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Effect of oral dietary supplement for chicks subjected to thermal oscillation on performance and intestinal morphometry

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ABSTRACT. The aim of the study was to evaluate the efficacy of a nutritional formulation based on amino acids and vitamins supplemented in the drinking water for chicks in the first week of life subjected to thermal oscillation on performance, organ development and intestinal morphometry from 1 to 21 days. 640-male broiler chicks were distributed in a 2x2 factorial completely randomized design (with or without dietary supplementation and at comfort temperature or thermal oscillation). Chicks subjected to thermal oscillation presented worse performance ($p < 0.05$) than those under thermal comfort of 1 to 7, 1 to 14 and 1 to 21 days. Nutritional supplementation did not alter the performance ($p < 0.05$) of the birds, but resulted in a higher body weight ($p < 0.05$) regardless of the environmental thermal condition. At 7 days, chicks under thermal comfort had better intestinal morphometric parameters ($p < 0.05$), in relation to birds under thermal oscillation. In conclusion, the temperature oscillations caused negative consequences to the productive performance and the intestinal morphology of chicks for which dietary supplementation was not enough to mitigate the effects of the environmental challenge during the first week of life of the birds.

Keywords: broilers, weight gain, intestinal mucosa, ambient temperature, post-hatching.

Efeito de suplemento nutritivo oral em pintainhos submetidos à oscilação térmica sobre o desempenho e a morfometria intestinal

RESUMO. O objetivo do trabalho foi avaliar a eficácia de uma formulação nutricional à base de aminoácidos e vitaminas suplementadas na água de bebida de pintainhos na primeira semana de vida, submetidos à oscilação térmica sobre o desempenho produtivo, desenvolvimento de órgãos e morfometria intestinal de um a 21 dias. Foram utilizados 640 pintos de corte machos, distribuídos em um delineamento inteiramente casualizado em esquema fatorial 2x2 (com suplementação nutritiva oral ou não e em temperatura de conforto ou oscilação térmica). As aves submetidas à oscilação térmica apresentaram pior desempenho ($p < 0,05$) em relação às aves do grupo conforto térmico de um a sete, um a 14 e um a 21 dias. A suplementação nutritiva não alterou o desempenho ($p < 0,05$) das aves, mas resultou em maior peso dos órgãos ($p < 0,05$) independentemente da condição térmica ambiental. Aos sete dias, as aves em conforto térmico apresentaram melhores parâmetros morfométricos intestinais ($p < 0,05$), em relação às aves submetidas à oscilação térmica. Em conclusão, as oscilações de temperatura ocasionaram consequências negativas ao desempenho produtivo e à morfologia intestinal das aves na qual a suplementação nutritiva não foi suficiente para amenizar os efeitos do desafio ambiental na primeira semana de vida das aves.

Palavras-chave: frangos de corte, ganho de peso, mucosa intestinal, temperatura ambiente, pós-eclosão.

Introduction

The period immediately after hatching is crucial for the development of chicks due mainly to the morphophysiological events of the gastrointestinal tract (Boleli, Maiorka, & Macari, 2008; Roto, Kwon, & Ricke, 2016).

One of the important adaptations for the chick intestinal maturation is the source of nutrients, which during the embryonic period consisted mainly of protein and lipids of the yolk and which becomes exogenous and consists basically of carbohydrates. Ingestion of exogenous foods is accompanied by a rapid development of the gastrointestinal tract and associated organs to ensure the maximum assimilation rate of the ingested nutrients (Karasov & Douglas, 2013; Roto et al., 2016).

The gastrointestinal tract, more specifically the intestinal mucosa is the main site for multiple processes, such as digestion, nutrient metabolism, nutrient uptake, immunological recognition and development of immunological tolerance (Sommer & Backhed, 2013).

