The Effects of amino acid balance on heat production and nitrogen utilization in broiler chickens : measurement and modeling

Ji-Hyuk Kim and Murdo G. MacLeod[1]
National Livestock Research Institute, 9 Seongwhan-eub, Cheonan-si, Chungnam 330-801, Korea
[1]Roslin Institute(Edinburgh), Roslin, Midlothian, EH25 9PS, UK

Abstract

Three experiments were performed to test the assumption that imbalanced dietary amino acid mixtures must lead to increased heat production (HP). The first experiment was based on diets formulated to have a wide range of crude protein (CP) concentrations but a fixed concentration of lysine, formulated to be the first-limiting amino acid. In the second (converse) experiment, lysine concentration was varied over a wide range while CP content was kept constant. To prevent the masking of dietary effects by thermoregulatory demands, the third experiment was performed at 30 ℃ with the diets similar to the diets used in the second experiment. The detailed relationships among amino acid balance, nitrogen (N) metabolism and energy (E) metabolism were investigated in a computer-controlled chamber calorimetry system. The results of experiments were compared with the predictions of a computerised simulation model of E metabolism. In experiment 1, with constant lysine and varying CP, there was a 75 % increase in N intake as CP concentration increased. This led to a 150 % increase in N excretion, with no significant change in HP. Simulated HP agreed with the empirically determined results in not showing a trend with dietary CP. In experiment 2, with varying lysine but constant CP, there was a 3-fold difference in daily weight gain between the lowest and highest lysine diets. HP per bird increased significantly with dietary lysine concentration. There was still an effect when HP was adjusted for body weight differences, but it failed to maintain statistical significance. Simulated HP results agreed in showing little effect of varying lysine concentration and growth rate on HP. Based on the results of these two experiments, the third experiment was designed to test the response of birds to dietary lysine in high ambient temperature. In experiment 3 which performed at high ambient temperature(30 ℃), HP per bird increased significantly with dietary lysine content, whether or not adjusted for body-weight. The trend was greater than in the previous experiment (20 ℃).

Key words : amino acid balance, broiler chicken, heat production, modeling, lysine, nitrogen metabolism

Introduction

Dietary protein quality influences growth but also affects the environment because of different rates of nitrogen excretion. A reduction in nitrogen excretion and increased efficiency of nitrogen deposition can be achieved by matching the amino acid composition of the diet with amino acid requirements. This would also would be expected to have implication for energy metabolism. The conventional expectation has been that a balanced blend of amino acids must lead to decreased energetic costs of catabolism and excretion (Baldini, 1961 ; Guillaume and Summers, 1970). MacLeod (1997) found, however, that heat production (HP) was closely correlated with rate of protein accretion(which in turn was strongly. associated with the intake of the first-limiting amino acid) and was affected little by total crude protein (CP) intake. Boorman and Ellis (1996) found no adverse effect of protein quality on lysine utilisation and detected some indication of increasing net utilisation with decreased protein quality.

However, the experiment of MacLeod (1997) used a rather heterogeneous series of diets and it was felt that more linear series of diets would lead to more secure conclusions. The first experiment described in this paper was, therefore, based on diets formulated to have a wide range of linearly varying CP concentration but equal concentrations of lysine, which was fixed as the first-limiting amino acid. The hypothesis being tested was that growth rate would be fixed by lysine concentration and that the energy cost of nitrogen excretion would therefore vary with excess N intake. The second experiment tested the converse, with diets of constant CP content but linearly varying lysine concentrations, with lysine again fixed as the first-limiting amino acid. The hypothesis being tested here was that HP would vary with growth rate (specifically protein accretion rate), which would itself be controlled by dietary lysine concentration. The experimental results were compared with simulations using the mechanistically based model of energy metabolism described by MacLeod (1994, 1998). To prevent the masking of dietary effects by thermo-regulatory demands, the third experiment was performed at a higher ambient temperature. At higher temperatures, it is possible that a further interaction may occur: any additional thermogenic effect of the diet may lead to reduced food intake if the bird is unable to dissipate additional heat. The hypothesis being tested here was that there would be a clearer relationship between HP and the first limiting amino acid at higher temperature without the effect of thermo-regulation. This is because the heat produced by the metabolism of food can potentially replace thermoregulatory heat production. The detailed relationships among amino acid balance, nitrogen metabolism and energy metabolism were investigated in a indirect calorimetry apparatus.

