Agronomy Research **16**(2), 556–563, 2018
https://doi.org/10.15159/AR.18.069

Productive performance of broilers at the final stage of breeding submitted to different levels of metabolizable energy in different thermal environments

K.P. Oliveira[1], C.F.S. Ferreira[1], I.F.F. Tinoco[1], R.R. Andrade[1], M. Barbari[2,*], V.M.F. Cruz[3], F.J.F. Baptista[3], M.F.A. Vieira[4], L. Conti[2] and G. Rossi[2]

[1]University of Viçosa, Department of Agricultural Engineering of Federal, Av. Peter Henry Rolfs, s/n Campus University of Viçosa, CEP: BR36570-900, Viçosa, Brazil
[2]University of Firenze, Department of Agricultural, Food and Forestry Systems, Via San Bonaventura, 13, IT50145 Firenze, Italy
[3]University of Évora, Department of Rural Engineering, Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Núcleo da Mitra, Évora, Portugal
[4]Federal Rural University of Amazonia – UFRAPA-256, s/n – Nova Conquista, Paragominas – PA, 68627-451
[*]Correspondence: matteo.barbari@unifi.it; kelle.oliveira@ufv.br

Abstract. The Brazilian poultry industry is an activity in constant development due to the high indices of productive efficiency. The accelerated evolution of poultry production has allowed to obtain early and very efficient broilers able to convert different foods into animal protein. However, due to this intensive breeding system, a series of metabolic and management problems appeared, with emphasis on thermal stress. The objective of this work was to evaluate the physiological responses of broiler chickens in the final stage of breeding (21 to 42 days of life), submitted to two thermal conditions, one representative of the thermoneutrality situation (T1) and one giving a situation of cyclic stress by heat (T2). For each experimental thermal condition, the birds were submitted to different levels of metabolizable energy of 3,050, 3,125, 3,200, 3,275 kcal kg^{-1}. At 28, 35 and 42 days, the birds and the feed leftovers were weighed to measure the performance variables: CR (feed intake), GP (weight gain) and CA (feed conversion), viability of the rearing (Vb), productive efficiency index (PEI).
As conclusions, the GP was 13.6% higher for the birds maintained at the thermoneutrality situation T1. The PEI was 32.5% higher for the birds maintained in T1 condition, when compared to those kept in T2. However, both in thermoneutral and in heat stress conditions, the increase in the level of metabolizable energy in the diet did not influence the performance and the productive efficiency index of broiler chickens aged between 21 and 42 days of age.

Key words: broilers, feed, metabolizable energy, productivity, thermal stress.

INTRODUCTION

The Brazilian poultry industry is an activity in constant development thanks to the indexes of productive efficiency with the largest and most advanced technological collection of the agricultural sector. The accelerated evolution of poultry breeding resulted in the production of early and very efficient broilers able to convert different foods into animal protein. However, due to this intensive process, a series of metabolic and animal management problems emerged, with emphasis on thermal stress. Broilers have a large mass, so they produce great quantities of pollutants (Aarnink et al., 2009; Kic & Růžek, 2014) and metabolic heat. The thermal environment inside the barn is a major factor influencing the performance, health and welfare of broilers in intensive farms. Due to their considerable feed intake and the subsequent high metabolism, broilers produce a high level of surplus heat (Syafwan et al., 2011) that can bring to heat stress (Reiter & Bessei, 2000). High ambient temperature has a negative effect on broiler production efficiency (Sandercock et al., 2001). Broilers exposed to high temperature and relative humidity find it difficult to maintain their core body temperature (Borges et al., 2007). To improve the thermal conditions inside the building in hot season it is necessary to apply an intensive ventilation and sometimes a cooling of supplied air, but also passive systems can be effective (Kic, 2016).

Feeding, besides influencing productive performance and carcass characteristics, is the factor that affects the production costs of broilers. For this reason rations providing the best cost/benefit ratio are explored. Dietary energy needs for maintenance increase when broiler chickens are subjected to environmental temperature above their thermal neutral zone (Hurwitz et al., 1980). Apparent metabolizable energy needs of broilers are influenced by ambient temperature (Dozier III et al., 2007). Considering that birds voluntarily reduce feed intake as the ambient temperature rises above the thermal comfort range, a ration formulated for thermoneutral conditions would not be adequate to meet the energy requirement of birds in a heat stress environment.

