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Does Low-Protein Diet Improve Broiler Performance under Heat Stress Conditions?

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ABSTRACT

Nutrition for broilers under high temperatures is extremely important for brazilian broiler chicken industry because the amounts of consumed nutrients and environmental temperature have great effects on bird performance and carcass quality. Among diet nutrients, protein has the highest heat increment; thus, during many years, diets with low protein level were recommended in order to reduce heat production in broiler chickens under heat stress. However, reports have shown that low-protein diets have negative effects on broiler performance when environmental temperature is high, because during heat stress, low food intake associated to a low diet protein induce amino acid deficiencies. Other studies have shown that broilers fed low-protein diets increase their energy requirement for maintenance with higher heat production. Thus, with the growth of broiler industry in tropical areas more challenges need to be faced by the farmers. So, both the ambient and nutritional conditions ought to be well managed to avoid negative effects on poultry production once they can affect the metabolism (body heat production under low temperature and body heat dissipation under high temperature) with consequence on poultry performance (meat and eggs).

INTRODUCTION

Broiler chickens are homoeothermic animals, which means that they maintain their central body temperature within a slight range irrespective of ambient temperature. So, birds have a thermoneutral zone that should be described as being a range in the environmental temperature in which energy needs for thermoregulation is minimum and the net energy for production is maximum (Furlan & Macari, 2002). Heat stress is one of the most important factors responsible by losses in animal production traits. Ain Baziz *et al.* (1996) observed that in heat-stressed birds body weight gain reduced more than food intake, since part of metabolizable energy intake was used for heat dissipation, impairing feed conversion.

The improvement of rearing conditions during heat stress can be done by interfering in the ambient (fans, fogging, and bird density), building (ceiling height, roof type, and localization), breeding (lines more resistant to heat) and nutritional practices (protein, energy, electrolytes). Among nutritional practices, reduction of diet protein level due to its greater heat increment compared to carbohydrate and fat (Musharaf & Latshaw, 1999) have been recommended during many years, aiming to reduce the amount of heat to be dissipated by the broiler chickens under heat stress (Waldroup, 1982). Nevertheless, recent findings have demonstrated that diets with low concentrations of crude protein worsen performance of broilers reared under heat stress (Alleman & Leclerq, 1997; Faria Filho, 2003).

This review discuss the effects of protein levels in the diets, formulated using the ideal protein concept, on broiler chickens performance when raised under heat stress conditions.

LOW-PROTEIN DIETS UNDER HEAT STRESS

Ideal protein should be understood as being that that has all amino acids in the exact amount and proportion for attending the maintenance and the highest protein deposition requirements. According the ideal protein concept, all amino acids are equally limiting to animal growth; thus, reduction of any amino acid, independent of the level, will cause its own deficiency and protein will become non-ideal. The first ideal protein profile for broiler chickens was published by Baker & Han (1994). The recommended profile was based on many trials carried out by researchers from University of Illinois(Klain *et al.*, 1960; Dean & Scott, 1965; Huston & Scott, 1968; Sasse & Baker, 1973; Baker *et al.*, 1979), where purified diets (synthetic amino acids) were tested aiming to establish a standard amino acid profile for attending broiler chickens requirements at initial phase.

Despite many studies had been done for evaluating the effect of diet protein on broiler performance, very few studies have been done comparing the different amino acid profiles for broiler chickens growth and body composition. More recently, investigations evaluating diet protein levels at initial phase showed that protein reduction affect chick performance (Araújo, 2001; Costa *et al.*, 2001; Hussein *et al.*, 2001; Bregendahl *et al.*, 2002; Faria Filho, 2003). During the growing phase, the findings are more contradictory. Costa *et al.* (2001) and Sterling *et al.* (2002) supplemented low-protein diets with methionine, lysine and threonine and found a reduction in the performance when compared to control diet. On the other hand, Araújo (2001), using these same amino acids (methionine, lysine and threonine), reported that is possible to use diets containing 17% of protein without affecting broiler chicken performance. Ferguson *et al.* (1998b) and Sabino (2001) using these same amino acids, and including tryptophan, reported a reduction in the performance of the broiler chickens when fed with low-protein diets.

