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Effect of water restriction and sodium levels in the drinking water on broiler performance during the first week of life

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ABSTRACT - A trial was carried out to evaluate the performance of female ROSS 308 broilers, from 1 to 21 days of age, submitted to 20% of water restriction (WR) or *ad libitum* water and four different sodium levels by adding NaCl to the drinking water (0, 150, 300, or 450 ppm) from 1 to 7 days of age. A control group, with four replications (rep), housed one day before the beginning of the experiment, was used as reference for WR calculation. Two commercial diets where fed from 1 to 7 days and from 8 to 21 days to all birds. The chicks were raised in battery cages. A randomized complete design, in a 2 × 4 factorial arrangement, with four replications/treatment and 14 birds/replicate, was applied. Feed intake (FI), weight gain (WG) and feed conversion ratio (FCR) in the first week were influenced by WR. During this period, there was a significant interaction between factors, showing that in chicks not submitted to WR, water consumption increased with sodium levels. Also, at 7 days of age, excreta and carcass dry matter contents were higher in WR animals. During the second week, WR continued to affect FI, but the previously WR broilers presented better FCR, higher WG, and water consumption than the non-WR broilers. Mortality was not affected either by WR or sodium levels. At 21 days of age, except for FI, no significant differences were observed between restricted and non-restricted birds. Sodium levels up to 450 ppm were not toxic to the birds. These results suggested that if optimal conditions are offered, broilers quickly overcome unfavorable circumstances to their growth.

Key Words: broilers, compensatory growth, minerals, water

Efeito da restrição hídrica e dos níveis de sódio da água de bebida na primeira semana sobre o desempenho de frangos de corte

RESUMO - Avaliou-se o desempenho de frangos de corte, fêmeas Ross 308, até os 21 dias de idade submetidos à restrição hídrica de 20% ou água à vontade e quatro níveis de sódio, por meio da adição de NaCl na água (0, 150, 300 ou 450 ppm) na primeira semana de vida. Um grupo controle, com quatro repetições, alojado um dia antes do início do experimento, foi usado como referência no cálculo da restrição hídrica. Foram fornecidas duas dietas comerciais nos períodos de 1 a 7 dias e de 8 a 21 dias. As aves foram criadas em baterias metálicas, distribuídas em esquema fatorial 2 × 4, com 4 repetições de 14 aves por tratamento. O consumo de ração, o ganho de peso e a conversão alimentar dos pintos aos 7 dias de idade foram influenciados pela restrição hídrica. Nesse período, houve interação entre os fatores, comprovando que os pintos que não sofreram restrição hídrica aumentaram o consumo de água com o aumento dos níveis de sódio na água. Também aos 7 dias de idade, a matéria seca das excretas e das carcaças foi maior nos animais em restrição hídrica. Na segunda semana, o efeito da restrição hídrica anterior continuou prejudicando o consumo de ração, mas as aves submetidas previamente à restrição apresentaram melhor conversão alimentar, maior ganho de peso e maior consumo de água em relação àquelas mantidas com consumo à vontade. A mortalidade não foi afetada por qualquer dos fatores analisados. Aos 21 dias de idade, com exceção do consumo de ração, as respostas para os demais parâmetros de desempenho foram iguais entre aves sob restrição e sem restrição hídrica. Valores de até 450 ppm de sódio não são tóxicos aos animais. Em condições adequadas, frangos de corte conseguem reverter rapidamente circunstâncias adversas a seu crescimento.

Palavras-chave: água, aves, crescimento compensatório, minerais

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Introduction

Water is considered an essential nutrient as it is involved in every metabolic function of the body. It represents about 70% of body weight, and its body content decreases per weight unit as the animal ages, despite the increase in water consumption. Water turnover rate is high compared to that of other compounds (Leeson & Summers, 1997).

Water intake is a determinant of broiler performance, as it influences bird health and welfare status (Brooks, 1994; Soares et al., 2007). Thus, water availability is essential to achieve efficient broiler production. However, there are many factors that may influence water intake by the birds, such as the intake of feed and minerals (Leeson & Summers, 1997), water quality (Brooks, 1994; Manning et al., 2007) as well as its availability and temperature (Teeter et al., 1987).

