º C had lower weight gain and ingested less food than chicks reared at 25°C and less water than chicks kept at 35°C. Relative weights of the liver, heart, and gizzard were affected by environmental temperature, whereas yolk sac and bursa of Fabricius relative weights were not. The data showed that all bone parameters increased with bird age. Environmental temperature did not affect tibia or femur width, however a significant increase in bone weight and length occurred with increasing environmental temperature. These results indicate that brooding temperature of 20°C during the first seven days post-hatching was stressful decreasing broiler bone development and reducing chicks body weight.

RESUMO

O presente trabalho teve como objetivo estudar o efeito de diferentes temperaturas-ambiente durante a primeira semana de vida de pintos de corte sob parâmetros zootécnicos, desenvolvimento visceral e crescimento ósseo. Foram utilizados 240 pintos de um dia, alojados em 3 câmaras climáticas, com temperaturas constantes de 20, 25 e 35°C do 1° ao 7° dia de vida. Diariamente, o consumo de água e ração, bem como o peso vivo, o peso relativo do fígado, moela, coração, saco vitelino e bursa de Fabricius foram avaliados. A tíbia e o fêmur também foram pesados e o comprimento e espessura (diâmetro médio) mensurados. As aves criadas a 20°C ganharam menos peso e consumiram menos ração do que aves mantidas a 25°C e menos água do que aves mantidas a 35°C. O peso relativo do fígado, coração e moela foram afetados pela temperatura ambiente, entretanto, não foi observado efeito da temperatura de criação sobre o peso do saco vitelino e bursa de Fabricius. Os dados mostraram que todos os parâmetros ósseos pesquisados aumentaram com a idade das aves. A temperatura ambiente não afetou a espessura da tíbia e do fêmur, mas foi observado um aumento significativo no peso e comprimento dos ossos com o aumento da temperatura ambiente. Os resultados desse experimento mostraram que o estresse por frio (20°C) reduziu o crescimento ósseo bem como o peso vivo das aves, durante os primeiros sete dias após a eclosão.

INTRODUCTION

Embryo development has been extensively studied (Mather & Laughlin, 1976; Kirk et al., 1980; Mayes & Takeballi, 1984; North & Bell, 1990), but little is known about the anatomic-physiological parameters during the first week post-hatch, especially in highly selected broiler chick strains. The development of the chicks in the first week of life is an important condition for their future performance because physiological processes such as cell hyperplasia and hypertrophy, maturation of the thermoregulatory and immunological systems, growth and differentiation in the gastrointestinal tract will markedly influence the body weight and feed conversion of the birds until market age.

It is known that the thermoneutral temperature for broiler chicks up to 7 days of age ranges between 33 and 35º C, and that temperatures higher than these may induce hyperthermia and dehydration, leading to a lower feed consumption and delayed growth (Mickelberry et al., 1966). On the other hand, a lower environmental temperature induces hypothermia and may lead to pulmonary hypertension in broilers.

Post-hatch development had been studied in turkey and Leghorn chicks. Sell et al. (1991) reported that the body weight of turkey chicks increased linearly from 2 to 8 days of life, with residual yolk decreasing rapidly starting on day 26 of incubation and being nearly depleted on day 4 post-hatching; these authors also observed that gizzard weight increased until day 4 post-hatching and then remained relatively constant up to 8 days. Yang & Siegel (1997) in a study of heart and lung development in Leghorn lines found that both relative weight of heart and lung declined with chick age.

Thus, the objective of the present study was to evaluate the body weight, viscera and bone development of broiler chicks brooded at three different environmental temperatures (20º C, 25º C and 35º C) during the first week post-hatching.

MATERIALS AND METHODS

The experiment was conducted using four hundred and eighty day-old male broiler chicks of the Ross strain reared in litter pens (5 cm of wood shavings and population density of 10 birds/m^2) up to 7 days. On the first day, chicks were weighed, and randomly allocated to three environmentally controlled rooms, where ambient temperature was maintained at 20°C, 25°C or 35°C, respectively. For all temperatures water and ration were supplied ad libitum throughout the experiment.