Kerr & Kidd (1999a) using growing diets with protein ranging from 19 to 13%, reported that it should be possible to reduce two percent of diet protein content without affecting weight gain and feed conversion when methionine and lysine were added. When glutamic acid and essential amino acids were added (following ideal profile recommended by Baker & Han (1994) data of weight gain was worst than those obtained when only lysine and methionine were used. The findings also revealed that the reduction of four percent in the protein diet did not affect feed conversion. In other study, Kerr & Kidd (1999b) verified that feeding birds with a diet of 18.2% of protein, threonine-supplemented or not, did not affect weight gain and feed conversion.

Protein intake *vs* environmental temperature

It is well known that environment influence animal performance, so the acute or chronic effects of environmental variables need to be considered; on the other hand, and authors have been reported that protein has higher caloric increment than carbohydrate and fat (Musharaf & Latshaw, 1999). Heat increment is represented by energy released during digestion, absorption and nutrient metabolism and other metabolic mechanisms related to physiological/ metabolic events (Pond *et al.*, 1995). On the other hand, the term "heat production" is related to heat increment plus energy lost with maintenance (Church & Pond, 1977), which is required for thermal modulation (body temperature maintenance), normal activity (walking, eating, drinking) and basal metabolism (energy spent for vital process during fasting, resting at thermoneutral temperature). So, considering that protein has high caloric increment, reduction of diet crude protein level has being recommended for broiler chickens under heat stress aiming to decrease the amount of heat produced by animals and to reduce their harmful effects on bird performance.

Studies have demonstrated that low-protein diets increase heat production. Nieto *et al.* (1997) feeding broilers with low-protein diet (6.6 vs 20.0%) from 10th to 24th day of age reported an increase in the requirement of metabolizable energy for maintenance (966 *vs* 824 $kJ.kg^{-0.75}.dia^{-1}$). In a similar way, Buyse *et al.* (1992) found that low-protein diets (15 *vs* 20%) increased heat production (1,254 *vs* 1,059 $kJ.kg^{-0.75}.day^{-1}$, respectively) by 28 day-old broiler chickens. These results were associated to the increase of plasma level of thyroid hormone triiodothyronine (T_3) in broiler chickens fed low-protein diets (Buyse *et al.*, 1992). It is well known heat stress decreases feed intake and causes nutrient deficiency. Deficiency of arginine, lysine, isoleucine, methionine (Carew *et al.*, 1997) and tryptophan (Carew *et al.*, 1983) increase plasma concentration of T_3 in broiler chickens and, consequently, increased heat production of broiler fed low-protein diets.

Nevertheless, Alleman & Leclerq (1997) observed that the low performance of broiler chickens raised under heat stress (32°C) from 21 to 42 days of age, was impaired when protein level was reduced from 20 to 16% in the diets supplemented with methionine, lysine, threonine, arginine and valine. Recently, Faria Filho (2003) evaluating diets with low protein content (20%, 18.5% and 17%), formulated according to ideal protein concept for broiler chickens from 21 to 42 days of age and raised at 20, 25 or 33ºC, observed a reduction of weight gain and feed conversion in birds at 33ºC, but, at 20 or 25ºC there were no performance changes (Figure 1). These findings did not support the hypothesis that crude protein might be reduced in diets for heat-stressed broilers due to its high caloric increment.

