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Effects of the Reduction of Dietary Heat Increment on the Performance, Carcass Yield, and Diet Digestibility of Broilers Submitted to Heat Stress[1]

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ABSTRACT

This experiment aimed at verifying the effect of different diets and thermal environments on the performance, carcass yield, and diet digestibility of 21 to 42-day-old broilers. A total number of 288 21-day-old male Ross broilers were distributed in a 2 x 2 + 2 factorial arrangement, with six replicates, including the following factors: two environments (TNE – thermoneutral: 21-25°C and 73% RH; CHS – cyclic heat stress: 25-32°C and 65%RH), and two diets (control: 2.4% soybean oil and 19.5% protein; summer: 4.0% soybean oil and 18.5% protein). In TNE, two additional treatments were included with feed restriction of birds fed both the control and summer diets (pair-feeding), thereby maintaining the same feed intake level for both types of diet. Diet did not influence performance, dry matter and protein digestibilities, or carcass and part yields. TNE birds had better performance ($p<0.001$) as compared to CHS birds, but FCR was not different. CHS birds had lower breast yield ($p<0.0001$), and higher thigh yield ($p<0.02$) than TNE birds. In the pair-feeding treatments, environment did not influence performance, but dry matter digestibility was significantly lower in CHS ($p<0.03$), whereas protein digestibility was not affected. The difference in feed intake was the main responsible factor for the variation in the performance of heat-stressed birds.

INTRODUCTION

Increases of protein and energy levels in broiler diets to compensate reduction in intake during hot weather are frequently recommended. The replacement of carbohydrates by fat as energy sources is recommended, as well as the supply of adequate amino acid profile. The use of oil in substitution of carbohydrates is justified by the fact that fats, among all ingredients, oil presents the lowest heat increment (9%), as compared to protein (26%) (Ribeiro & Laganá, 2002).

Dale & Fuller (1980) observed less harmful effects of high temperatures on weight gain when 27.5% of dietary metabolizable energy (ME) was replaced by fat (dietary addition of 8% vs. 2.25%). These authors found that, when birds were submitted to cyclic heat stress (CHS), growth rate improved when fat was added to the diet. However, fat had no effect when birds were submitted to chronic heat stress. One of the differences between continuously high temperatures (chronic heat stress) and cyclic heat stress is that, in CHS, birds are able to dissipate heat during the cooler night period, which is not possible when birds are maintained to constantly high temperatures. Therefore, birds submitted to heat stress ingest feed during the cooler periods, influencing nutritional requirements (Balnave & Oliva, 1990), response to feed supplements (Smith & Teeter, 1987), and compensatory weight gain (Ribeiro *et al.*, 2001a).

As to dietary protein concentration, two strategies are suggested to minimize CHS effects on growth rate:

a) the use of low-protein diets in order to decrease heat increment, with some authors recommending lowering dietary protein content with the supplementation of essential amino acids (Waldroup, 1976; Austic, 1985; Cheng *et al.*, 1997); and

b) the use of high-protein diets to compensate lower feed intake caused by heat, as recommended by Temim *et al.* (2000).

The latter used diets containing 10 to 33% crude protein (CP), and observed that 28 to 33% CP diets resulted in better weight gain and feed conversion ratio than the 20% CP diet fed to 4-6-week-old broilers maintained under continuous heat (32°C). However, the authors stress that, in this case, only highly digestible protein sources should be used, as increasing dietary protein content through low digestibility ingredients would cause higher heat increment (HI), and therefore, the heat stress would be worsened.

Research studies showed that birds submitted to heat stress not only cause lower feed intake. Dale & Fuller (1980), using pair-feeding, observed that even when feed intake was the same, birds submitted to heat stress did not present the same growth rate as those kept in thermoneutral environment. These authors assert that feed efficiency is reduced during heat stress, which can be caused by lower feed digestion – first stage of nutrient utilization –, as well as to a higher energy requirement to maintain body temperature. Stress implies in an increase in energy needs, as there is high activity of the neural muscular system and other tissues. At the onset of stress, skeletal muscle tone increases by the action of catecholamines, preparing the individual for possible physical activity, which is equivalent to maintaining an alert state. Therefore, the body requires higher levels of glucose and other nutrients, such as amino acids, salts, and vitamins, which are essential to sustain an increase in activity (Cabral *et al.*, 1997).