From one day to seven days, ten birds per treatment were weighed then sacrificed daily via cervical dislocation and liver, gizzard, heart, yolk sac, and bursa of Fabricius were removed and immediately weighed. Tibia and femur were also removed and dried in an oven at 105°C for 75 hours. After 12 hours at room temperature the bones were weighed (± 0,01 g), and the length and width (in the medial part of the bones) were measured using a caliper (± 0,01 mm). Feed and water intake were recorded daily up to 7 days of age.

The experiment was performed using a split-plot design with the main plot as the environmental temperature (20, 25 or 35°C) and age (1 to 7 days) as the sub-plot. Data were subjected to statistical analysis using the General Linear Model (GLM) procedure of SAS® (SAS Institute, 2000). Differences between means were verified by the Tukey test. The water and feed consumption data for the three environmental temperatures were analyzed by comparing the regression lines identical according to Graybill (1961).

RESULTS

Feed and water intake

Seven days post-hatch exposure to ambient temperature of 20°C resulted in lower feed consumption (Figure 1) when compared with birds at 25°C. Total feed consumption per chick was: 92.7 g at 20°C, 116.2 g at 25°C, and 103.6 g at 35°C. Data concerning the effect of environmental brooding temperature on water intake are presented in Figure 2. Results showed that chicks exposed to low ambient temperature (20°C) had lower water intake than chicks brooded at high environmental temperature (35°C), with a total water intake of 190.3, 249.3 and 272.1 mL per chick at 20 °C, 25 °C and 35 °C, respectively.

Body and visceral weight

The influence of environmental brooding temperature and age on body weight and relative visceral weight (percent of body weight) are presented in Table 1. Chicks submitted to thermoneutral temperature (35ºC) or low (20ºC) environmental temperature showed lower ($p<0.01$) body weight when compared with chicks raised at moderate temperature (25ºC). Body weight was *significantly ($p<0.01$) affected by age, being observed an increase of 26, 45 and 55 %, in body weight on the 3rd , 5th and 7th days of life, respectively. No significant ($p>0.05$) interactions were found between environmental brooding temperature and age for body weight (Table 1).*

Relative weights of the liver, heart and gizzard were significantly affected by environmental brooding temperature, but no differences ($p>0.05$) in yolk weight and bursa of Fabricius were found between treatments (Table 1). A significant brooding temperature vs age interaction was also observed for liver, heart and bursa of Fabricius. Liver and heart of birds kept at thermoneutral temperature (35°C) had lower ($p<0.01$) relative weights at 7 days of age when compared with chicks brooded at 20°C but did not differ from birds reared at 25°C (Table 2). The relative weight of the bursa of Fabricius was not adversely affected by brooding temperature seven days post-hatching.

Bone Growth

Table 3 shows the results for tibia and femur growth. It was observed that brooding temperature affected tibia and femur growth, with chicks brooded at 25°C and 35°C showing higher ($p<0.01$) tibia weight and tibia e femur length when compared to birds kept at 20°C. Tibia and femur width was not affected by brooding temperature ($p>0.05$). Tibia and femur weight, length and width increased ($p<0.01$) with broiler chick age, and no significant ($p>0.05$) interaction was observed between brooding temperature and age for bone growth.

DISCUSSION

The present study indicate that chicks brooded at 20°C had lower feed and water intake during a 7 day post-hatching period compared with birds kept at 25 and 35°C, respectively. These results probably are related to the heat conserving behavior of these birds, since at low ambient temperature (20) it was observed that they clustered to avoid heat loss and the frequency to the feeder and drinker was reduced. Environmental temperature is an important factor for broiler performance, and chicks brooded at 35°C showed a significantly lower body weight. Van der Hel et al. (1991) observed that high thermal exposure of chicks during the 1st day post-hatching resulted in body weight losses. Exposure to high temperatures during the first 2 days of life causes body weight losses of about 12% in chicks (Van der Hel et al., 1992). In this trial, we also observed that chicks reared at low ambient temperature ate less feed and their body weight was significantly lower when compared to birds kept at 25°C. Noy & Sklan (1999) indicated a body weight decrease in chicks with no access to feed during 48 h post-hatching. Malheiros et al. (2000) also reported a lower body weight at 7 days of age in birds raised at low environmental temperature.