Materials and Methods

Male broiler chicks (1d old) from the same commercial line were obtained in batches at 14d intervals (so that they were of identical age at the time of measurement) and reared to 20d of age on a common starter diet. At 21d of age, chicks were randomly allocated (in pairs) to calorimeter chambers (Lundy et al., 1978). The experiments had an acclimatisation period of 7d in which animals were allowed to become accustomed to the diet and calorimeter chamber. The 5 replicate pairs of birds on each diet were allocated according to a 5×5 Latin square design with five 2-week measurement periods and 5 treatments. The E and N metabolism measurements were made continuously from d 28 to d 32.

In Experiment 1, the lysine concentration of each experimental diet was a constant 11 g/kg, with CP concentration ranging from 180 g/kg to 300 g/kg and TME concentration constant at 13.4 MJ/kg (Table 1).

In Experiment 2, lysine concentration ranged from 6~14 g/kg at a constant CP concentration of 300 g/kg and constant TME concentration of 13.4 MJ/kg (Table 2). This range was achieved by supplementing a basal diet with 0 to 10 g/kg of L-lysine HCl (Table 3, 4). The diets were kept iso-nitrogenous by substitution of glutamic acid as lysine concentration increased (Table 4).

In Experiment 3, experimental diets, detailed procedures and measurements were the same as Experiment 2 except for the environmental temperature (30 ℃).

In all experiments, other amino acids were maintained at concentrations 1.5 times the published recommendations, to ensure that no other amino acid became limiting. Both diets were pelleted. Food and water were available *ad libitum* and the birds were kept on a 23L:1D lighting cycle. Food intake, water intake, body-weight gain and HP were measured daily. HP was measured by means of the computer-controlled multi-chamber calorimetry system at Roslin Institute. Daily droppings collections were also made to investigate the utilisation of N. The measurements were made from d 28 to d 32.

Statistical analysis was by analysis of variance, including diet, column (chamber) and row (measurement period) in the model. The simulations were done using the mean bird weight at time of measurement (1,150 g) and the mean food intake (128 g/d).

Table 1. Specifications and ingredients of experimental diets for Experiment 1

Diet		1	2	3	4	5
TME MJ/kg		13.4	13.4	13.4	13.4	13.4
CP g/kg		180	210	240	270	300
Lysine concentration g/kg		11.0	11.0	11.0	11.0	11.0
Lysine : CP ratio		0.061	0.052	0.046	0.041	0.037
CP:TME ratio		1.34	1.57	1.79	2.01	2.24
Ingredients (g/kg)	Wheat meal	586.0	552.5	519.0	485.5	452.0
	Barley	150.0	112.5	75.0	37.5	0
	Maize meal	81.0	60.8	40.5	20.3	0
	Maize gluten meal (60% CP)	0	54.5	109.0	163.5	218.0
	Soya bean meal (48% CP)	0	61.0	122.0	183.0	244.0
	Casein	101.0	75.1	50.1	25.0	0
	Choline chloride	0.3	0.3	0.3	0.3	0.3
	Fat blend	28.0	31.0	34.1	37.1	40.1
	Dicalcium phosphate	11.5	12.1	12.6	13.2	13.7
	Sodium chloride	3.8	3.7	3.6	3.5	3.4
	Limestone flour	14.7	14.4	14.1	13.8	13.5
	Vitamin/mineral supplement	5.0	5.0	5.0	5.0	5.0
	Pellet binder	10.0	10.0	10.0	10.0	10.0
	Lysine	0.8	0.6	0.4	0.2	0
	Arginine	4.70	3.50	2.35	1.18	0
	Methionine	2.70	2.03	1.35	0.68	0
	Threonine	0.50	0.38	0.25	0.13	0