The functional element of the small intestine is the mucosa, which can be characterized as a nutrient-permeable layer (Oliveira, Marques, Gravena, & Moraes, 2008), composed of physical, chemical and microbiological components and acts as a selective barrier between tissues of the bird and its luminal environment (Yegani & Korver, 2008).

The development of the intestinal mucosa occurs by cytological processes where totipotent cells in constant renewal and proliferation differentiate up and migrate from the crypt and other regions along the villi and are extruded at the apex of the villi, causing an increase in villus volume, depth of crypts and enzymatic activity of the mucosa (Uni, Platin, & Sklan, 1998).

According to Noy and Sklan (1997), the adequate uptake of nutrients in the first days of the chick's life is directly related to functional maturation of the intestine, involving morphological and physiological changes and providing increase in digestion and absorption surface area (Sklan, 2001; Tarachai & Yamauchi, 2000).

In addition, during the first 10 days of broiler life, the ability of the intestine to use nutrients increases progressively. Absorption of yolk sac contents increases villus height development and enterocyte maturity (Geyra, Uni, & Sklan, 2001), which further favors performance characteristics, since broiler growth depends on availability of nutrients for supply organs like small intestine, pancreas, liver, heart and lungs, to key pathways such as demand tissues, muscles and adipose tissue.

The development of the immune system begins during the embryonic phase and continues in the post-hatch period. During the first week of life, there is a rapid increase in leukocytes along with an increase in the size of lymphoid organs (Panda, Raju, Rao, Sunder, & Reddy, 2010). However, the increase in the number of these cells and the size of the lymphoid organs is necessary for the development of acquired immunity. The yolk sac is important because it transfers passive immunity from the yolk to the newly hatched chick in the form of immunoglobulins, however, it must have at its disposal adequate sources of exogenous nutrients.

The provision of pre-starter dietst hermally processed and adequate in nutritional composition is essential. However, nutritional supplements of amino acids with relevant participation in the regulation of gene expression, cellular signaling, antioxidant responses, neurotransmission, and immunity can contribute directly to these processes. Moreover, amino acids such as glutamate, glutamine and aspartate are important metabolic fuels for the small intestine to maintain digestive function and to maintain the integrity of the intestinal mucosa (Wu, 2014).

Another important factor for intestinal and organ development is the maintenance of environmental temperature, especially during the first week of life of the chick. Birds do not have mechanisms responsive to regulate body temperature (Boleli et al., 2008).

In the post-hatch period, the chicks act as poikilothermic animals and become completely homeothermic, at about 10 days of age (Willemsen et al., 2010). When subjected to temperature below the thermal comfort zone, the chicks destine part of the ingested energy to generate heat and with this they maintain body temperature, however, with negative reflexes on the productive indices (Yardimci, Sengor, Sahin, Bayram, & Cetingiil, 2006), mainly on feed conversion. Thus, the metabolic expenditure to provide extra energy for the maintenance of body temperature is determinant in the production costs of the broiler, given the short life span.

According to Van Den Brand, Molenaar, Van Der Star and Meijerhof (2010), the best intestinal development can optimize the use of nutrients and the metabolism that can contribute to increased heat production and environmental temperature. However, the relationship between nutritional supplementation in the post-hatch period and the morphological and intestinal changes of chicks submitted to environmental temperature variations and the consequences on the productive performance in the initial phase of the chicks' life is poorly known.

The objective of this study was to evaluate the efficacy of a dietary formulation based on amino acids and vitamins supplemented in drinking water for chicks in the first week of life, subjected to thermal oscillation on productive performance, organ development and intestinal morphometry from 1 to 21 days.

Material and methods

The experiment was conducted at the Experimental Aviary of the Federal University of Paraná, Palotina Sector. All procedures for rearing animals and collection of biological material were approved by the Committee on Ethical Conduct on the Use of Animals in Experimentation under protocol 24/2016.

640-male Cobb 500 broiler chicks from 40 week old matrices were assigned to a completely randomized design in a 2x2 factorial arrangement (with or without dietary supplementation and under comfort temperature or thermal oscillation), totaling 4 treatments with 16 replicates of 10 birds each.