Nitsan (1995) verified that the pancreas and small intestine/body weight ratio increased 4 times and the liver/body weight ratio increased twice during the first week of life. Studies with chicks have shown that the components of the gastrointestinal tract increase in mass very rapidly after hatching; however, the liver maximum proportion of body mass does not occur until 6 to 8 days post-hatching (Sell, 1996). Deaton et al. (1969) found an increase in relative liver size for birds reared at the lower ambient temperature when compared to birds reared at the higher ambient temperature. Plavnik & Yahav (1998) reported that relative liver weight decreased in chickens kept at 35°C, possibly due to a decrease in metabolic needs. Our results revealed that the relative liver weight of the birds reared at 20°C ambient temperature showed a significantly higher ratio (percent of the body weight) than birds brooded at the 25°C on the 7th day of age (Table 2).

Heart development seems to be dependent on rearing temperature at least during the first week post-hatching, since the relative weight of the heart was higher for the broiler chicks living at 20° C than for the birds living at 25° C or 35° C. Plavnik & Yahav (1998) observed that relative heart weights at 8 weeks of age increased significantly with decreasing environmental temperature. Yang & Siegel (1997) showed that both heart and lung weights relative to body weight decreased as the Leghorn chicks grew, and differences between selected and non-selected lines for antibody titers against sheep erythrocytes were observed before hatching for heart and post-hatching for lungs, suggesting a growth priority for the heart during late embryonic development, whereas lung development occurs after hatching. In the present experiment the heart demonstrated an inconsistent growth during the first week post-hatching, independent of temperature or age. The results in Table 2 show that the heart had a high relative weight in birds raised at cold temperatures, and this effect could be linked to the high metabolic demand, with increasing cardiac output to supply the oxygen demand.

Researchers have reported that energy and protein content in the yolk sac seems to be enough to maintain the chicks for three days after hatching (Sell et al., 1991; Reis et al., 1998; Uni et al., 1998). Our findings demonstrated that from day 1 to day 3 there was a dramatic reduction in the relative yolk sac weight irrespective of chick brooding temperature (Table 1). Moafi & Atikinson (1990) verified that yolk sac disappearance was not dependent on broiler chick fasting period. On the other hand, Nitsan et al. (1991) showed that yolk sac content contributes 50% and 40% of total energy and protein during the first day post-hatch and 2% and 6% on the fourth day of life, respectively. Baião (1994) also reported that chicks fed 24, 48 and 72 hours after hatching showed a similar decrease in yolk sac weight. Thus, these data indicate that the absorption of the yolk sac content seems to be independent of rearing temperature and fasting period.

The bursa of Fabricius development was not affected (p>0.05) by environmental brooding temperature. Phelps et al. (1987) observed that the bursa does not mature until 5 or 6 weeks of age, and therefore early temperature variation may have no real impact on bursa weight. However, Corless & Sell (1999) verified that the bursa of Fabricius weight was adversely affected by delaying access to feed for 30 h post-hatch.

Environmental temperature could be an important factor for linear bone growth. Leeson & Caston (1993) reported that high environmental temperature was able to induce a 10% increase in shank length of Leghorn pullets at 14 weeks of age. Other studies have demonstrated that high environmental rearing temperature reduces tibia and humerus weight (Yalçin et al., 1996) and long bone growth (Bruno et al., 2000) in broiler chickens. In the present study, we found that environmental temperature did not affect (p>0.05) tibia or femur width; however, the bone weight and length of chicks reared at 20°C were lower when compared with birds reared at 25 and 35°C (Table 3).