Studies have demonstrated the influence of water sodium content on layer production (Balnave, 1993; Watkins et al., 2005) and egg quality (Damron, 1998). The maximum acceptable level is 50 ppm, as higher values negatively affect performance parameters and may cause intoxication, whose main symptoms are marked weakness, generalized paralysis, violent convulsions, renal tubule degeneration, hypertension linked to vascular diseases, and death (Waggoner & Good, 1984).

The amount of water intake is important, as it has a direct influence on feed intake (Viola et al., 2009; Soares et al., 2007). Considering the high metabolic rate of modern commercial broilers strains, water can be one of the means used by the birds for thermoregulation (Marks, 1985), and therefore it should be provided continuously to allow full development of the birds.

The delay in housing of day-old chicks results in reduced daily gain that is not recovered until market age, as well as higher mortality (Vieira & Moran, 1999). The main negative effect of delaying feed and water supply to broiler chicks is the reduction in the size of the organs of the digestive tract (Noy & Sklan, 1997). Fasting early in the life of chicks has severe consequences later, impairing body weight and muscle development due to changes in the proliferation of satellite cells (Halevy et al., 2000). Therefore, it is essential to make water and feed available to the newly-hatched chicks as soon as possible.

The objective of the present study was to evaluate the effects of water restriction and supplementation of four sodium levels (0, 150, 300, and 450ppm) in the drinking water during the first seven days of life on the performance of broilers up to 21 days of age. The presence or absence of compensatory weight gain, the relation between sodium level and water availability, and harmful effects of sodium levels were assessed.

Material and Methods

A total number of 504 one-day-old female Ross 308 broilers were randomly distributed in 36 cages, with 14 birds per cage, and reared up to 21 days of age in the same environment, with continuous light and controlled environmental temperature, according to the specifications of the genetic line manual (Agroceres Ross, 2000).

Different combinations of water restriction and sodium levels added to the drinking water were evaluated. In four combinations, birds were offered water *ad libitum* (no water restriction), and the drinking water contained four graded levels of sodium (0, 150, 300, or 450 ppm). In another four combinations, birds were submitted to 20% water restriction, and received the same sodium levels in the drinking water as described above.

A control group (n=56), with four replications of 14 chicks of the same genetic strain and reared under the same environmental conditions as the experimental birds, was housed one day before, and was used as reference to calculate the water restriction. Their daily water consumption was calculated, and 20% less water was offered to the experimental birds.

Water was obtained from the public water network, and was stored in four 90-L water tanks. Sodium levels were adjusted to achieve the proposed levels in each water tank by adding sodium chloride. Samples from each tank were analyzed for total sodium content (Standard Methods, 1999) by the Laboratório de Análises de Solo, of the Universidade Federal do Rio Grande do Sul, in Brazil, and yielded the following results: 17 ppm total sodium in the water with no addition of sodium chloride, and 191, 348, and 515 ppm total sodium in the water from the tanks with 150, 300, and 450 ppm sodium chlorine addition, respectively.

Feed was offered *ad libitum* during the entire experimental period. Water was offered *ad libitum*, with no sodium chloride addition, from seven until the end of the experimental period, at 21 days of age. Commercial mash feeds were used in the pre-starter and starter periods, or from 1-7 and 8-21 days of age, respectively. These feeds were based on corn and soybean meal, and purchased in the local market. All birds were fed the same diet. According to the analyzed results, the pre-starter diet contained, per kg, 23.4% crude protein (CP), 1.24% calcium (Ca), 0.76% total phosphorus (Ptotal), 0.21% sodium (Na), and 3,050 kcal apparent metabolizable energy (AME). The starter feed contained 20.1% CP, 1.27% Ca, 0.83% Ptotal, 0.19% Na, and 3,100 kcal AME/kg.