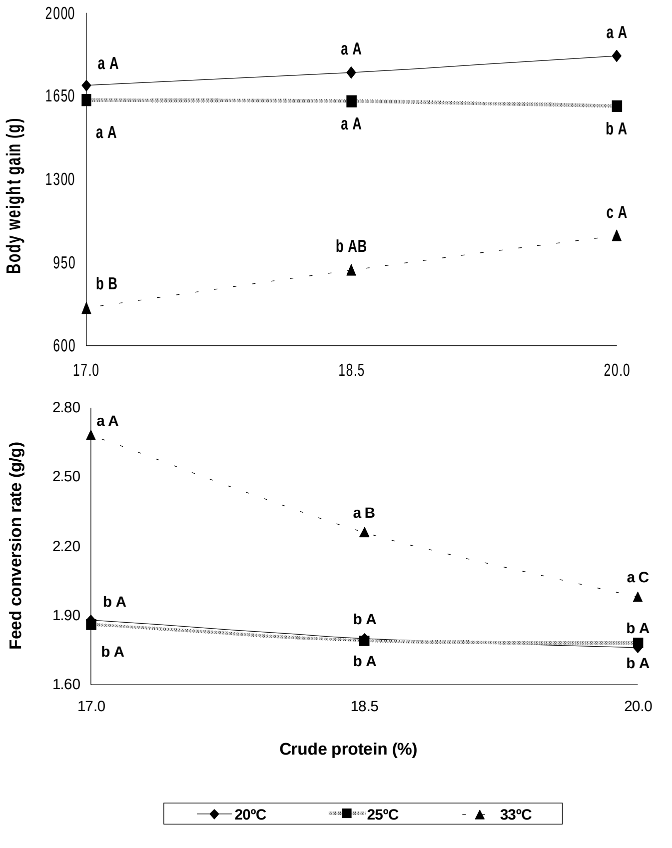

Figure 1 – Effects of crude protein in each temperature (capital letters in horizontal) and ambient temperature within each crude protein level (small letters in vertical). Means followed by different letters are statistically different by Tukey test (p<0.05). Faria Filho (2003).

Protein intake *vs* feed intake

It is well known that birds reduce feed intake under heat stress conditions. According to Ain Baziz *et al.* (1996), broiler chickens reduce feed intake around 3.6% for every increase (1°C) in environmental temperature from 22 to 32ºC. This reduction aims to avoid increasing of endogenous heat production since heat production is high when feed intake increase (Koh & Macleod, 1999a,b; Longo, 2000). By the way, considering the low feed intake of heat-stressed birds associated to diets with low-protein content there is a deficiency of amino acids intake.

Some works have demonstrated that the reduction in the crude protein levels in the diet does not affect feed intake of broiler chickens (Blair *et al.*, 1999; Sabino, 2001). Modulation of feed intake is not a consequence only of crude protein amount, but also of protein quality, meaning concentration and balance of amino acids. Faria Filho (2003) verified that low-protein diets, formulated according to ideal protein concept, did not increase feed intake. So, the excess of essential non-limitating amino acids, usual in commercial diets, may help to avoid these nutrient deficiencies during heat stress conditions.

Reports of Sakomura (1998) revealed that there is no increase in bird metabolic requirements of amino acids at high environmental temperature, but amino acid requirements indicates how amino acids percentage in the diet should be changed according to the temperature.

Protein intake *vs* water intake

Water intake during heat stress is a limiting factor for survival and growth, since water has a fundamental role in heat exchange systems for temperature regulation (Furlan & Macari, 2002) and the maintenance of hydric balance in birds. So, special management is necessary during heat stress especially that associated water (amount and quality), since the increase in water consumption reduces the increase in body temperature. Macari *et al.*(1994) suggested that, during heat stress, water temperature might be maintained around 20°C. Teeter (1994) found that heat-stressed broilers drinking (30 mL.Kg^{-1} of live weight) water heated at 41° C did not change their body temperature, but when the water was offered at 12.7°C there was a reduction of 1°C in body temperature.

Another important point related to water intake is the nutritional composition of ration. Marks & Pesti (1984) verified that broiler fed diets with 17% protein drunk significantly less water than those fed diets with high protein (26%). Also, Alleman & Leclercq (1997) observed that in broiler fed diets with low crude protein content (16%) reduced water intake, independent of raising ambient temperature (22 or 32ºC) (Figure 2). It is interesting to emphasize that, as expected, birds raised at 22ºC showed increase in water intake with the age, but birds at 32ºC had a constant water intake from 25th to 40th day of age. However, independent of environmental temperature, low-protein diets promoted decrease in water intake, which is undesirable in situation heat stress. These results may be related to the lower potassium content of diets with low protein level, since in this situation rations are balanced with reduced inclusion of soybean meal, an ingredient rich in this mineral.