These results indicate that a rearing environmental temperature of 20°C during the first seven days post-hatching decreases tibia development and femur weight and length, and reduces chicks body weight.

Table 1 – *Mean values and analysis of variance for the effects of environmental rearing temperature (TP) and age (AG) on body weight, and relative visceral weight (expressed as percentage of body weight) of broiler chicks. Each value represents the mean ± SEM (n=10).*

	Body weight (g)	Liver (%)	Heart (%)	Yolk (%)	Bursa Fabricius (%)	Gizzard (%)
Temperature (ºC)						
20	65.79^{b} (2.93)	4.54 (0.10)	1.00 (0.01)	0.97 (0.15)	0.24 (0.01)	6.79^{a} (0.12)
25	75.53^{a} (2.84)	4.37 (0.09)	0.86 (0.02)	0.98 (0.13)	0.22 (0.01)	6.16^{b} (0.11)
35	70.40^{b} (2.49)	4.28 (0.09)	0.83 (0.02)	0.99 (0.12)	0.22 (0.01)	6.57^{a} (0.11)
Age (days)						
1	44.74^{d} (1.29)	4.27 (0.13)	0.86 (0.04)	3.08^{a} (0.20)	0.14 (0.01)	7.10^{a} (0.21)
2	49.93^{d} (1.65)	4.24 (0.12)	0.84 (0.02)	1.37^{b} (0.13)	0.16 (0.01)	7.11^{a} (0.14)
3	60.34^{c} (1.36)	4.75 (0.19)	0.93 (0.03)	0.92^{c} (0.06)	0.22 (0.01)	6.78^{ab} (0.16)
4	66.63^{c} (2.11)	4.45 (0.11)	0.98 (0.03)	0.66^{c} (0.06)	0.29 (0.01)	6.64^{ab} (0.13)
5	80.89^{b} (2.14)	4.47 (0.10)	0.96 (0.03)	0.48^{c} (0.07)	0.30 (0.02)	6.21^{bc} (0.10)
6	92.41^{a} (1.73)	4.14 (0.18)	0.86 (0.02)	0.20^{d} (0.04)	0.22 (0.01)	5.81^{c} (0.10)
7	98.94^{a} (3.63)	4.50 (0.17)	0.88 (0.03)	0.16^{d} (0.05)	0.25 (0.01)	5.90^{c} (0.20)
Source of variation						
TP	**	*	**	NS	NS	**
AG	**	NS	**	**	**	**
TP x AG	NS	**	**	NS	**	NS

a-d - Means within a column for each variable with no common superscript differ significantly.
NS - Not significant (p>0.05).
** Significant at p<0.05.*
*** Significant at p<0.01.*

Table 2 *- Interaction between environmental rearing temperature and age on liver, heart and bursa of Fabricius relative weights of broiler chicks. Each value represents the mean ± SEM (n=10).*