Feed intake (g), body weight (g), daily weight gain (g), feed conversion ratio (g/g), and water intake (mL) were evaluated weekly. At the end of each week, two birds per replicate were sacrificed to evaluate relative organ weight, including heart weight (W_{HEA}), liver weight (W_{LIV}), small + large intestine weight (W_{INT}), and proventriculus +gizzard weight (W_{PR+G}), which were expressed as a percentage of bird live weight at sacrifice. Complete carcasses (including organs) were frozen for subsequent dry matter determination. Sacrifice and organ collection procedures complied with the norms established in the Guide for Care and Use of Agricultural Animals in Research and Teaching (1999).

Excreta were collected for dry matter determination during two periods: from days 5-7, and from days 8-10. Excreta were collected daily three hours after feed and water supply, when the trays were cleaned, according to the recommendations of Smith et al. (2000).

Data were analyzed considering three periods (period 1: 1-7 days, period 2: 7-14 days, and period 3: 14-21 days) for the observation of possible compensatory growth, which occurs immediately after the restriction period (Yu & Robinson, 1992). Data of the entire experimental period (1-21 days of age) were also analyzed. Responses were submitted to analysis of variance using a randomized complete experimental design, with the treatments distributed in a 2 × 4 factorial arrangement. There were four replications for each combination of factors, except for the levels of 300 and 450 ppm sodium – both for birds with no water restriction and those submitted to 20% water restriction – where five replications per treatment were used.

Data were analyzed using a mixed model with repeated measurements in time by the MIXED (mixed models) procedure of the SAS® (Statistical Analysis System) statistical package, version 8.2 for Windows®. The covariance matrix was chosen using the Akaike information criterion (Wolfinger, 1993) to detect the effects of the main causes of variation (water restriction, sodium level, and period), as well as their interactions (Littel et al., 2000). Means were calculated using LSMEANS, and were compared by probability of difference (PDIFF) by the Student t-test at 5% significance level, except for the water restriction vs. sodium level interaction in period 1, to which 10% significance was applied.

Results and Discussion

The effect of period was highly significant (P<0.0001) for all performance parameters, which was expected, as the birds were growing.

The performance results of period 1 (1 to 7 days) show a significant interaction between the factors water restriction and sodium levels (P<0.10) for water intake at 10% significance level (Table 1). Water intake presented significant variation only by the birds not submitted to water restriction, as the others were not able to adjust their intake (Table 2). The increase in water intake related to sodium ingestion is well known, and was previously reported in the literature (Borges et al., 1999; Smith et al., 2000; Watkins et al., 2005). At seven days of age, weight gain decreased and the feed conversion ratio worsened (P<0.05) when the chicks were submitted to water restriction. However, neither ANOVA nor the analyses of regression showed any significant effect of sodium levels,

Table 1 - Feed intake, body weight, body weight, feed conversion ratio (FCR), and water intake of female broilers submitted or not to water restriction and different sodium levels in the drinking water

Performance parameter	Water restriction		Sodium level in the water				Restriction vs. sodium level	CV (%)
	No	Yes	0 ppm	150 ppm	300 ppm	450 ppm		
			1-7 days					
Feed intake (g)	135A	117A	128a	127a	124a	126a	ns	4.5
Body weight at 7 days (g)	177A	141A	157a	160a	160a	158a	ns	5.5
Weight gain, 1-7 days (g)	140A	103B	120a	123a	123a	120a	ns	7.4
FCR (g:g)	0.986A	1.141B	1.082a	1.063a	1.024a	1.061a	ns	6.8
Water intake (mL)	328A	259B	279	298	294	304	0.10	3.6
			7-14 days					
Feed intake (g)	379A	354B	369a	367a	371a	358a	ns	4.9
Body weight at 14 days (g)	442A	416A	432a	430a	429a	425a	ns	4.1
Weight gain, 7-14 days (g)	265B	275A	275a	270a	269a	267a	ns	6.3
FCR (g:g)	1.476B	1.309A	1.344a	1.369a	1.386a	1.345a	ns	6.7
Water intake (mL)	643B	690A	654a	668a	651a	692a	ns	6.2

Means followed by different capital letters on the lines relative to the factor water restriction (columns 1 and 2) are different by the LSmeans test (P<0.05). Means followed by different small letters on the lines relative to the factor sodium level (columns 3 to 6) are different by the LSmeans test (P<0.05).

demonstrating the lack of influence of sodium levels up to 450ppm on broiler performance. Similar performance responses under water restriction conditions were previously reported in the literature (Kellurup et al., 1965).