When submitting broilers to chronic stress at 32°C and using pair-feeding, Bonnet *et al.* (1997) reported that dry matter, protein, fat, and starch digestibilities were lower as compared to birds submitted to a temperature of 22°C.

The present study aimed at:

a) verifying if higher oil and lower protein (lower HI) diets benefited the metabolism, performance, and carcass traits of broilers submitted to cyclic heat stress (25-32°C); and

b) verifying the direct effect of high environmental temperature on the performance and nutrient utilization, using pair-feeding technique.

MATERIAL AND METHODS

The experiment was carried out in temperature-controlled rooms, called Cold Battery and Hot Battery, of the poultry sector of the Animal Science Laboratory (Laboratório de Ensino Zootécnico – LEZO), of the Federal University of Rio Grande do Sul, Brazil. A total number of 288 21-day-old male Ross broilers was housed in 0.72 m^2 cages, equipped with metal trays for the collection of excreta. Birds were distributed in a 2 x 2 + 2 factorial arrangement, with six replicates of eight birds each. Birds were submitted to one of two environments: TNE (thermoneutral environment) or CHS (cyclic heat stress); and were fed one of two diets, control diet and summer diet, described in Table 1. Diets were formulated according to the recommendations of Rostagno *et al.* (2000). Under the TNE environment, two further treatments were applied: feed restriction, maintaining the same feed intake as birds submitted to CHS, for both diets (control and summer diets). In order to calculate the amount of food supplied, the feed intake of CHS birds, which feed was offered *ad libitum*, was measured daily, and the measured amount was offered to TNE birds on the next day. Therefore, treatments were: A – CHS, control diet; B – CHS, summer diet; C – TNE, control diet, *ad libitum*; D – TNE, summer diet, *ad libitum*; E – TNE, control diet, same intake as A; and F – summer diet, same intake as B.

The summer feed contained 1.6% more oil and 1% less CP than the control diet, but maintaining the same energy, lysine, and methionine+cystine levels. Vitamin and mineral supplementation was the same for both diets.

TNE room temperature was kept at 21-25°C, and relative humidity at 65% until 28 days, and 81% from 28 to 42 days. In order to simulate cyclic heat stress environment, birds were submitted to daily cycles of 12 hours of thermoneutral temperature (25°C), 3 hours of increasing temperature (25 to 32°C), six hours at 32°C, and 3 hours of decreasing temperature (32 to 25°C). Relative humidity was kept at 65% during the entire experimental period.

Weight gain, feed intake, and feed conversion ratio were calculated weekly. Apparent digestibility was measured by total excreta collection, four days weekly, for three weeks. Birds were submitted to six hours

Table 1 - Composition of experimental diets fed to 21-42-day-old broilers.

	Control diet	Summer diet
Ingredients		
Corn	62.17	58.45
Soybean meal (46%)	31.33	30.42
Soybean oil	2.4	4.00
limestone	1.42	1.35
Dicalcium phosphate	1.67	1.70
Salt	0.49	0.50
Vitamin supplement[1]	0.05	0.05
Mineral supplement[2]	0.1	0.1
Lysine	0.09	0.14
Mehtionine hydroxi-analog[3]	0.245	0.27
Choline 60 %	0.03	0.04
Kaolin	_	3.00
Nutritional levels		
ME (kcal/kg)	3100	3100
CP (%)	19.5	18.5
Sodium	0.21	0.21
Lys	1.14	1.14
Met + Cys	0.83	0.83
Arginine	1.27	1.20
Thr	0.75	0.71
Try	0.24	0.23
Arg:Lys ratio	1.16	1.12
Ca	0.95	0.95
Available P	0.42	0.42