The utilization of metabolizable energy in growing broilers can be estimated by using an energy balance technique (Lopez & Leeson, 2007). Metabolizable energy intake is well documented to influence body composition (Morris, 2004) and performance of growing broilers (Leeson et al., 1996). The determination of the nutritional requirement of metabolizable energy is fundamental in the different phases of broiler breeding, as the digestibility increases with the age of the bird due to the development of the digestive tract, which leads to the improvement of its capacity to assimilate nutrients and energy from feed (Mello et al., 2009).

According to Bou et al. (2005), the inclusion of vegetable oil in rations of birds kept under heat stress reduces the depressive effects of temperature on its performance. The beneficial effect of the addition of oil in the rations of animals submitted to heat stress is associated to changes in gastrointestinal physiology and to the lower caloric increment verified during the digestion, absorption and assimilation of nutrients of the rations containing higher oil content (Bertechini, 2012).

On the basis of the above consideration, the objective of the present research was to evaluate the effect of different levels of metabolizable energy in the diet of broilers, raised under two levels of thermal conditions on performance and productive efficiency index. In one case the temperature was maintained inside the thermoneutral zone and in the other one conditions of cyclic heat stress were realized.

MATERIALS AND METHODS

The experiment was conducted in four climatic chambers, located in the experimental area of the Centre for Research in Environment and Engineering of Agroindustrial Systems (AmbiAgro), belonging to the area of Rural Buildings and Environment of the Department of Agricultural Engineering of the Federal University of Viçosa, Minas Gerais, Brazil.

Each climate chamber has the dimensions of 2.5 x 3.5 x 2.5 m (respectively height, length and width), equipped with an electric resistance air heater (2,000 W of power), an air conditioner of the hot / cold split type of 3,500 W, an air humidifier with a capacity of 4.5 L and a mist flow rate of 300 mL h^{-1}.

The heater and humidifier were operated by an electronic controller MT-531 R i Plus of temperature and humidity (0.1 °C resolution, control humidity 20 to 85% RH, with 0.1% RH resolution).

Ventilation applied inside the climatic chambers was obtained through axial exhausters, AMB, Model FD 08025S1M DC 12V 0.15A, with automatic activation, during the whole experimental period. The ventilation was controlled in order to maintain the desired temperatures and the quality of the air in accordance with the norms described in the Protocol of Good Practices of Production of Chickens (Brazilian Poultry Association, 2008). The axial fans were able to guarantee twice renews of air per hour in the climatic chambers.

The experiment was carried out in the final stage of breeding, between the 21st and 42nd day of life of the birds. For the trials 280 broilers of the Cobb 500 line, with an average initial weight of 1,267 kg (± 5%), were used. The birds were put in cages with the following dimensions: 1.0 m wide x 0.5 m long x 0.5 m high (Fig. 1). To replicate the field conditions each cage contained seven birds, with a density of 14 birds.m^{-2}. A new 5 cm thick bed of woodchips was provided at the beginning of the trials.

Figure 1. View of cages used for the trials. Each cage (1.0 m wide x 0.5 m long x 0.5 m high) contained 7 broilers.

Two temperatures were applied, one representative of the thermoneutrality situation (T1) and the other of the situation of cyclic stress by heat (T2), as determined by Pareja (2014). In condition T1 the birds were submitted to a fixed temperature of 25 °C, during 24 hours a day throughout the experimental period. For condition T2, the birds were subjected to 12 hours of heat stress from 7:00 AM to 7:00 PM at 31 °C while during the other 12 hours they were kept at 25 °C, as shown in Table 1.

Table 1. Experimental treatments, defined on the basis of air temperatures (°C), for broilers between 21 and 42 days

Temperature	Situation	Temperature (°C) 7:00h to 19:00h	Temperature (°C) 19:00h to 07:00h
T1	Thermoneutrality	25	25
T2	Heat Stress	31	25

The air relative humidity (RH) was controlled during the experimental period in both treatments, in the range from 55 to 65%, through the automatic system present in the climatic chambers.

For each imposed thermal condition, the birds were submitted to four levels of metabolizable energy, 3,050, 3,125, 3,200 and 3,275 kcal kg^{-1}, according to the recommendations of Rostagno et al. (2011), presented in Table 2.