NRC (1994) information also indicated a positive relation between feed intake and water consumption. According Nilipour & Butcher (1998), the loss of metabolic efficiency and reduced feed intake *per se* harm production parameters as a consequence of water restriction, resulting in growth stunting and worse feed conversion ratio in birds under water restriction. Viola et al. (2009) also observed a negative linear effect of 10 to 40% water restriction on the broiler feed conversion ratio; however, this effect did not increase with restriction level, i.e., the worst effect was due to water restriction itself, regardless the level.

On the other hand, in the present study, excessive sodium intake did not affect performance parameters or cause any of the intoxication signs as previously described (Waggoner & Good, 1984). Some mortality was observed during Period 1, but only in the treatments no water restriction/300ppm Na (2 birds), no water restriction/450 ppm Na, and water restriction/450 ppm Na (1 bird each); however, the cause of mortality was not related to the studied factors. Watkins et al. (2005), using up to 500 mg/L sodium levels in the drinking water, also did not observe any performance reduction or increase in mortality.

The increase in water intake may be explained by the higher osmotic pressure, which activates the rennin-angiotensin system. The rennin released by the kidneys converts angiotensionogen into angiotensin II, which stimulates the thirst regulating center in the brain, promoting an increase in water ingestion (Sturkie, 1986).

Bird performance during the week after being submitted to water restriction and different sodium levels in the drinking water did not indicate any interaction between these factors. The significant differences in the performance results obtained at the end of the second week were due to the impact of water restriction during the previous week. Feed intake was negatively influenced by restriction, but there was a compensatory effect on water intake, as the birds submitted to water restriction in the previous week ingested more water than those offered water *ad libitum*. Weight gain and the feed conversion ratio were also better in the birds submitted to restriction, reflecting a period of recovery.

The results obtained in the week after the treatments were applied may be explained by the concept of compensatory gain, which occurs when a delay in bird growth due to feed restriction during the first stages of life is compensated by a higher weight gain rate as compared to birds of the same age that were not submitted to restriction (Lippens et al., 2002). One of the reasons for this phenomenon is that animals under feed restriction adapt their metabolic requirements, reducing organ weight and total energy requirement. After feed restriction, due to the smaller size of the organs, the consumed energy allows higher growth rate of the muscle and adipose tissue

Table 2 - Details of the effects of the interactions between water restriction and sodium levels on the water intake of 1- to 7-day-old broilers

Sodium level in the water (Na)	No restriction (mL)	With restriction (mL)
0	298aB	259A
150	336bcB	259A
300	329bB	259A
450	348cB	259A

Means followed by different small letters in the same columns are different by the LSmeans test (P<0.05). Means followed by different capital letters on the same lines are different by the LSmeans test (P<0.05).

Table 3 - Feed intake, body weight, weight gain, feed conversion ratio (FCR), and water intake of 14- to 21-old female broilers submitted or not to water restriction and different sodium levels in the drinking water during the first week of life

	Feed intake (g)	Body weight at 21 days (g)	Weight gain 14-21 days (g)	FCR (g:g)	Water intake (mL)
			Water restriction		
Yes	739a	810a	368b	2.061b	1067b
No	697b	798a	383a	1.748a	1153a
			Sodium level in the drinking water		
0 ppm	733a	815a	383a	1.935a	1159a
150 ppm	717a	805a	375a	1.924a	1121a
300 ppm	711a	797a	368a	1.949a	1048a
450 ppm	709a	800a	375a	1.900a	1112a
Restriction × sodium level	ns	ns	ns	ns	ns
CV (%)	9.1	5.4	9.3	12.4	9.6

Means followed by different letters in the same column are different (P<0.05) by the LSmeans test.

(Leeson & Zumbair, 1997). Researchers such as Plavnik & Hurwitz (1985, 1988) observed an improvement in the feed conversion ratio when there was compensatory gain. The results of the present study are consistent with the findings of Lippens et al. (2002), who found differences in the feed conversion ratio only at feed restriction levels higher than 20%.