The treatment with oral dietary supplementation was provided with a commercial formulation based on amino acids and vitamins (Promotor L®, Hertape Calier Saúde Animal, S.A), adding 1 mL liter^{-1} of drinking water, according to the manufacturer's recommendation. The composition and nutritional levels of the product are described in Table 1.

Table 1. Composition and guarantee levels per liter of the product (Promotor L®, Hertape Calier Saúde Animal, S.A.).

Amino acid	Concentration	Vitamin	Concentration
Glutamin Acid	21.5g	Vitamin B1	1.75g
Pantothenic Acid	7.g	Vitamin B12	1.250,00μg
Aspartic Acid	9.5g	Vitamin B6	1.125g
Alanine	11.5g	Vitamin K3	0.5g
Arginine	6.1g		
Biotin	1.0mg		
Cystine	2.1g		
Phenylalanine	5.5g		
Glycine	9.6g		
Histidine	4.7g		
Inositol	2.5g		
Isoleucine	6.0g		
Leucine	12.5g		
Lysine	9.5g		
Methionine	2.2g		
Nicotinamide	16.25g		
Proline	9.5g		
Serina	7.0g		
Tyrosine	5.3g		
Threonine	5.0g		
Tryptophan	2.0g		
Valine	6.2g		

The birds had *ad libitum* access to drinking water and feed throughout the experimental period. The ambient temperature oscillation was obtained by keeping the birds during the first week of life under thermal comfort during the day (31-32°C) and under cold stress at night (24-25°C). Air quality was maintained by minimal ventilation. Birds received diets based on corn and soybean according to nutritional recommendations of Rostagno et al. (2011).

The productive performance (body weight, feed intake, weight gain and feed conversion) of the animals was evaluated at 7, 14 and 21 days of age by weighing the birds and the feed leftovers. Mortality was observed and recorded daily for the correction of feed intake and feed conversion, according to Sakomura and Rostagno (2007).

At 7 and 21 days of age, 16 birds from each treatment were previously weighed and euthanized by cervical dislocation, provided for in the Normative 1000 of the Federal Council of Veterinary Medicine (CFMV). At 7 days of age, weight of breast, yolk residue, liver, pancreas, gizzard + proventriculus and small intestine were obtained immediately after dissection and removal of the exogenous tissues to calculate the relative weight by the formula: relative weight = (organ weight/body weight) × 100.

At 7 and 21 days of age, fragments of approximately 5 cm of the jejunum (in the region of the Meckel's diverticulum) were collected, which were longitudinally opened on styrofoam boards, and washed with saline solution. Samples were fixed in buffered formalin and after stiffening, they were paraffin-embedded. Each fragment was subjected to semi-serial cuts of 5 μm thickness and stained with hematoxylin-eosin.

For the morphometric study, images were captured using light microscopy (Olympus BX 50), using the computerized image analysis system (Image Pro-Plus - Version 5.2 - Cyber Media). The length and width of 20 villi and the depth and width of 20 crypts of each slide were measured. These morphometric measures were used to calculate the absorption surface area of the intestinal mucosa, using the formula proposed by Kisielinski, Willis and Prescher (2002):

$$\text{Absorption área} = \frac{((LV \times AV) + (LV/2 + LC/2)^2 - (LV/2)^2)}{((LV/2 + LC/2)^2)}$$

where: LV -villus width; AV - villus height; LC - crypt width.

Data analysis was performed by ANOVA of the General Linear Model (GLM) procedure using SAS software (Statistical Analysis System [SAS], 2004).

Results and discussion

In the period from 1 to 7 days of age, the birds subjected to thermal comfort presented higher body weight and greater weight gain ($p < 0.05$) in relation to birds subjected to thermal oscillation. There was no significant difference ($p > 0.05$) between treatments for feed intake and feed conversion (Table 2).