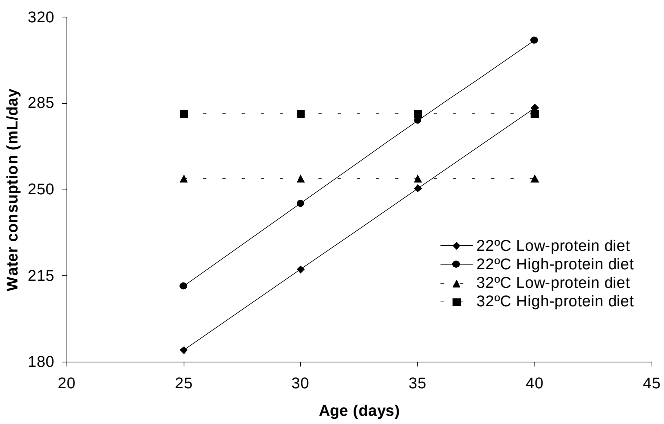

Figure 2 – Water intake by broiler chickens raised at 22 or 32ºC and fed with low or high crude protein levels (20 vs 16%). Alleman & Leclerq (1997).

Trials have shown that additives, as sodium bicarbonate and potassium chloride might increase water intake. Branton *et al.* (1986) reported that the addition of 0.63% of bicarbonate (6.25 g per liter) in drinking water of broiler under severe heat stress increased water intake in 20%, and also reduced mortality. Smith & Teeter (1987) observed better water intake, growing rate and feed conversion when 0.36% of KCl was added in drinking water.

It is important to consider that broiler under heat stress should have more potassium requirement due to the development of respiratory alkalosis resulted of acid-base unbalance and characterized by increase of blood pH. Due to high respiratory frequency, partial pressure of CO_2 decreases inducing concentration falls of carbonic acid and, consequently, of hydrogen ions (H^+) in the blood. At this time, there is exchange of H^+ by K^+ in renal tube for maintaining H^+ level. This passage of K^+ from outer to inner of cell causes potassium secretion to renal tube lumen. As a consequence, kidneys decrease competition between H^+ and K^+ for urine and the losses of K^+ increases concomitantly with its requirement by heat-stressed broilers (Borges *et al.*, 2003). This increase in potassium requirement associated to the reduced level of this ion in low-protein diets should be consider as a threatening factor for performance of heat-stressed broilers fed diets with low-protein content.

Amino acid digestibility

There are few reports showing the effect of environmental temperature on the amino acid digestibility. In heat stress conditions, there is a decrease in amino acid digestibility, but this effect depends on bird sex, being more evident in females (Wallis & Banalve, 1984). Brake *et al.* (1998), observed that broiler chickens under heat stress during the growing phase had reduced rate of arginine intestinal absorption *in vitro*, which led the authors to suggest the ideal arginine:lysine ration should be higher for broilers in this environmental situation.

Protein intake *vs* carcass composition

Besides nutritional management (amount), ration composition (quality) is other important factor affecting carcass composition. Among the different nutritional components, proteins (amino acids) are fundamentals, because they are related with synthesis of structural tissues. For example, in growing animals amino acids deposition in the skeletal muscle represent 65% of whole daily protein intake (Macari *et al.,* 1994). However, amino acid deposition is pre-established by bird, according genetic information, in other words, there is a limit for daily deposition independent of protein intake. But daily deposition variations may be dependent on the kind of diet nutrient.

Also, it is necessary to consider that bird requirements are based on amino acids and not on crude protein (CP). Leeson & Summers (1997) found reduction in the amount of fat deposition with the increase of diet protein, but within a range from 20 to 36% of CP there was only a small change in carcass protein content. So, for reaching maximum amino acid deposition with minimum fat deposition, the bird amino acid daily requirements need to be attended. In this way, Sklan & Plavinik (2002) verified that birds fed diets with low protein content had their performance limited by essential amino acid deficiency. Araújo (2001) reported a lower carcass yield in broiler fed diets with low crude protein content from 21 to 42 days of age.

Faria Filho (2003) reported that low-protein diets increased abdominal fat deposition. Aletor *et al.* (2000) found in broilers fed diets with crude protein ranging from 21.0 to 15.3%, even when it was supplemented with non-essential amino acids (alanine, aspartic and glutamic acids) for reaching the same protein level of control diet (22.5%), higher body fat deposition than those broilers fed control diet.