Table 2. Specifications of experimental diets for Experiment 2 and 3

Diet	6 (11)	7 (12)	8 (13)	9 (14)	10 (15)
TME MJ/kg	13.4	13.4	13.4	13.4	13.4
Crude protein (CP) g/kg	300	300	300	300	300
Lysine concentration g/kg	6	8	10	12	14
Lysine : CP ratio	0.020	0.027	0.033	0.040	0.047

Table 3. Formulation of basal diets in Experiment 2 and 3

Diet	g/kg
Wheat meal	468.8
Barley	86.8
Maize gluten meal (60% CP)	346.5
Maize oil	10
Choline chloride	0.3
Fish meal	9.6
Dicalcium phosphate	29.1
Sodium chloride	2.9
Limestone flour	15
Vitamin/mineral supplement	5
Pellet binder	10
Arginine	8
Methionine	1.4
Threonine	1.83
Tryptophan	0.8

Table 4. Composition of supplements in Experiment 2 & 3

Diet	Supplements (g/kg of diet)		
	Lysine	Glutamic acid	Maize starch
6 (11)	0	15.83	0
7 (12)	2.5	11.88	1.45
8 (13)	5.0	7.92	2.91
9 (14)	7.5	3.95	4.38
10 (15)	10.0	0	5.83

Results and Discussion

Experiment 1 : Effect of constant lysine and varying CP

There was no significant effect of varying CP concentration on food intake (Table 5). However, CP concentration had a significant effect on the water intake ($P<0.01$). Water intake increased as CP concentration increased. It was about 25 % greater with birds on the high protein diet than on the moderate protein diet. Dry matter excretion was also significantly affected by CP concentration ($P=0.001$). No significant difference was found between the birds in body-weight gain. However, the birds fed on the 18 % CP diet showed 25 % higher body-weight gain compared with the birds fed on the 30 % CP diet. Food conversion efficiency (FCE) was not affected by CP concentration. Although the birds fed on the highest protein diet showed slightly lower FCE, there was no significant difference between

Table 5. Effect of crude protein(CP) content on food intake, water intake, weight gain, food conversion efficiency(FCE) and dry matter(DM) excretion

Diet	1	2	3	4	5	SED	P
Food intake (g/bird.d)	132.1	127.3	126.6	123.7	129.1	4.99	NS
Food intake (g/kgW$^{0.75}$.d)	119.8	113.4	112.7	111.6	117.0	3.99	NS
Water intake (ml/bird.d)	170.5	172.8	181.8	195.0	214.7	11.65	0.016
Water intake (ml/kgW$^{0.75}$.d)	154.7	153.6	161.8	175.7	194.7	10.03	0.008
Water : Food ratio	1.29	1.35	1.44	1.57	1.66	0.05	<0.001
Weight gain (g/bird.d)	80.0	74.0	76.9	75.0	67.7	6.62	NS
FCE	0.61	0.58	0.61	0.60	0.53	0.04	NS
Excretion, DM (g/bird. d)	30.7	32.8	34.9	39.0	41.6	2.11	0.002
Excretion, DM (g/kgW$^{0.75}$.d)	27.9	29.2	31.1	35.2	37.7	1.84	0.001

treatments. The results indicated that there was no effect of CP concentration ranging from 18 to 30 % of diets on food intake. It seems that control of energy intake or first limiting amino acid took priority over the control of CP intake. MacLeod (1990) reported that there was no effect of CP concentration on food intake when he fed diets ranging from 130 to 260 g/kg. These results are also in agreement with Shariatmadari and Forbes (1993) who reported that there was no significant difference in food intake and growth rate between diets ranging from 172 to 280 CP g/kg.