In relation to the periods of 1 to 14 and 1 to 21 days of age, the birds under thermal comfort presented higher body weight ($p < 0.05$) than the birds subjected to thermal oscillation. However, for the other variables, no significant differences were detected ($p > 0.05$).

Pioneering studies by Renwick, Washburn and Lanza (1985) report the negative effect of thermal oscillation on the development of broiler lines of different genetic origins.

The same was observed by Nguyen et al. (2015), reporting several metabolic changes induced by temperature oscillation. These authors conclude that the prolonged action of the cold causes cellular modifications, neuroendocrine, physiological and immunological readaptation and that all these disorders cause severe damages to the energetic homeostasis of the chick. In the period from 7 to 14 days of age, the birds subjected to thermal comfort presented higher body weight ($p < 0.05$) than those under thermal oscillation. The other variables analyzed did not present difference ($p > 0.05$) (Table 3).

Table 2. Performance of broilers from 1 to 7, 1 to 14 and 1 to 21 days of age supplemented or not with oral dietary solution based on amino acids and vitamins and kept under thermal comfort or subjected to thermal oscillation.

	Live weight (g)	Weight gain (g)	Feed intake (g)	Feed Conversion
	1 – 7 days			
Supplementation				
Supplemented	158.91	111.90	157.43	1.413
Control	157.33	110.70	143.94	1.298
Temperature				
Thermal Comfort	160.26[a]	114.85[a]	156.96	1.367
Thermal Oscillation	155.88[b]	107.75[b]	144.82	1.346
CV, %	4.45	6.89	19.18	19.14
Supplementation(S)	0.3999	0.5356	0.0707	0.0846
Temperature (T)	0.0171	0.0005	0.1109	0.7751
S x T	0.9362	0.7054	0.3210	0.4601
	1 – 14 days			
Supplementation				
Supplemented	412.00	371.09	567.72	1.545
Control	410.79	366.69	551.99	1.478
Temperature				
Thermal Comfort	420.43[a]	372.56	563.02	1.510
Thermal Oscillation	402.35[b]	635.03	556.68	1.514
CV, %	5.72	5.28	16.18	14.05
Supplementation (S)	0.8379	0.3983	0.4900	0.2210
Temperature (T)	0.0032	0.1293	0.7807	0.9513
S x T	0.1491	0.2236	0.2905	0.9875
	1 – 21 days			
Supplementation				
Supplemented	826.24	1265.61	1269.52	1.615
Control	808.12	1245.39	1241.48	1.612
Temperature				
Thermal Comfort	834.18[a]	786.31	769.80	1.583
Thermal Oscillation	800.18[b]	770.28	786.79	1.644
CV, %	5.58	5.32	11.08	10.14
Supplementation (S)	0.8379	0.1063	0.4235	0.9267
Temperature (T)	0.0032	0.1273	0.5634	0.1394
S x T	0.1491	0.2015	0.2730	0.5863

Lowercase letters in the column differ significantly ($p < 0.05$).

Table 3. Performance of broilers from 7 to 14 and 14 to 21 days of age supplemented or not with oral dietary solution based on amino acids and vitamins and kept under thermal comfort or subjected to thermal oscillation.

	Liveweight,g	Weight gain, g	Feed intake, g	Feed Conversion
	7 – 14 days			
Supplementation				
Supplemented	412.00	214.41	410.28	1.920
Control	410.79	213.81	396.14	1.857
Temperature				
Thermal Comfort	420.43[a]	215.91	402.47	1.867
Thermal Oscillation	402.35[b]	212.30	404.21	1.912
CV, %	5.72	8.16	15.76	15.21
Supplementation (S)	0.8379	0.8921	0.3893	0.3886
Temperature (T)	0.0032	0.4117	0.9147	0.5419
S x T	0.1491	0.1280	0.4164	0.9704
	14 – 21 days			
Supplementation				
Supplemented	826.24	414.23[a]	694.31	1.678
Control	808.12	397.32[b]	679.47	1.695
Temperature				
Thermal Comfort	834.18[a]	413.73[a]	691.41	1.649[b]
Thermal Oscillation	800.18[b]	397.82[b]	682.37	1.725[a]
CV, %	5.58	6.90	10.60	8.61
Supplementation (S)	0.1174	0.0189	0.4181	0.6173
Temperature (T)	0.0042	0.0268	0.6211	0.0419
S x T	0.3032	0.6458	0.5183	0.8738