The performance results of the third week (Table 4) indicated higher weight gain and better feed conversion ratio, in addition to higher water intake, for the birds previously submitted to water restriction (P<0.05). Feed intake was higher (P<0.05) in the group that was not water-restricted.

When the entire experimental period was evaluated (1 to 21 days), it was observed that, despite having significantly lower feed intake during the first week (Table 5), the birds submitted to water restriction presented better feed conversion ratio during the second and third weeks, reaching the same body weight at 21 days of age as those offered water *ad libitum* (Table 4). The high sodium levels fed during the first week did not influence subsequent bird performance. Some published studies show that the subsequent development of birds submitted to feed fasting or housing delay is harmed (Noy & Sklan, 1997; Vieira & Moran, 1999; Halevy et al., 2000). Although those studies were also carried out under experimental conditions, special aspects of the present study, such as rearing the birds in cages, number of hours of light, ratio of birds per drinker and feeder, and environmental conditions, may have determined the observed responses. However, it must be noted that the compensatory phenomenon was evident in the present study, indicating the remarkable recovery capacity of the birds, provided they are submitted to adequate management, environment, nutrient supply, etc. On the other hand, we recognize that, in the field, it is not always possible to provide optimal conditions, and that health challenges tend to be greater, causing slower growth rates, which often has economic impacts. Mortality during the entire experimental period was low, only 2%, and uniformly distributed among the different combinations of water restriction and sodium levels.

Table 4 - Feed intake, weight gain, feed conversion ratio (FCR), and water intake of 1- to 21-old female broilers submitted or not to water restriction and different sodium levels in the drinking water during the first week of age

	Feed intake (g)	Weight gain 1-21 days (g)	FCR (g:g)	Water intake (mL)
		Water restriction		
No	1163a	773a	1.507a	2038a
Yes	1118b	761a	1.469a	2102a
		Sodium level in the drinking water		
0 ppm	1156a	778a	1.487a	2092a
150 ppm	1142a	768a	1.491a	2087a
300 ppm	1132a	760a	1.492a	1994a
450 ppm	1131a	762a	1.484a	2108a
Restriction × sodium level	ns	ns	ns	ns
CV (%)	4.2	5.7	4.2	6.2

Means followed by different letters in the same column are different (P<0.05) by the LSmeans test.

Table 5 - Organ weight relative to body weight of female broilers submitted or not to water restriction and different sodium levels in the drinking water during the first week of life

	Heart	Liver	Intestine	Proventriculus+gizzard
		%		
		7 days		
No restriction	0.82	3.99	9.07	6.72b
With restriction	0.84	4.38	9.84	7.50a
CV (%)	27.1	20.5	20.5	18.4
		14 days		
No restriction	0.87	3.68	5.46	4.43
With restriction	0.89	3.62	5.46	4.56
CV (%)	16.3	11.3	11.5	12.0
		21 days		
No restriction	0.80	2.69	4.53	3.56
With restriction	0.78	2.74	4.54	3.74
CV (%)	16.9	11.2	10.8	12.4

Means followed by different letters in the same column are different (P<0.05) by the LSmeans test.

Considering the analysis of relative organ weight (Table 5), at the end of the first week, there was a proportional increase only of the proventriculus+gizzard (P<0.05) in the birds under water restriction. The growth of the digestive tract during the period of water restriction was possibly prioritized over body growth. Susbilla et al. (1994) submitted 5- to 11-day-old broilers to feed restriction and also observed this phenomenon. At the end of the second and the third weeks, relative organ weight was not different between water-restricted and non-restricted birds. The priority for organ growth may have contributed to the capacity of the bird to compensate body growth after water restriction by increasing the efficiency of the digestive processes. According to Lilja et al. (1985), the increase in digestive organ size improves bird capacity to ingest and digest feed. Sodium levels did not affect organ weight in any of the evaluated ages.