Table 2. Composition of rations used during experimental trials

Ingredients	Metabolizable Energy kcal kg^{-1}			
	3,050	**3,125**	**3,200**	**3,275**
Corn grain	65.6327	63.8867	62.1406	60.3946
Soybean meal 45%	27.1138	27.4137	27.7135	28.0134
Meat and bone meal 40%	3.8260	3.8392	4.5412	5.9846
Soybean oil	1.6544	3.0978	3.8524	3.8655
Limestone	0.4177	0.4125	0.4073	0.4021
Common salt	0.3886	0.3891	0.3896	0.3901
Dl-methionine (99% purity)	0.3119	0.3135	0.3151	0.3167
L-lysine HCL (99% purity)	0.3040	0.2979	0.2918	0.2856
Vitamin supplement[1]	0.2500	0.2500	0.2500	0.2500
Mineral supplement[2]	0.2500	0.2500	0.2500	0.2500
L-threonine (99% purity)	0.0920	0.0918	0.0916	0.0914
Choline chloride 60%	0.0500	0.0500	0.0500	0.0500
L-tryptophan (99% purity)	0.0088	0.0078	0.0069	0.0059
	100,00	100,00	100,00	100,00
Calculated composition				
Metabolizable energy (kcal kg^{-1})	3,050.0	3,125.0	3,200.0	3,275.0
Crude protein (%)	19.8000	19.8000	19.8000	19.8000
Vegetable fat (%)	4.9015	6.2739	7.6464	9.0188
Calcium (%)	0.7600	0.7600	0.7600	0.7600
Phosphorus available (%)	0.3500	0.3500	0.3500	0.3500
Lysine dig. for birds (%)	1.1300	1.1300	1.1300	1.1300
Methionine + Cystine dig. for birds (%)	0.8300	0.8300	0.8300	0.8300
Methionine dig. for birds (%)	0.5721	0.5727	0.5734	0.5741
Threonine dig. for birds (%)	0.7300	0.7300	0.7300	0.7300
Tryptophan dig. for birds (%)	0.2040	0.2040	0.2040	0.2040
Sodium (%)	0.2000	0.2000	0.2000	0.2000

[1]Guaranteed levels per kg of product (minimum): Folic acid 0.3 mg, Pantothenic acid 12 mg, Nicotinic acid 50 mg, Biotin 0.05 mg, Niacin 30 mg, Vitamin A 10,000.000 IU, Vitamin B1 1. 5 mg, Vitamin B12 0.015 mg, Vitamin B2 6 mg, Vitamin B6 4 mg, Vitamin D3 2,000.000 IU, Vitamin E 28 IU, Vitamin K3 3 mg, Excipient q.s. 1,000 g.

[2]Guaranteed levels per kg of product (minimum): Cobalt 2 mg, Copper 10 mg, Iron 50 mg, Iodine 0.7 mg, Manganese 78 g, Selenium 0.18 mg, Zinc 55 mg, Excipient q.s. 1,000 g.

The rations were provided in order to keep feeders always full (*ad libitum*), following the criteria used in the field. The water was also supplied *ad libitum* being replaced three times a day, thus avoiding the heating of the water in the drinkers. The feeders used were trough type and the drinkers were nipple type.

Data on productive performance were collected: weight gain (kg); feed intake (kg); feed conversion.

The birds were weighed at 21, 28, 35 and 42 days of age to evaluate body weight and weight gain (GP). The feed consumption was calculated on the basis of the difference between the amount of feed supplied and surplus in these periods, following a methodology by Sakomura & Rostagno (2007).

Mortality was recorded on a daily basis, for later conversion of the viability data (Vb).

The productive efficiency index (PEI) was calculated using the following equation (Stringhini et al., 2006).

$$PEI = \frac{weight\ gain\ x\ viability\ of\ creation}{days\ until\ the\ end\ of\ the\ experiment\ x\ food\ conversion}\ x\ 100$$

Statistical analysis

In order to evaluate the effect of the ambient temperature and metabolizable energy levels on the average values of the analysed variables, representative of the productive performance and the productive efficiency index, a statistical analysis was performed using the subdivided plots scheme for T1 and T2 with four subplots (3,050, 3,125, 3,200 and 3,275 kcal kg^{-1}), in a completely randomized design, with five replications. The data were interpreted by means of analysis of variance and, for the quantitative factor, by regression, in which the models were chosen based on the significance of the regression coefficients using Student's t test, at the 5% probability level. The averages were compared using the Tukey test, at the 5% level of significance. For such analyses, the software SAEG, System for Statistical Analysis, version 9.1 (2007) was used.

All procedures used in this experiment were approved by the Committee on Ethics in the Use of Animals (CEUA) of the Federal University of Viçosa, Minas Gerais, Brazil, Protocol No. 75/2014.