Lowercase letters in the column differ significantly ($p < 0.05$).

Likewise, in the period from 14 to 21 days of age, the birds under thermal comfort also presented higher body weight ($p < 0.05$). In addition, weight gain was higher in birds supplemented with dietary supplements, as well as in birds subjected to thermal comfort ($p < 0.05$). The birds under thermal comfort presented better feed conversion ($p < 0.05$) in relation to birds subjected to thermal oscillation.

According to Cassuce, Tinôco and Baêta (2013), thermal oscillations in the early life of chicks are marked by physiological disturbances that compromise the whole life of the animals. Besides the energy deviation for body regulation, the thermal oscillation promotes alterations in the processes of cellular hyperplasia and hypertrophy, maturation of the thermoregulatory system and differentiation of the gastrointestinal mucosa, negatively influencing the weight gain and feed conversion of the birds, which hardly will be recovered in the subsequent growth stages and until the slaughter stage (Schiassi et al., 2015).

Some authors (Geyra et al., 2001; Wu, 2014) have already evaluated oral nutritional supplementation in young birds and observed an increase in weight gain only in the third week of life of birds, which were maintained under thermal comfort in the first week of life. They concluded that the amino acids provided were directly involved in the processes of intestinal ontogeny.

Undeniably, the effect of the thermal oscillation in the first week is the factor of strongest impact on the growth of broilers. In this way, the supplementation of additives may not be sufficient to minimize the negative reflexes of the environmental discomfort.

The supplementation with additive based on amino acids and vitamins, regardless of the environmental condition in the first week of life of the birds, resulted in a greater ($p < 0.05$) absolute weight of the small intestine, breast, liver, spleen and bursa of Fabricius (Table 4).

For the yolk weight, there was a significant interaction ($p = 0.0594$) between oral supplementation and temperature. The breakdown of the interaction shows that birds under thermal comfort and supplemented presented greater weight of the yolk residue ($p < 0.05$) than birds not supplemented. Birds that received the oral nutritional supplement and were kept under thermal comfort temperature presented higher weight of the yolk residue ($p < 0.05$) than those subjected to thermal oscillation (Table 5).

Significant interaction was also detected for the relative weight of the intestine ($p < 0.05$). In the breakdown of the interaction, it was observed that the relative weight of the intestine of birds that did not receive dietary supplementation and were subjected to thermal oscillation was higher ($p < 0.05$) than birds kept under thermal comfort (Table 5).

The yolk sac is a vascularized membrane similar to the placenta in mammals, which involves the yolk during embryonic development and is responsible for the transfer of nutrients to the embryo.

Table 4. Absolute and relative weight of broilers at 7 days of age supplemented or not with oral dietary solution based on amino acids and vitamins and kept under thermal comfort or subjected to thermal oscillation.