Parameter	Temperature (°C)	Age (days)						
		1	2	3	4	5	6	7
Liver (%)	20	4.36^{Aab} (0.12)	3.85^{Ab} (0.17)	4.69^{Aab} (0.31)	4.61^{Aab} (0.22)	4.47^{Aab} (0.16)	4.73^{Aab} (0.30)	5.07^{Aa} (0.36)
	25	4.1^{Aa} (0.35)	4.2 7^{Aa} (0.23)	4.86^{Aa} (0.25)	4.33^{Aa} (0.12)	4.74^{Aa} (0.20)	4.36^{Aa} (0.30)	3.97^{Ba} (0.24)
	35	4.33^{Aab} (0.14)	4.56^{Aa} (0.20)	4.71^{Aa} (0.42)	4.40^{Aa} (0.25)	4.20^{Aab} (0.10)	3.31^{Bb} (0.14)	4.46^{ABa} (0.19)
Heart (%)	20	0.98^{Aab} (0.06)	0.83^{Ab} (0.03)	1.06^{Aa} (0.05)	1.08^{Aa} (0.05)	1.07^{Aa} (0.03)	1.00^{Aab} (0.05)	1.02^{Aab} (0.05)
	25	0.86^{Abab} (0.05)	0.77^{Ab} (0.03)	0.90^{ABab} (0.04)	0.96^{ABa} (0.04)	0.84^{Bab} (0.04)	0.86^{Abab} (0.03)	0.83^{ABab} (0.06)
	35	0.74^{Bb} (0.05)	0.93^{Aa} (0.03)	0.84^{Bab} (0.05)	0.88^{Bab} (0.06)	0.95^{ABa} (0.03)	0.73^{Bb} (0.04)	0.79^{Bab} (0.04)
Bursa of	20	0.13^{Ac} (0.01)	0.13^{Bc} (0.01)	0.28^{Aab} (0.01)	0.28^{Aab} (0.03)	0.35^{Aa} (0.02)	0.25^{Ab} (0.02)	0.24^{Ab} (0.04)
Fabricius (%)	25	0.14^{Ad} (0.01)	0.16^{ABbc} (0.01)	0.23^{ABa} (0.01)	0.31^{Aa} (0.02)	0.27^{Aab} (0.02)	0.20^{Abcd} (0.04)	0.26^{Aab} (0.03)
	35	0.15^{Ad} (0.02)	0.18^{Acd} (0.01)	0.17^{Bcd} (0.01)	0.28^{Aab} (0.03)	0.29^{Aa} (0.04)	0.21^{Abcd} (0.02)	0.24^{Aabc} (0.02)

A-B - Means within a column with no common superscript differ significantly ($p<0.01$).
a-d - Means within a row with no common superscript differ significantly ($p<0.01$).

Table 3 – *Mean values and analysis of variance for the effects of environmental rearing temperature (TP) and age (AG) on tibia and femur weight, length, and width of broiler chicks. Each value represents the mean ± SEM (n=10).*

	Bone weight (g)		Length (mm)		Width (mm)	
	Tibia	Femur	Tibia	Femur	Tibia	Femur
Temperature (ºC)						
20	0.17^{b} (0.01)	0.12^{b} (0.01)	31.38^{b} (0.31)	23.35^{b} (0.24)	1.90 (0.03)	1.88 (0.04)
25	0.20^{a} (0.01)	0.14^{a} (0.01)	32.67^{a} (0.35)	24.15^{a} (0.28)	1.91 (0.03)	1.92 (0.04)
35	0.19^{a} (0.01)	0.13^{ab} (0.01)	32.48^{a} (0.32)	23.97^{a} (0.23)	1.91 (0.03)	1.91 (0.04)
Age (days)						
1	0.11^{f} (0.01)	0.07^{f} (0.01)	28.95^{d} (0.14)	21.46^{d} (0.16)	1.66^{c} (0.02)	1.63^{cd} (0.01)
2	0.13^{ef} (0.01)	0.09^{e} (0.01)	29.68^{d} (0.20)	22.11^{d} (0.15)	1.62^{c} (0.02)	1.59^{d} (0.02)
3	0.14^{de} (0.01)	0.11^{de} (0.01)	31.41^{c} (0.20)	23.50^{c} (0.14)	1.84^{b} (0.02)	1.83^{b} (0.02)
4	0.16^{d} (0.01)	0.12^{d} (0.01)	31.50^{c} (0.22)	23.08^{c} (0.18)	1.80^{b} (0.02)	1.73^{bc} (0.04)
5	0.21^{c} (0.01)	0.16^{c} (0.01)	33.04^{b} (0.24)	24.39^{b} (0.25)	2.09^{a} (0.03)	2.13^{a} (0.04)
6	0.25^{b} (0.01)	0.18^{b} (0.01)	34.94^{a} (0.28)	25.92^{a} (0.19)	2.14^{a} (0.02)	2.17^{a} (0.03)
7	0.28^{a} (0.01)	0.20^{a} (0.01)	35.72^{a} (0.26)	26.29^{a} (0.27)	2.18^{a} (0.03)	2.26^{a} (0.04)
Source of variation						
TP	**	**	**	**	NS	NS
AG	**	**	**	**	**	**
TP x AG	NS	NS	NS	NS	NS	NS

a-f - Means within a column for each variable with no common superscript differ significantly.
NS - Not significant (p>0.05).
** Significant at p<0.01.