RESULTS AND DISCUSSION

Table 3 shows the ANOVA summary for the variables viability (Vb) and productive efficiency index (PEI) corresponding to climatic chambers temperatures (TEMP) and metabolizable energy levels (EL).

As it can be observed in Table 3, temperatures (TEMP) significantly influenced the variables of the average weight gain ($P < 0.01$) and the results of the productive efficiency index (PEI) of the chickens ($P < 0.05$). The levels of metabolizable energy in the diet did not significantly influence the productive efficiency index. Similar results were found by Leandro et al. (2003), who verified that the different treatments did not influence PEI, for the total period of rearing (1 to 46 days), although nutritional plans 1 and 2 obtained numerically better indexes for males and females.

Table 3. Summary of variance analysis of the variables of average weight gain (GP), feed conversion (CA) in kg, viability (Vb) and productive efficiency index (PEI) in %, for broilers aged between 21 and 42 days, submitted to different temperatures (TEMP) and different levels of metabolizable energy (EL) (DF: Degree of Freedom)

Factor	DF	GP	CA	Vb	PEI
TEMP	1	0.327**	0.034^{NS}	2,040.816^{NS}	12,380.400*
Residue (a)	8	0.011	0.025	647.959	1,582.858
EL	3	0.041^{NS}	0.070^{NS}	34.013 ^{NS}	846.730^{NS}
TEMP x EL	3	0.005	0.028^{NS}	40.816 ^{NS}	117.017^{NS}
Residue (b)	24	0.015	0.026	386.054	1,255.247

** – significative 1%, * – significative 5%, ^{NS} – not significative.

Table 4 presents the results of the test of averages applied to the mean weight gain variable (GP) of the birds, influenced by the temperatures.

It is observed in Table 4 that the average weight gain (GP) was 13.6% higher for the birds maintained at the thermoneutral temperature (T1, 25°C), when compared to those maintained at the temperature of cyclic stress by temperature (T2, 25–31 °C). This is due to the fact that when kept under heat stress, broilers reduce their growth in a higher proportion than feed consumption, which results in a worse feed conversion ratio, as cited.

Table 5 shows the results of the test of averages applied to the index of productive efficiency index (PEI) of broilers, influenced by temperatures.

Table 4. Mean values of the average weight gain index (GP) in kg, for chickens at the temperatures T1 (25 °C) and T2 (25–31 °C)

Temperature	GP
T1	1.494a
T2	1.315b

The averages followed by at least one letter in the column do not differ at the 1% level of significance by the Tukey test.

Table 5. Average values of the productive efficiency index (PEI) in %, for chickens at the temperatures T1 (25 °C) and T2 (25–31 °C)

Temperature	PEI
T1	143.449a
T2	108.263b

The averages followed by at least one letter in the column do not differ at the 1% level of significance by the Tukey test.

In Table 5 it can be observed that the productive efficiency index (PEI) was 32.5% higher for the birds maintained at the thermoneutral temperature (T1, 25 °C), when compared to those maintained at the temperature of the cyclic stress by temperature (T2, 25–31 °C). This difference is due to the fact that birds exposed to high temperatures reduce feed intake to decrease metabolic heat production and thereby maintain homeothermia, which also results in a decrease in growth. This aspect is well documented in literature (Hurwitz et al., 1980; Dozier III et al., 2007).

The stress generated to the animal by the variation of the thermal environment directly influences the productivity, in relation to variations in the heat exchanges with the environment, the amount of feed consumed, the body weight gain and, consequently, the nutritional requirements, as well documented in several works (Souza & Batista, 2012; Mohammed et al., 2018).

CONCLUSIONS

As conclusion, the weight gain was 13.6% higher for the birds maintained in the thermoneutrality situation (T1). This is due to the fact that when kept under thermal stress, broilers reduce their growth in a higher proportion than food consumption, which results in a worse feed conversion ratio.

The productive efficiency index was 32.5% higher for birds kept in condition T1. This difference is due to the fact that birds exposed to high temperatures reduce feed intake to decrease the production of metabolic heat and thus maintain homeothermia, which also results in a decrease in growth.

However, both in thermoneutral and in heat stress conditions, the increase in the level of metabolizable energy in the diet did not influence the performance and the productive efficiency index of broiler chickens aged between 21 and 42 days.

ACKNOWLEDGEMENTS. AmbiAgro, CNPq, CAPES and FAPEMIG.

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