	Intestine	Yolk sac	Breast	Liver	MP*	Spleen	Thymus	Bursa of Fabricius
				Absolut weight, g				
Supplementation								
Supplemented	22.65[a]	0.16	22.50[a]	6.62[a]	14.91	0.19[a]	0.12	0.31[a]
Control	21.05[b]	0.09	20.69[b]	6.11[b]	14.05	0.16[b]	0.12	0.27[b]
Temperature								
Thermal Comfort	21.60	0.14	22.06	6.31	14.84	0.18	0.12	0.29
Thermal Oscillation	22.09	0.10	21.14	6.43	14.11	0.17	0.11	0.29
CV, %	14.42	88.32	13.62	13.66	13.65	27.27	27.85	20.13
Supplementation (S)	0.0466	0.0280	0.0167	0.0217	0.0876	0.0265	0.7156	0.0074
Temperature (T)	0.5413	0.1952	0.2177	0.5829	0.1441	0.3940	0.2795	0.7005
S x T	0.1000	0.0594	0.9492	0.4175	0.5874	0.2575	0.3829	0.7284
				Relative weight, %				
Supplementation								
Supplemented	13.38	0.09	13.28	3.88	8.81	0.11	0.07	0.18
Control	13.19	0.06	12.95	3.84	8.82	0.10	0.07	0.17
Temperature								
Thermal Comfort	12.91	0.08	13.14	3.77	8.86	0.10	0.07	0.17
Thermal Oscillation	13.67	0.06	13.09	3.94	8.77	0.10	0.07	0.18
CV, %	10.84	90.50	9.56	11.26	12.09	27.83	26.27	20.94
Supplementation (S)	0.6072	0.0801	0.2921	0.6743	0.9674	0.1596	0.1686	0.3474
Temperature (T)	0.0391	0.2574	0.8803	0.1135	0.7282	0.8058	0.6418	0.5782
S x T	0.0424	0.0808	0.7785	0.4119	0.6267	0.1722	0.4058	0.7533

MP: Gizzard + proventriculus; Lowercase letters in the column differ significantly ($p < 0.05$).

Table 5. Unfolding of the interaction supplementation x temperature for yolk weight and the relative weight of the intestine at 7 days of age.

	Supplemented	Control	P Value
Temperature	Absolut weight of yolk sac, g		
Thermal Comfort	0.21[aA]	0.08[aB]	0.0215
Thermal Oscillation	0.11[bA]	0.10[aA]	0.7606
P Value	0.0453	0.6404	
Temperature	Relative weight of the intestine, %		
Thermal Comfort	13.37	12.44[b]	0.0641
Thermal Oscillation	13.39	13.95[a]	0.3004
P Value	0.9796	0.0076	

Lower case letters in the column and upper case in the row differ significantly ($p < 0.05$).

Upon hatching, the chick has in its abdominal cavity a yolk sacof approximately 12% of its weight (Fernandes et al., 2014). In the yolk sac, the necessary nutrients are concentrated for the proper development of the intestine and immunoglobulins for the first defenses of the post-hatch chick. The total absorption of this residue occurs between the 6th and 7th day of life (Boleli et al., 2008).

The issue of greater retention of the yolk sac is quite controversial. Ulmer-Franco, Fasenko and Christopher (2010) consider that birds with greater retention of the yolk sac have greater deposition of immunoglobulins. On the other hand, some studies show that this retention can affect muscle growth (Noy & Uni, 2010; Panda et al., 2010).

The maximum development of the intestine occurs in the first three weeks of life of the bird, a period related to the complete absorption of the yolk sac and the adequacy of the intestine to the exogenous diet (Uni et al., 1998). The growth of the intestine is proportional to the increase in the metabolic rate (Noy & Uni, 2010), which may explain the greater relative weight of the intestine that may represent an attempt to increase the absorption rate in birds subjected to unfavorable temperature conditions. However, this compensatory mechanism resulted in worse weight gain of these birds.

Controversially, Roto et al. (2016) emphasize that in situations of high temperatures, the opposite is observed, that is, there is a reduction in the weight of the intestine, as a consequence of a physiological adjustment in an attempt to reduce the production of corporal heat.

The evaluation of intestinal morphometry at the end of the temperature oscillation period showed that the birds subjected to this condition had lower ($p < 0.05$) crypt depth and smaller absorption area ($p < 0.05$) in relation to the birds kept under thermal comfort, as presented in Table 06. As a consequence of this result, a higher ($p < 0.05$) villus: crypt ratio and villus width were observed, which contributed to the greater relative weight of the small intestine.