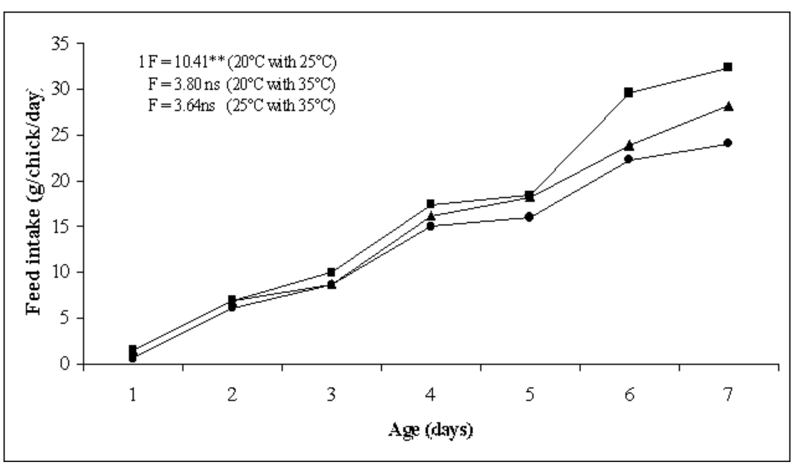

***Figure 1 -** Feed intake (g/chick/day) of broiler chicks reared at different environmental temperatures, 20°C (—●—); 25°C (—■—) and 35°C (—▲—) , during the first week post-hatching.*
1F - value for regression lines identical.

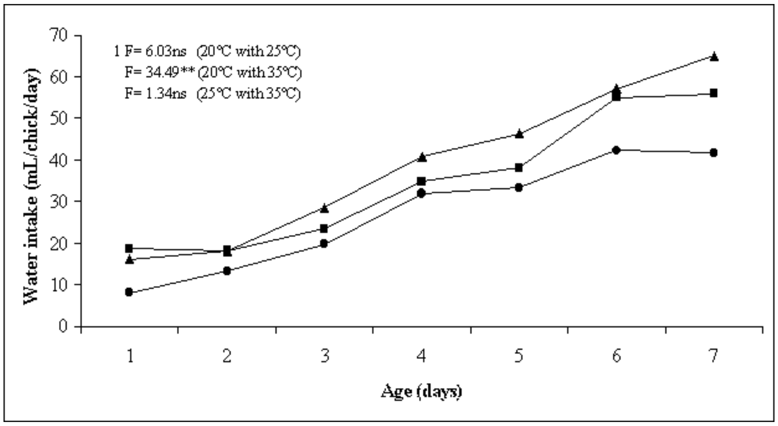

Figure 2 - *Water intake (mL/chick/day) of broiler chicks reared at different environmental temperatures, 20°C (—●—); 25°C (—■—) and 35°C (—▲—), during the first week post-hatching.*
1F - value for regression lines identical.

REFERENCES

Baião NC Efeito do jejum entre o nascimento e o alojamento de pintos sobre o desempenho do frango e digestibilidade da ração. Belo Horizonte, Escola de Veterinaria da UFMG; [Ph.D. Thesis], Belo Horizonte, MG, 1994; 123p.

Bruno LDG, Furlan RL, Malheiros, EB, Macari M. Influence of early quantitative food restriction on long bone growth at different environmental temperatures in broiler chickens. British Poultry Science 2000; 41:389-394.

Corless AB, Sell JL. The effects of delayed access to feed and water on the physical and functional development of the digestive system of young turkeys. Poultry Science 1999; 78:1158-1169.

Deaton JW, Reece FN, McNally EH, Tarver WJ. Liver, heart and adrenal weights of broilers reared under constant temperatures. Poultry Science 1969; 48:283-288.