The effect of rearing temperature and diet protein level on broiler chicken chemical composition of carcass cuts is not reported in the literature. Recently, Faria Filho (2004, unpublished data) verified an increase in the ether extract and a reduction in the protein content of breast, drumstick + thigh and wings from broiler fed low-protein diets, with these effects being more strongly observed when the birds were raised under heat stress (Tables 2,3 and 4). It was also observed an increase in dry matter of drumstick + thigh and wings when the broilers were fed with diets containing low-protein diet and reared at high ambient temperature.

High-protein diets under heat stress

Many trials were carried out for evaluating the performance of broilers chickens reared under heat stress conditions and fed high-protein diets. Temim *et al.* (1999) reported that feeding broiler chickens with high protein diet (25 *vs* 20%) at high ambient temperature (32°C) during growing period improved weight gain (Table 1). Temim *et al.* (2000a), testing diets with crude protein content ranging from 10 to 33%, also, found an improvement in birds performance when using diets of 28 and 33% of crude protein, even when the birds were raised under heat stress.

Table 1 – Feed intake, weight gain and feed conversion of broiler chickens under thermoneutral temperature (22°C) or heat stress (32°C) fed diets with low or high crude protein (CP) contents (20 *vs* 25%).

Variables	Thermo neutral		Heat stress	
	20% CP[1]	25% CP	20% CP	25% CP
Feed intake (g.day^{-1})	162 a	157 a	115 b	122 b
Weight gain (g.day^{-1})	87.2 a	89.7 a	47.1 c	54.3 b
Feed conversion	1.86 c	1.76 d	2.52 a	2.35 b

1- For each independent variable, means followed by different letters within line are statistical different (Mannwhitney U 5%). Temim *et al.* (1999).

Geraert *et al.* (1993) observed that diets with high protein content (23 *vs* 19%) were able to reduced heat production in broilers under heat stress (32°C) between 3rd and 9th week of age. Zarate *et al.* (2003) evaluated a commercial diet, with or without essential amino acid supplementation (10% over commercial levels), in broiler chicken raised during the summer and concluded that amino acid supplementation had a minimum effect on heat production, with more energy utilization for fat deposition than to protein synthesis.

Temim *et al.* (2000b) evaluated protein turnover in *Pectoralis major* (breast muscle), *Sartorius* and *Gastrocnemius* (leg muscles) of broiler raised at 22 or 32°C and fed diets with 20 or 25% of crude protein. These authors found that high-protein diet did not change muscle protein turnover. Considering that heat production is positively correlated with body protein synthesis instead of protein intake, and there is no evidence indicating an increase of heat production due to amino acid excess (Macleod, 1997), we should speculate that utilization of high-protein diets for broiler chickens reared under heat stress is not able to change heat production in the birds. Beside, at high temperature, diets with high protein might help muscle protein synthesis due to proteolysis reduction (Temim *et al.*, 2000b). However, high-protein diets increase nitrogen excretion (Aletor *et al.*, 2000), which has a negative environmental impact. Thus, basically three items need to be considered for defining the better diet protein level for broiler chickens: 1) productivity; 2) final product quality (low protein diets increase fat deposition) and, 3) environmental impact (nitrogen excretion).

CONCLUSIONS

1. Low-protein diets increase maintenance energy requirement and decrease broiler chicken performance at high ambient temperature.
2. Carcass protein and fat deposition are affected by the level of protein in the diet and, also, by environmental rearing temperature.

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Table 2 – Effect of environmental temperature and diet protein level on chemical composition (% dry matter) of breast at 42 day-old broilers.