Since there was no significant difference in food intake, there was a significant increase in N intake as CP concentration increased; the increase was by about 52 % between the lowest and highest CP diets (Table 6). However, N retention did not change significantly as diet protein content increased. N loss in excreta significantly increased with CP content ($P<0.001$). CP content had highly significant effects on efficiency of N utilisation ($P<0.001$). The birds fed on the highest CP diet had the lowest efficiency of N utilisation, resulting in a increase in N excretion of about 150% compared with birds fed on moderate CP diet. The efficiency of N utilisation was maximal in Diet 1 and significantly decreased as CP concentration increased. Blair et al. (1999) showed that reduction in dietary CP content caused a 10~27 % reduction in the total amount of nitrogen excreted during the 6-week broiler rearing period and with layers, there was a 30~35 % reduction in daily N output. They also reported that reduction in dietary CP from about 21 to 18 % resulted in a reduction of more than 20 % in daily N output. This is similar to the result in present experiment which showed 20 % reduction in N output as CP level decreased from 21 to 18 %. The efficiency of N utilisation decreased as

Table 6. Effect of crude protein(CP) content on nitrogen(N) intake, retention and loss, and efficiency of nitrogen utilisation

Diet	1	2	3	4	5	SED	P
N intake (g/bird.d)	4.10	4.18	5.29	5.90	6.18	0.212	<0.001
N intake (g/kgW$^{0.75}$.d)	3.17	3.72	4.72	5.32	5.61	0.178	<0.001
N retention (g/bird.d)	2.68	2.43	2.60	2.61	2.60	0.147	NS
N retention (g/kgW$^{0.75}$.d)	2.44	2.16	2.32	2.36	2.35	0.116	NS
N loss (g/bird.d)	1.41	1.75	2.68	3.29	3.59	0.168	<0.001
N loss (g/kgW$^{0.75}$.d)	1.28	1.56	2.40	2.97	3.26	0.154	<0.001
Efficiency of N retention	0.66	0.58	0.49	0.44	0.42	0.022	<0.001

Table 7. Effect of crude protein(CP) content on heat production(HP) and energy(E) utilisation

Diet	1	2	3	4	5	SED	P
TME intake (kJ/bird)	1870	1918	1824	1844	1763	64.5	NS
TME intake (kJ/kgW$^{0.75}$.d)	1696	1708	1622	1663	1598	48.3	NS
E retention (kJ/bird.d)	725	800	680	754	654	45.7	0.056
E retention (kJ/kgW$^{0.75}$.d)	657	712	604	680	593	37.2	0.039
HP (kJ/bird.d)	1037	1021	1038	988	999	33.4	NS
HP (kJ/kgW$^{0.75}$.d)	939.7	908.9	928.3	890.7	902.3	26.24	NS
Simulated HP (kJ/bird.d)	977	977	970	978	979	-	-

* The simulation results cannot be given a standard error since the model is not stochastic.

CP content increased.

There was no significant effect of amino acid balance on HP despite the very large change in N excretion (Table 7). Simulated HP agreed with the empirically determined results in not showing a trend with dietary CP. Although no significant difference in TME intake was detected between diets, there was a tendency for TME intake to be lower on higher CP diets. TME intakes were higher on the moderate protein, balanced diets (Diet 1 and 2) than high protein, imbalanced diets (Diet 3, 4 and 5). These results suggest that HP was correlated with the first limiting amino acid intake rather than total CP intake.

Experiment 2 : Effect of varying lysine and constant CP

Food intake increased as lysine concentration increased (Table 8). The birds fed on diet 9 (1.2 % lysine) showed the highest food intake and consumed 20 % more food when compared with birds fed on diet 6 (0.6 % lysine). Food intake of the birds fed on diet 10 (1.4 % lysine) was slightly lower than in the birds fed on diet 9. However, this significant difference disappeared when food intake was adjusted for body-weight. Lysine concentration also influenced water intake (P=0.007). It increased by 100 % in the birds fed on diet 9 when compared with the birds fed on the lowest lysine diet. Dry matter excretion differed significantly (P=0.05) but not when expressed in terms of $W^{0.75}$. Daily body-weight gain increased significantly as lysine concentration increased($P<0.001$). However, Diet 10(1.4% lysine) resulted in a reduction in body-weight gain compared with Diet 9. There was a 3-fold range in daily weight gain with variation in dietary lysine concentration. The groups fed on lysine