Graybill FA. An introduction to linear statistical models. New York McGraw-Hill, v I 1961; 463 p.

Kirk S, Emmans GC, McDonald R, Arnot D. Factors affecting the hatchability of eggs from broiler breeders. British Poultry Science 1980; 21:37-53.

Leeson S, Caston LJ. Does environmental temperature influence body weight:shank length in Leghorn pullets? Journal of Applied Poultry Research 1993; 2:245-248.

Malheiros RD, Moraes VMB, Bruno LDG, Malheiros EB, Furlan RL, Macari M. Environmental temperature and cloacal and surface temperatures of broiler chicks in first week post-hatch. Journal of Applied Poultry Research 2000; 9:111-117.

Mather CM, Laughlin KF. Storage of hatching eggs: the effect on total incubation period. British Poultry Science 1976;17:471-479.

Mayes FJ, Takeballi MA. Storage of the eggs of the fowl (Gallus domesticus) before incubation: a review. World's Poultry Science Journal 1984; 40:131-140.

Mickelberry WC, Rogler JC, Stadelman WJ. The influence of dietary fat and environmental temperature upon chick growth and carcass composition. Poultry Science 1966; 45:313-321.

Moafi M, Atikinson JL. The effect of availability on spare yolk utilization by broiler chicks. Poultry Science 1990; 69:95 (Abstr.).

Nitsan Z, Bem-Avrahan G, Zoref Z, Nir I. Growth and development of the digestive organs and some enzymes in broiler chicks after hatching. British Poultry Science 1991; 32:515-523.

Nitsan Z. The development of digestive tract in post-hatched chicks. In: 10th European Symposium on Poultry Nutrition, Antalya, Turkey. Proceedings. 1995; pp.21-28.

North MO, Bell DB. Commercial Chicken Production Manual. 4th ed. Van Nostrand Reinhold, New York, N.Y. 1990.

Noy Y, Sklan D. Energy utilization in newly hatched chicks. Poultry Science 1999; 78:1750-1756.

Phelps PVF, Edens FW, Christensen VL. The posthatch physiology of the turkey poult I. Growth and development. Comparative Biochemistry Physiology 1987; 86 A:739-743.

Plavnik I, Yahav S. Effect of environmental temperature on broiler chickens subjected to growth restriction at an early age. Poultry Science 1998; 77:870-872.

Reis LH, Gama LT, Chaveiro Soares M. Effects of short storage conditions and broiler breeder age on hatchability, hatching time, and chick weights. Poultry Science 1998; 76:1459-1466.

SAS Institute SAS® (Statistical Analysis System). User's guide:Statistics. SAS Institute Inc., Cary, NC 2000.

Sell JL, Angel CR, Piquer FJ, Mallarino EG, Al-Batshan HA. Developmental patterns of selected characteristics of the gastrointestinal tract of young turkeys. Poultry Science 1991; 70:1200-1205.

Sell JL. Physiological limitations and potential for improvement in gastrointestinal tract function of poultry. Journal of Applied Poultry Research 1996; 5:96-101.

Uni Z, Ganot S, Sklan D. Posthatch development of mucosal function in the broiler small intestine. Poultry Science 1998; 77:75-82.

Van der Hel W, Verstergen MWA, Henken A M, Brandma HA. The upper critical temperature in neonatal chicks. Poultry Science 1991; 70:1882-1887.

Van der Hel W, Verstergen MWA, Pijls L, Van Kampen M. Effect of two day temperature exposure of neonatal broiler chicks on growth performance and body composition during two weeks at normal conditions. Poultry Science 1992; 71:2014-2021.

Yalçin S, Ozkan S, Settar P, Tolon B. Influence of ambient temperature and genotype on bone parameters and incidence of leg disorders of male and female broilers. In: XX World's Poultry Congress, New Delhi, India, vol. II, Proceedings 1996; pp.577-580.

Yang A, Siegel PB. Late embryonic and early posthatch growth of heart and lung in White Leghorn lines of chickens. Growth Development & Aging 1997; 61:119-126.