Water restriction significantly influenced the dry matter content of the excreta and carcasses of 7-day-old birds (Table 6), but did not affect these parameters when birds were 10 days of age, no longer submitted to water restriction. These results are conflicting with the findings of Ogunji et al. (1982), Maiorka et al. (1998), and Smith et al. (2000), who did not find any relation between water intake and excreta humidity. According to Smith et al. (2000), some alterations occur in the water balance of birds that ingest high sodium levels. The reasons are not clear, although water loss through respiration may be a contributing factor. However, in the present experiment, no significant relation between sodium levels and excreta dry matter content was observed.

Table 6 - Dry matter percentage in the carcass and excreta of female broilers submitted or not to water restriction and different sodium levels in the drinking water during the first week of age

	Excreta 5-7 days of age	Excreta8-10 days of age %	Carcass 7 days of age
	Water restriction		
No	23.28b	21.33a	25.64a
Yes	34.40a	21.07a	27.31b
	Sodium levels in the drinking water		
0	29.39a	21.04a	26.61a
150	28.74a	21.24a	26.10a
300	28.53a	21.27a	26.43a
450	28.68a	21.23a	26.75a
Restriction × sodium level	ns	ns	ns
CV (%)	7.3	5.3	4.9

Means followed by different letters in the same column are different (P<0.05) by the LSmeans test.

Conclusions

Water restriction harms broiler performance during their first week of life, but the negative effects are reversed after water is fed *ad libitum*, allowing the birds to recover performance levels. When birds are submitted to water restriction during the first week of life, they present subsequent compensatory growth, as shown by their better performance during the second and third weeks of the experiment as compared to the birds offered water *ad libitum*. The addition of 450 ppm of sodium in the drinking water did not cause intoxication in the broilers.

Literature Cited

AGROCERES ROSS. **Manual de manejo de frangos de corte AgRoss**. Campinas: Melhoramento Genético de Aves S.A., 2000. 104p.

BALNAVE, D. Influence of saline drinking water on eggshell quality and formation. **World's Poultry Science Journal**, v.49, p.109-111, 1993.

BORGES, S.A.; ARIKI J.; SANTIN E. et al. Balanço eletrolítico em dieta pré-inicial de frangos de corte durante o verão. **Revista Brasileira de Ciência Avícola**, v.1, p.175-179, 1999.

BROOKS, P.H. Water – Forgotten nutrient and novel delivery system. Biotechnology in the Feed Industry. In: ALLTECH'S TENTH ANNUAL SYMPOSIUM, 10., 1994, Loughborough. **Proceedings...** Loughborough: Nottingham University Press, 1994. p.211-234.

DAMRON, B.L. Sodium chloride concentration in drinking water and eggshell quality. **Poultry Science**, v.77, p.1488-1491, 1998.

GUIDE FOR THE CARE AND USE OF AGRICULTURAL ANIMALS IN AGRICULTURAL RESEARCH AND TEACHING. Savoy: Federation of Animal Science Societies, 1999. 90p.

HALEVY, O.; GEYRA, A.; BARAK, M.Z. et al. Early posthatch starvation decreases satellite cell proliferation and skeletal muscle growth in chicks. **Journal of Nutrition**, v.130, p.858-864, 2000.

KELLURUP, S.U.; PARKER, J.E.; ARSCOTT, G.H. Effect of restricted water consumption on broiler chickens. **Poultry Science**, v.44, p.79-83, 1965.

LEESON, S.; SUMMERS, J.D. Ingredient evaluation and diet formulation. In: **Commercial poultry nutrition**. University Books, Guelph, 1997. p.100-170.

LEESON, S.; ZUMBAIR, A.K. Nutrition of the broiler chicken around the period of compensatory growth. **Poultry Science**, v.76, p.992-999, 1997.

LILJA, C.; SPERBER, I.; MARKS, H.I. Postnatal growth and organ development in Japanese quail selected for high growth rate. **Growth**, v.49, p.51-62, 1985.

LIPPENS, M.; HUYGHEBAERT, G.; DE GROOTE, G. The efficiency of nitrogen retention during compensatory growth of food-restricted broilers. **British Poultry Science**, v.43, p.669-676, 2002.