Table 8. Effect of lysine concentration on food intake, water intake, weight gain, food conversion efficiency(FCE) and dry matter(DM) excretion

Diet	6	7	8	9	10	SED	P
Food intake (g/bird.d)	88	107	104	133	118	11.9	<0.05
Food intake (g/kgW$^{0.75}$.d)	96	105	100	116	107	8.0	NS
Water intake (ml/bird.d)	130.8	196.2	205.6	262.4	235.6	22.45	<0.001
Water intake (ml/kgW$^{0.75}$.d)	142.6	193.4	197.6	229.8	214.8	19.17	0.007
Water : Food ratio	1.49	1.88	1.95	1.97	2.00	0.17	0.058
Wt gain (g/bird.d)	31.3	53.6	67.4	95.1	85.3	9.06	<0.001
FCE	0.36	0.50	0.65	0.71	0.72	0.06	<0.001
Excretion, DM (g/bird. d)	25.4	29.8	26.8	37.7	32.5	3.79	0.05
Excretion, DM (g/kgW$^{0.75}$.d)	27.8	29.1	26.0	33.0	29.6	2.84	NS

Table 9. Effect of lysine concentration on nitrogen(N) intake, retention and loss, and efficiency of nitrogen utilisation

Diet	6	7	8	9	10	SED	P
N intake (g/bird.d)	4.39	5.35	5.14	6.95	5.91	0.597	0.012
N intake (g/kgW$^{0.75}$.d)	4.82	5.23	4.93	6.08	5.38	0.404	0.06
N retention (g/bird.d)	1.68	2.08	2.40	3.20	2.81	0.354	0.008
N retention (g/kgW$^{0.75}$.d)	1.83	2.04	2.27	2.80	2.56	0.262	0.02
N loss (g/bird.d)	2.72	3.27	2.74	3.75	3.09	0.336	0.051
N loss (g/kgW$^{0.75}$.d)	2.98	3.19	2.66	3.29	2.82	0.241	NS
Efficiency of N retention	0.38	0.39	0.46	0.46	0.48	0.029	0.018

deficient diets (Diet 6, 7) showed much lower growth rate than the groups fed on the diets which had higher lysine concentration. It is known that severe amino acid imbalance primarily results in reduced food intake which, in turn, can affect growth rate (Okumura and Mori, 1979 ; Summer and Leeson, 1985). Amino acid excess can also result in impaired growth performances (Katz and Baker, 1975 ; Han and Baker, 1993).

Lysine concentration had a significant effect on N intake (Table 9). However, the significance disappeared when the measurement was adjusted for body-weight. N loss was not significantly different between diets but there was a tendency for it to increase as lysine concentration increased. N retention was significantly affected by lysine concentration and therefore lysine intake($P = 0.02$). N retention was highest in the birds fed on diet 9 and the increase was by 53% compared with diet 6, the lowest lysine diet. Efficiency of N retention significantly increased as lysine concentration increased.

Heat production per bird increased significantly ($P<0.05$) with rate of growth and therefore with dietary lysine content (Table 10). A trend remained when heat production was adjusted for body weight difference ($kgW^{0.75}$) but it was no longer statistically significant. There was a trend for heat production to increase with food intake. Simulated HP results also showed little effect of varying lysine concentration and growth rate on HP. The resultant regression between HP and lysine intake gave less than half the gradient determined by MacLeod (1997), in an experiment using a more diverse range of diets.