1 - Vitamin mix (content per kg/product): Vit.A. 10,000 IU; Vit D3 3,000 IU; Vit E 60 mg; Vit K3 3 mg; Vit B1 3 mg; Vit. B2 8 mg; Vit B6 4 mg; Vit B12 0,014 mg; Pantothenic Acid 20 mg; Niacin 50 mg; Folic Acid 2 mg; Biotin 0.15 mg. 2 - Mineral mix (content per kg/product):: Fe 40 mg; Zn 80 mg; Mn 80 mg; Cu 10 mg; I 0.7 mg; Se 0.3 mg. 3 - Bioequivalence of 88%. 4 - Calculated levels based on Rostagno *et al.* (2000).

before the beginning of the collection period and six hours before the end of collection to promote gastrointestinal emptying (Ribeiro *et al.*, 2001a). Measures were obtained in the cages, and each experimental unit consisted of the group of birds in each cage. Excreta was daily collected during four days, weighed, homogenized, placed in duly identified plastic bags, and an aliquot (10%) was frozen (-10°C) until analyses. After thawing, excreta were acidified to pH 4.0, dried until constant weight at 60°C, and dry matter was analyzed (Ribeiro *et al.*, 2001b). The kaolin added to the summer diet was discounted from feed intake and excreta for digestibility calculation, as recommended by Pucci *et al.* (2003).

Birds were slaughtered at 42 days of age. After weighing, birds were submitted to neck dislocation, bleeding, scalding, defeathering, evisceration, and chilling for 40 minutes, after which the carcass was cut up.

Analyses of variance were performed using the GLM (General Linear Models) procedure of SAS software package, and means were compared using LSMeans.

RESULTS AND DISCUSSION

Table 2 shows the performance responses of birds fed *ad libitum*. There was no significant interaction between environment and diet for any parameter. Birds under CHS fed *ad libitum* presented lower feed intake ($p<0.001$) as compared to those under TNE. Feed intakes lower than those observed in the present experiment (11%) were reported by Austic (1985), Howlider & Rose (1987), Smith (1993), and Czarick & Tison (1990). These authors observed that the first response of the bird to heat stress is a reduction in intake, and as a result of not ingesting the necessary amounts of nutrients, performance and welfare are compromised, and mortality increases. A decrease in feed intake, in an attempt to generate less heat, was also observed by Teeter *et al.* (1984) and Bonnet *et al.* (1997). Under chronic heat stress, the bird significantly reduces feed intake, as compared to cyclic heat stress, which can be explained by the absence of a comfort period in case of continuous heat stress. The lower reduction in feed intake in the present experiment, as compared to the above mentioned studies, is linked to the magnitude, duration, and type of stress to which the birds were submitted, and which must be considered, as acclimation is associated to feed intake (Teeter *et al.*, 1992).

Table 2 - Performance of broilers submitted to different environments (cyclic heat stress and thermoneutral) and diets (control and summer) in the period of 21 to 42 days of age, and fed *ad libitum*.

	Ave. weight (kg)	Weight gain (kg)	Feed intake (kg)	Feed conversion ratio (kg/kg)
		Environment		
Cyclic heat stress (CHS)	2.37^b	1.58^b	3.00^b	1.92
Thermoneutral (TNE)	2.50^a	1.74^a	3.48^a	1.92
P	0.003	0.001	0.001	0.61
		Diet		
Summer	2.41	1.64	3.24	1.91
Control	2.45	1.66	3.21	1.93
P	0.28	0.59	0.90	0.27
CV%	3.8	5.3	7.1	3.1

* Means followed by different letters in the same column are significantly different.

Diet type did not influence feed intake, differently from Bonnet *et al.* (1997), who observed significant increase in feed intake in birds submitted to chronic heat stress of 32°C and fed a summer diet (105 *vs.* 113 g/birds/day).

Birds under CHS also presented lower body weight (p<0.003) and weight gain (p<0.001) as compared to those under TNE due to the reduction in feed intake. At the end of the experiment, average weight of birds under CHS was 6% lower than those under TNE, which was also observed by Ribeiro *et al.* (2001a), who submitted birds to cyclic heat stress for a longer period (21 to 56 days of age). Oliveira Neto *et al.* (2000), Lana *et al.* (2000), and Howlider & Rose (1987) also found lower growth rates and final weight in CHS birds. Bonnet *et al.* (1997) reported a 50% reduction in weight gain of birds submitted to chronic stress at 32°C as compared to birds kept in thermoneutral environment of 22°C, after three weeks.