MAIORKA, A.; MAGRO, N.; BARTELS, H.A. et al. Different sodium levels and electrolyte balances in pre-starter diets for broilers. **Revista Brasileira de Ciência Avícola**, v.6, p.143-146, 2004.

MANNING, L.; CHADD, S.A.; BAINES, R.N. Key health and wealfare indicators for broiler production. **World's Poultry Science Journal**, v.63, p.46-62, 2007.

MARKS, H.L. Sexual dimorphism in early feed and water intake of broilers. **Poultry Science**, v.64, p.425-428, 1985.

NATIONAL RESEARCH COUNCIL - NRC. **Nutrient requirements of poultry**. 8.rev.ed. Washington, DC.: National Academy Press, 1994. 155p.

NILIPOUR, A.H.; BUTCHER, G.D. Water: The cheap, plentiful and taken for granted nutrient. **World Poultry**, v.14, p.26-27, 1998.

NOY, Y.; SKLAN, D. Posthatch development in poultry. **Journal Applied Poultry Research**, v.6, p.344-354, 1997.

OGUNJI, P.A.; BREWER, R.N.; ROLAND, D.A. et al. Effect of dietary sodium chloride, protein and strain difference upon water consumption and fecal moisture content of broiler breeder males. **Poultry Science**, v.62, p.2497-2500, 1982.

PLAVNIK, I.; HURWITZ, S. The performance of broiler chicks during and following a severe feed restriction at an early age. **Poultry Science**, v.64, p.348-355, 1985.

PLAVNIK, I.; HURWITZ, S. Early feed restriction in chicks: effect of age, duration and sex. **Poultry Science**, v.67, p.384-390, 1988.

SMITH, A.; ROSE, S.P.; WELLS, R.G. et al. Effect of excess dietary sodium, potassium, calcium and phosphorus on excreta moisture of laying hens. **British Poultry Science**, v.41, p.598-607, 2000.

SOARES, L.F.; RIBEIRO, A.M.L.; PENZ JR., A.M. Influência da restrição hídrica, durante a fase pré-inicial, no desempenho de frangos de corte. **Revista Brasileira de Zootecnia**, v.5 S, p.1579-1589, 2007.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER. **Spectrophotometer atomic absorption**. In: CLESCERI, L.S.; GREENBERG, A.E.; EATON, A.D. (Eds). 20.ed. Washington D.C.: American Public Health Association, 1998. p.4-91.

STATISTICAL ANALYSIS SYSTEM - SAS. **SAS (2001) User's guide**. Version 8.2. Cary: SAS Institute, 2001. 956p.

STURKIE, P.D. Kidneys, extrarenal salt excretion, and urine. In: STURKIE, P.D. (Ed.). **Avian Physiology**. New York: Springer-Verlag, 1986. p.359-382.

SUSBILLA, J.P.; FRANKEL, T.L.; PARKINSON, G. et al. Weight of internal organs and carcass yield of early food restricted broilers. **British Poultry Science**, v.35, p.677-685, 1994.

TEETER, R.G.; SMITH, M.O.; SANGIAH, S.A. et al. Efectos de consumo alimenticio y el periodo de ayuno sobre la temperatura corporal y sobrevivencia de aves estresadas por el calor. **Nutrition Reports International**, v.35, p.531-537, 1987.

VIEIRA, S.L.; MORAN JR., E.T. Effects of delayed placement and used litter on broiler yields. **Journal Applied Poultry Research**, v.8, p.75-81, 1999.

VIOLA, T.H.; RIBEIRO, A.M.L.; PENZ JR. A.M. et al. The Influence of Water Restriction on the Performance and Organ Development of Young Broilers. **Revista Brasileira de Zootecnia**, v.38, p.323-327, 2009.

WAGGONER, R.; GOOD, R. Water quality and poultry performance. In: VMA ANNUAL CONFERENCE, 1984, Pennsylvania. **Proceedings...** Pennsylvania: Pennsylvanian State University, 1984. 81p.

WATKINS, S.E.; FRITTS, C.A.; YAN, F. et al. The interaction of sodium chloride levels in poultry drinking water and the diet of broiler chickens. **Journal Applied Poultry Research**, v.14, p.55-59, 2005.