Table 10. Effect of lysine concentration on heat production(HP) and energy(E) utilisation

Diet	6	7	8	9	10	SED	P
TME intake (kJ/bird)	1174	1431	1394	1780	1576	159.4	<0.05
TME intake (kJ/kg$W^{0.75}$.d)	1287	1400	1338	1558	1435	107.6	NS
E retention (kJ/bird.d)	417	541	508	766	636	108.1	0.06
E retention (kJ/kg$W^{0.75}$.d)	453	532	482	672	578	91.1	NS
HP (kJ/bird.d)	757	890	885	1013	940	66.2	<0.05
HP (kJ/kg$W^{0.75}$.d)	832	868	849	890	860	37.6	NS
Simulated HP* (kJ/bird.d)	1049	1002	973	979	985	-	-

* The simulation results cannot be given a standard error since the model is not stochastic.

Table 11. Effect of lysine concentration on food intake, water intake, weight gain, food conversion efficiency(FCE) and dry matter(DM) excretion in high ambient temperature(30 ℃)

Diet	11	12	13	14	15	SED	P
Food intake (g/bird.d)	63.4	96.1	92.9	114.2	105.8	5.92	<0.001
Food intake (g/kg$W^{0.75}$.d)	74.3	98.9	96.8	110.3	100.5	5.55	<0.001
Water intake (ml/bird.d)	93.0	246.5	193.5	278.0	264.0	22.15	<0.001
Water intake (ml/kg$W^{0.75}$.d)	108.9	254.6	201.1	270.3	249.8	26.57	<0.001
Water : Food ratio	1.48	2.57	2.08	2.52	2.51	0.35	0.022
Wt gain (g/bird.d)	21.5	55.8	51.1	72.7	71.2	4.99	<0.001
FCE	0.34	0.58	0.56	0.64	0.67	0.04	<0.001
Excretion, DM (g/bird. d)	20.1	26.5	28.5	33.3	30.7	2.80	0.006
Excretion, DM (g/kg$W^{0.75}$.d)	23.6	27.2	29.7	32.1	29.1	2.44	0.045

Experiment 3 : Effect of varying lysine and constant CP in high ambient temperature

Food intake was affected by lysine concentration at high ambient temperature whether or not both values were adjusted for body weight (Table 11). It increased significantly by 48 % in Diet 14 compared with Diet 11 as lysine concentration increased ($P<0.001$). Water intake was also significantly affected, along with food intake, by lysine concentration ($P<0.001$). It increased by up to 150 % in the birds fed on Diet 14 compared with the birds fed on Diet 11. Body-weight gain was also significantly affected by lysine concentration ($P<0.001$). The greatest body-weight gain occurred on high lysine diets (Diet 14 and 15) and there was a 3.2-fold range in weight gain with variation of dietary lysine concentration(Table 5.1 and Figure 5.2).

Body-weight gain was closely correlated with lysine intake ($r=0.907$, $P<0.001$). Food intake, along with water intake, body-weight gain and dry matter excretion, was maximal on Diet 14 (12 g lysine/kg diet). Overall, the trends for food intake and weight gain to increase as lysine increased were similar to those of the previous experiment although average intake and growth were reduced at higher temperature.

Lysine concentration had a significant effect on N intake (Table 12). N loss was not significantly different between diets but there was a tendency to increase as lysine concentration increased. N retention, therefore, was significantly different between varying lysine diets($P<0.001$). N retention was highest in the birds fed on diet 14 and the increase was by 107 % compared with diet 11, the lowest lysine diet. Efficiency of N retention increased significantly as lysine concentration increased ($P<0.001$).

HP per bird increased significantly with dietary lysine content, whether or not adjusted for body-weight (Table 13). The trend was greater than in the previous experiment performed at

Table 12. Effect of lysine concentration on nitrogen(N) intake, retention and loss, and efficiency of nitrogen utilisation in high ambient temperature(30 ℃)

Diet	11	12	13	14	15	SED	P
N intake (g/bird.d)	2.79	4.09	4.01	4.80	4.55	0.251	<0.001
N intake (g/kg$W^{0.75}$.d)	3.17	4.13	3.95	4.35	4.14	0.254	0.005
N retention (g/bird.d)	0.97	2.04	1.69	2.42	2.42	0.111	<0.001
N retention (g/kg$W^{0.75}$.d)	1.04	2.02	1.54	2.06	2.12	0.212	0.001
N loss (g/bird.d)	1.82	2.05	2.32	2.37	2.13	0.195	0.094
N loss (g/kg$W^{0.75}$.d)	2.13	2.11	2.42	2.29	2.02	0.170	0.205
Efficiency of N retention	0.35	0.50	0.42	0.51	0.53	0.023	<0.001