As to feed conversion ratio (FCR), no significant differences were observed due to environment or diet type. Bonnet *et al.* (1997) compared diets containing 11.6 or 8.1% fat for birds under CHS, and also did not observe differences in FCR. However, Dale & Fuller (1980) found better FCR with the dietary addition of 8% fat as compared to 2.25% in birds submitted to CHS. The lack of environmental effect found in the present study is consistent with Lana *et al.* (2000), who also did not find FCR differences in birds submitted to 31°C as compared to those kept at 25°C. This was attributed to the proportional drop in feed intake and weight gain.

Table 3 shows the comparison of performance under TNE and CHS when birds were fed the same intake levels, from 21 to 42 days of age. There was no significant effect of treatments on performance parameters. These results are different from those obtained by Dale & Fuller (1980), Geraert *et al.* (1996), and Bonnet *et al.* (1997), who equalized feed intake, and reported different growth rates between birds kept in TNE and under CHS.

After observing that birds submitted to did not present the same growth rate as those in thermoneutral environment, Dale & Fuller (1980) suggested that processes, such as panting and opening wings, to attempt to dissipate heat require extra energy expenditure, causing a reduction in feed utilization. Acclimation, on the other hand, may explain the positive results observed in the third week of heat in the present experiment. Wildeman *et al.* (1994) concluded that acclimated broilers may have higher feed intake. The increase in water consumption promoted by high temperatures may, up to a certain extent of heat stress, allow the bird to maintain constant feed intake (May *et al.*, 1997).

Diet had no effect on performance

Table 4 shows that the environment influenced breast yield (p<0.01) and thigh yield (p<0.02) in birds fed *ad libitum*. TNE birds had higher breast yield, which is consistent with the findings of Smith (1993), whereas CHS birds presented higher thigh yield. Baziz *et al.* (1996) observed a reduction in breast yield, and increase in leg muscle (leg + thighs) yield in 4-7-week-old broilers kept under chronic heat stress (32°C).

Diet had no influence on carcass yield

Table 5 shows carcass yield results of birds submitted to feed restriction. TNE birds presented higher breast yield (p<0.002) and thigh yield (p<0.01) as compared to CHS birds. These differences were observed in birds of similar weights, as two of the treatments applied feed restriction. The higher respiratory rate, as a function of panting, increases breast muscle activity, as well as the absence of diaphragm, may have promoted the lower breast yield of CHS birds. According to Meltzer (1987), tissue temperature increase accelerates chemical reactions, thereby increasing oxygen demand and heat production.

Table 3 - Performance of broilers submitted to different environments (cyclic heat stress and thermoneutral) and diets (control and summer) in the period of 21 to 42 days of age, and fed at the same intake level.

	Weight gain (kg)	Feed intake(kg)	Feed conversion ratio (kg/kg)
	Environment		
Cyclic heat stress (CHS)	1.58	3.00	1.91
Thermoneutral (TNE – feed restriction)	1.54	3.08	1.91
p	0.34	0.23	0.99
	Diet		
Summer	1.56	3.03	1.88
Control	1.55	3.05	1.94
p	0.84	0.83	0.13
CV%	5.3	4.7	4.6

* Means followed by different letters in the same column are significantly different.

Table 4 - Carcass yield of broilers submitted to different environments (cyclic heat stress and thermoneutral) and diets (control and summer) in the period of 21 to 42 days of age, and fed *ad libitum*.

	Carcass (%)	Breast (%)	Leg (%)	Thighs (%)
		Environment		
Cyclic heat stress (CHS)	87.50	33.10 [b]	11.6	17.1 [a]
Thermoneutral (TNE)	87.10	34.50 [a]	11.6	16.6 [b]
p	0.33	<0.0001	0.90	0.02
		Diet		
Summer	87.50	34.0	11.6	16.7
Control	87.20	33.6	11.6	17.0
p	0.47	0.24	0.91	0.26
CV%	2.6	4.9	5.5	7.1

1 - Part yield: part weight/carcass weight. * Means followed by different letters in the same column are significantly different.