Variables	Crude Protein (%)	Environmental Temperature (°C) Hot	Cold	Thermo neutral	Mean
Dry matter (%)	20.0 (control)	28.9 b	29.3	29.1	28.4
	18.5	29.6 ab	29.9	28.8	30.0
	17.0	30.0 a	29.8	30.2	30.1
	Mean		29.7	29.4	29.5
	VC (%) = 2.51				
Crude Protein (%)[1]	20.0 (control)	73.4	73.5 aA	71.2 aB	75.4 aA
	18.5	71.5	72.6 abA	71.5 aA	70.5 bA
	17.0	70.1	71.6 bA	67.6 bB	71.0 bA
	Mean		72.6	70.1	72.3
	VC (%) = 1.30				
Ether extract (%)[1]	20.0 (control)	20.2	20.1 bB	22.2 bA	18.3 bC
	18.5	22.2	21.0 abA	22.0 bA	23.6 aA
	17.0	23.9	22.3 aB	26.2 aA	23.3 aB
	Mean		21.1	23.5	21.7
	VC (%) = 3.51				
Mineral (%)	20.0 (control)	6.4 a	6.4	6.5	6.3
	18.5	6.3 ab	6.3	6.6	5.9
	17.0	6.0 b	6.1	6.3	5.7
	Mean		6.3 A	6.5 A	6.0 B
	VC (%) = 3.95				

1 - Significant interaction among factors ($p<0.05$). For each independent variable, means followed by different capital letters within line or small letter within column are statistical different by Tukey test ($p<0.05$).

Table 3 - Effect of environmental temperature and diet protein level on chemical composition (% dry matter) of drumstick + thigh at 42 day-old broilers.

Variables	Crude Protein (%)	Environmental Temperature (°C) Hot	Cold	Thermo neutral	Mean
Dry matter (%)	20.0 (control)	32.4 b	33.0	33.1	31.0
	18.5	32.9 ab	33.3	33.2	32.1
	17.0	33.5 a	33.4	34.2	32.9
	Mean		33.2 A	33.5 A	32.0 B
	VC (%) = 1.36				
Crude Protein (%)	20.0 (control)	53.3 a	55.8	48.1	56.1
	18.5	49.7 b	51.0	46.7	51.4
	17.0	46.5 c	47.7	43.8	48.1
	Mean		51.5 A	46.2 B	51.9 A
	VC (%) = 2.92				
Ether extract[1] (%)	20.0 (control)	36.7	36.7 cAB	37.8 cA	35.6 bB
	18.5	38.4	38.2 bB	40.5 bA	36.4 abC
	17.0	39.8	39.6 aB	42.1 aA	37.7 aC
	Mean		38.2	40.1	36.5
	VC (%) = 2.69				
Mineral[1] (%)	20.0 (control)	10.0	7.5 cB	14.1 aA	8.3 cB
	18.5	12.0	10.8 bA	12.8 aA	12.3 bA
	17.0	13.7	12.7 aA	14.2 aA	14.2 aA
	Mean		10.3	13.7	11.6
	VC (%) = 12.92				

1 - Significant interaction among factors ($p<0.05$). For each independent variable, means followed by different capital letters within line or small letter within column are statistical different by Tukey test ($p<0.05$).

Table 4 – Effect of environmental temperature and diet protein level on chemical composition (% dry matter) of wings at 42 day-old broilers.

Variables	Crude Protein (%)	Environmental Temperature (°C) Hot	Cold	Thermo neutral	Mean
Dry matter (%)	20.0 (control)	36.2 c	36.2	36.5	36.0
	18.5	36.8 b	36.8	37.0	36.6
	17.0	37.4 a	37.4	37.6	37.2
	Mean		36.8 AB	37.0 A	36.6 B
	VC (%) = 1.24				
Crude Protein (%)	20.0 (control)	45.1 a	46.2	44.9	44.3
	18.5	43.9 ab	45.0	42.4	44.2
	17.0	42.7 b	45.6	40.5	42.0
	Mean		45.6 A	42.6 B	43.5 B
	VC (%) = 3.17				
Ether extract[1] (%)	20.0 (control)	39.0 bA	39.3 cA	39.2	39.1 bA
	18.5	38.9 bB	41.0 bA	39.6	38.8 bB
	17.0	41.9 aAB	42.7 aA	41.7	40.4 aB
	Mean		39.5	41.0	39.9
	VC (%) = 2.55				
Mineral[1] (%)	20.0 (control)	15.7	14.7	15.8	16.7
	18.5	16.6	16.2	16.6	16.8
	17.0	15.7	14.0	16.9	16.1
	Mean		15.0	16.4	16.6
	VC (%) = 9.87				

1 - Significant interaction among factors ($p<0.05$). For each independent variable, means followed by different capital letters within line or small letter within column are statistical different by Tukey test ($p<0.05$).

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