Table 13. Effect of lysine concentration on heat production(HP) and energy(E) utilisation

Diet	11	12	13	14	15	SED	P
TME intake (kJ/bird)	850	1288	1245	1530	1417	79.3	<0.001
TME intake (kJ/kg$W^{0.75}$.d)	995	1326	1297	1478	1347	74.4	<0.001
E retention (kJ/bird.d)	287	621	505	741	664	61.4	<0.001
E retention (kJ/kg$W^{0.75}$.d)	337	640	526	715	634	61.0	<0.001
HP (kJ/bird.d)	514.6	659.3	670.8	764.8	722.2	24.2	<0.001
HP (kJ/kg$W^{0.75}$.d)	611.2	694.6	713.0	755.6	705.9	19.9	<0.001

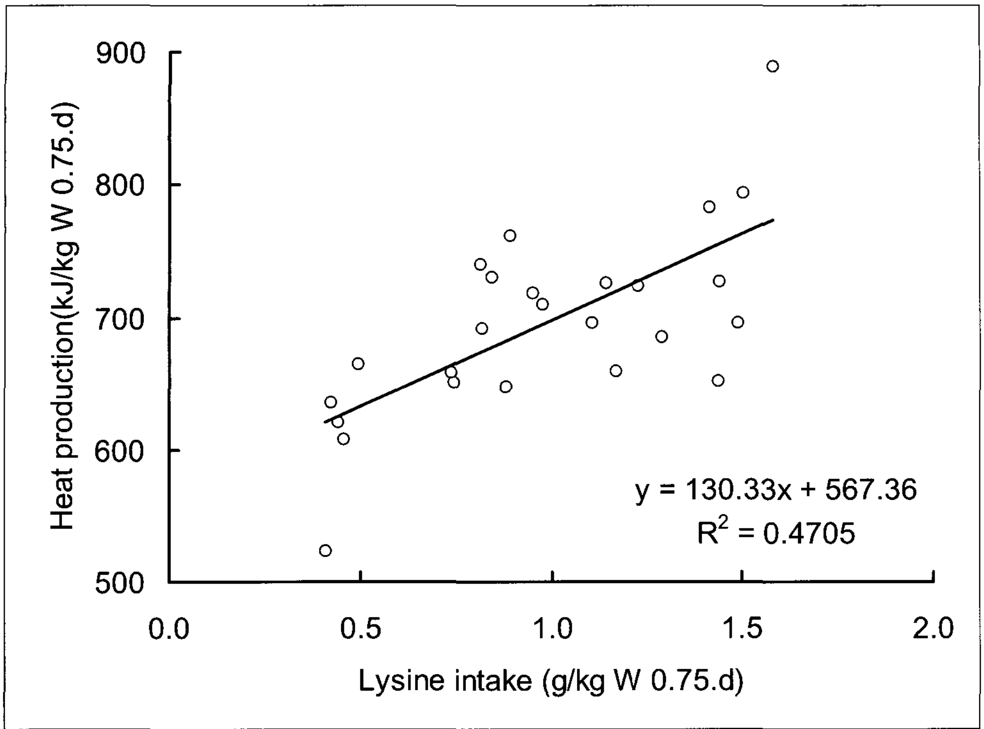

Figure 1. The relationship between lysine intake and heat production at high ambient temperature. Standard errors are showd in square brackets. HP = 130.3[28.8]I_{Lys} + 567.4[30.4] (P<0.001)

20 ℃. It was also highly correlated with lysine intake (r=0.686, P<0.001; Figure 1). There was a 23 % increase in HP in birds fed on Diet 14 compared with those fed on Diet 11. Birds fed on Diet 15 showed lower HP than the birds on lower lysine diets. Mean HP of all diet groups was about 20 % lower at 30 ℃ in comparison with the experiment at 20 ℃. A reduction in heat production(kJ/d) with increasing temperature was reported by Davis et al., (1973) and Farrell and Swain (1977) and when corrected to the same body weight by Klandorf et al. (1981) and MacLeod (1990, 1992).