Table 5 - Carcass yield of broilers submitted to different environments (cyclic heat stress and thermoneutral) and diets (control and summer) in the period of 21 to 42 days of age, and fed at the same intake level.

	Carcass (%)	Breast (%)	Leg (%)	Thighs (%)
		Environment		
Cyclic heat stress (CHS)	87.5	33.1 [b]	11.6	17.1 [a]
Thermoneutral (TNE – feed restriction)	87.9	34.1 [a]	11.8	16.6 [b]
p	0.35	0.002	0.11	0.01
		Diet		
Summer	87.9	33.6	11.7	16.9
Control	87.4	33.6	11.7	16.8
p	0.28	0.91	0.57	0.64
CV%	2.8	5.2	4.5	6.4

1 - Part yield: part weight/carcass weight. * Means followed by different letters in the same column are significantly different.

Dry matter digestibility (DMD) was lower (p<0.03) in CHS birds. This observation is consistent with Bonnet *et al.* (1997), as to a decrease in dry matter digestibility after a period of heat exposure. According to these authors, these results partially explain the lower performance of heat-stressed birds and partially by a reduction in feed efficiency in some cases (Benyi & Habi, 1998). Teeter *et al.* (1985) asserted that feed restriction may improve digestibility, as birds submitted to 25% feed restriction from 28 to 39 days of age, presented 5% higher diet digestibility.

Based on Sibbald (1979) and May *et al.* (1988), it is possible that the period of time feed-restricted birds remained with no feed may have contributed to improve diet digestibility, when restricted-fed CHS birds are compared with those fed *ad libitum*.

As to environment effect, literature information is controversial. May *et al.* (1988) observed birds under CHS presented reduced passage rate, and therefore, were able to improve diet digestibility. This response is associated to corticosterone, which would retain feed in the digestive tract longer, thereby favoring nutrient digestion and absorption. Washburn, (1991), Gordon & Roland, (1997) and Bonnet *et al.* (1997) observed that the increase in water consumption caused by high environmental temperatures, can increase feed passage rate, and therefore, it may decrease nutrient absorption.

As to diets, after correction for kaolin inclusion, no significant differences were found among treatments (p<0.56). Pucci *et al.* (2003) also did not find significant effect of higher oil inclusion in the feed on dry matter digestibility, when feed intake and excreta were corrected after kaolin withdrawal. On the other hand, Bonnet *et al.* (1997) e Vieira et al (2002) observed a reduction in dry matter digestibility in birds fed diets containing higher fat levels.

Table 6 – Diet digestibility of broilers submitted to different environments (cyclic heat stress and thermoneutral) and diets (control and summer) in the period of 21 to 42 days of age, and fed at the same intake levels.

	Dry matter digestibility (%)	Crude protein digestibility (%)
	Environment	
Cyclic heat stress (CHS)	70.80 [b]	66.03
Thermoneutral (TNE – feed restriction)	72.35 [a]	64.75
P	0.03	0.21
	Diet	
Summer	71.37	65.11
Control	71.78	65.67
P	0.56	0.57
CV%	2.29	3.58

* Means followed by different letters in the same column are significantly different.

Environment and diet had no influence on protein digestibility, in agreement with the study with layers under CHS of Koelkebeck *et al.* (1998). These results were different from those of Bonnet *et al.* (1997) and Wallis & Balnave (1984), who, in studies with broilers in heat environments, showed a consistent decrease in protein and amino acid digestibilities in complete diets. Sibbald (1982) observed that the results of many studies associating digestibility with heat stress are not conclusive.

CONCLUSIONS

The summer diet, which contained more oil and less protein, did not influence performance, diet digestibility, or carcass and part yields of birds submitted to cyclic heat stress as compared to those kept under thermoneutral environment. Heat conditions worsened bird performance, and decreased breast yield; however, thigh yield improved. In the pair-feeding treatments, environment did not affect performance, and showed that the reduction in feed intake was the main responsible factor for the performance reduction in heat-stressed broilers. In addition, in the pair-feeding treatments, dietary dry matter digestibility was significantly lower in birds submitted to cyclic heat stress, whereas crude protein digestibility was not affected.

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