Table 6. Morphometry of jejunal mucosa at 7 and 21 days of age of broilers supplemented or not with oral dietary solution based on amino acids and vitamins and kept under thermal comfort or subjected to thermal oscillation.

	Villus, μm		Crypt, μm			
	Length	Width	Depth	Width	V:C Ratio	Area, μm^2
	7 days					
Supplementation						
Supplemented	497.82	130.68	124.00	50.72	4.77	8.23
Control	507.28	127.45	119.33	51.74	4.62	8.81
Temperature						
Thermal Comfort	515.21	126.42	151.03[a]	49.44[b]	3.51[b]	8.99[a]
Thermal Oscillation	488.65	131.75	90.37[b]	53.11[a]	5.98[a]	7.96[b]
CV, %	14.91	11.12	20.39	10.90	46.69	20.03
Analysis of variance						
Supplementation (S)	0.6127	0.4020	0.6669	0.5918	0.6735	0.1921
Temperature (T)	0.1728	0.1734	<.0001	0.0178	<.0001	0.0259
S x T	0.6235	0.4988	0.4230	0.3383	0.5340	0.9178
	21 days					
Supplementation						
Supplemented	623.59	113.19[b]	76.15	53.15	8.26	10.93
Control	620.04	129.38[a]	75.09	55.04	9.06	10.46
Temperature						
Thermal Comfort	611.26	122.74	78.27	54.87	8.02[b]	10.24
Thermal Oscillation	634.32	118.95	72.94	53.21	9.31[a]	11.20
CV, %	16.39	21.01	20.05	14.72	21.19	23.02
Analysis of variance						
Supplementation (S)	0.9560	0.0167	0.7807	0.3626	0.0885	0.5214
Temperature (T)	0.3938	0.5816	0.1885	0.4337	0.0080	0.1279
S x T	0.9058	0.6806	0.3720	0.8678	0.4593	0.3683

Lowercase letters in the column differ significantly ($p < 0.05$).

There was no significant effect of the dietary supplement on jejunal mucosa morphometry ($p > 0.05$). In turn, at 21 days, two weeks after the environmental challenge, there was a smaller ($p < 0.05$) width of the jejunum villus in supplemented birds in relation to the control birds. The villus: crypt ratio of the jejunum of birds subjected to thermal oscillation remained higher in relation to the birds kept at thermoneutral temperature.

According to Marchini et al. (2009), the digestibility of food and the integrity of the intestinal mucosa are strongly related to variations in ambient temperature. These authors reported a negative effect of high temperatures up to the fourth week of age on the duodenal mucosa of the birds.

In the intestinal crypts, structures located between the villi, there are the basal cells responsible for cell renewal (Potten & Loeffler, 1987; Geyra et al., 2001). In agreement with Xia, Hu and Xia (2004), the greater depth of the crypt represents an important factor that determines the crypt's ability to sustain height increase as well as the villus structure. The height of the villi and the depth of the crypts are considered indicators of the good development of the intestine, in normal conditions they present bettervillus: crypt ratio. Nevertheless, in this work the best villus: crypt ratiowas found in birds subjected to thermal oscillation.

In accordance with Quinteiro et al. (2010), this may be a consequence of rapid re-epithelialization of the intestinal mucosa. On the other hand, stress in response to cold induces many cellular alterations that can lead to physiological adaptations (through the modulation of key genes related to metabolism, however still poorly known (Nguyen et al., 2015).

Conclusion

Temperature oscillations in the first week of life negatively influenced productive performance and intestinal morphology until the end of the initial phase.

Dietary supplementation based on amino acids and vitamins, despite increasing the weight gain of birds only at the end of the initial phase, did not provide the nutritional support expected to mitigate the effects of the environmental challenge in the first week of life.

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