Conclusion

As results suggested, there was no significant change in the energy cost of protein accretion between high-CP and low-CP diets. There was little indication of regulatory diet-induced thermogenesis when an imbalanced amino acid mixture or excess amino acids were fed. Based on the results, it may be concluded that control of first limiting amino acid or energy intake has priority in the control of food intake and growth. However, more research is needed to determine in detail which factors affect growth negatively. It should also be valuable to study effects of amino acids other than lysine to improve performance. It is clear that high ambient temperature had a large suppressing effect on food intake and performance of birds. The utilisation of protein and energy strongly interacts with ambient temperature and many of regions where the broiler industry are located have long periods of high ambient temperature that will impact negatively on growth performance. In the study of amino acid and energy requirement, therefore, the effect of ambient temperature always should be considered. As showed in N utilisation results, it is also confirmed that reduction of dietary CP level had a beneficial effect in terms of reducing N excretion.

적 요

본 실험은 사료내 아미노산 균형과 라이신 함량이 성장기 브로일러의 에너지 대사 중 Heat production(HP)과 질소 대사에 어떤 영향을 미치는지 규명하기 위해 실시하였다. 실험1은 여러 단계의 조단백 함량과, 제1제한 아미노산으로써 일정 농도의 라이신 함량으로 만들어진 사료로 테스트하였다. 실험2에서는 이와 반대로 일정한 조단백 함량과 각기 다른 수준의 라이신을 함유한 사료들을 사용하였다. Thermoregulatory demand에 따른 영향을 최소화하기 위해 실험3은 이전 실험들(20 ℃)보다 높은 온도인 30 ℃에서 시행되었다. 에너지 및 질소 대사 실험은 컴퓨터로 제어되는 multi-chamber calorimeter system을 사용하여 조사하였으며 사료의 단백질 및 라이신 조성에 따른 닭의 HP를 측정하였다. 또한 이를 통해 나온 결과들은 에너지 대사 컴퓨터 시뮬레이션 모델을 통한 예측치와 비교하였다.

다양한 단백질 함량과 일정한 라이신 함량의 사료를 통한 실험에서 단백질 함량이 증가함에 따라 질소 섭취에서는 75 %의 증가가 나타났다. 이것은 질소 배출에 있어서 150 %의 증가를 가져왔으나 이에 따른 HP에 유의적인 차이는 보이지 않았다. 다양한 라이신 함량과 일정한 단백질 함량의 사료를 사용한 실험2에서는 최저 라이신과 최고 라이신 처리구 간에 3배의 증체량의 차이를 보여주었다. HP에 있어서는 라이신 증가에 따라 유의적으로 증가하는 경향을 보였으나 체중 보정치에 있어서는 유의차가 사라졌다. 실험1과 실험2, 두 실험의 시뮬레이션을 통한 HP 계산치에 있어서도 처리구들 간에 차이를 보이지 않았다. 30 ℃에서 실시된 실험3에서는 실험2와 동일하게 라이신 함량 증가에 따라 HP가 유의적으로 증가하였으나 그 경향은 이전 실험보다 크게 나타났다. 결과를 종합할 때, 총 HP의 발생은 사료의 단백질 함량보다는 제한 아미노산 농도와 더욱 관련이 깊으며, 아미노산 불균형에 따른 질소 배출로 인해 발생하는 energy cost가 차지하는 비율은 높지 않은 것으로 사료된다. 또한 질소 축적율에서 볼 때, 사료내 아미노산 균형이 체내 질소 이용효율과 밀접한 관련이 있음을 확인하였다.

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