Applied Model of Nutrient Oxidation in Male Broilers Reared under Different Temperatures

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Abstract

Effects of the environmental temperatures on nutrient oxidation were evaluated in male broiler chickens. The chickens were allocated into twelve cages with six chickens per cage during the first week and three chickens in the following five weeks of experiment. The temperatures were set on T0 = 21^{o}C, T1 = 24^{o}C, and T2 = 28^{o}C. A 22 to 24-hour-respiration measurement was made in the middle of each five-day collection period using an open-air circulation respiration unit. The results showed that the increase of temperature decreased protein (OXP) and fat oxidation (OXF; P<0.05), but there was no difference (P>0.05) on carbohydrate oxidation (OXCHO). Lipogenesis from carbohydrate made up the main constitution (69 to 78%) to the total fat retention. In contrast, fat retention from protein (8.8 to 9.6) was the minor contribution, and there was no difference (P<0.05) among the groups. Furthermore, the conversion of dietary fat to the fat retention was increased (12.1 to 21.4) following the increase of the environment temperature. In conclusion, the temperature range of 21 to 28^{o}C used was still in the tolerable hot zone since the oxidation of protein, carbohydrate and fat were not influenced. However, the utilization of protein and fat depended on the environmental temperature except for carbohydrate.

Key Words : Nutrient Oxidation, Broiler, Temperature, Retention, Lipogenesis, Utilization)

Pengaruh Temperatur Lingkungan terhadap Oksidari Zat Makanan Ayam Broiler Jantan

Intisari

Pengaruh temperatur lingkungan terhadap oksidari zat makanan dievalusi dengan menggunakan ayam potong (broiler) jantan. Tujuh puluh dua ayam broiler umur satu hari dibagi dalam 12 kandang dengan 6 ekor per kandang pada minggu pertama dan 3 ekor ayam sampai pada lima minggu berikutnya. Terperatur di set serbagai perlakuan T0 = 21^{o}C, T1 = 24^{o}C dan T2 = 28^{o}C. Pengukuran pertukaran gas yaitu konsumsi O_2 and produksi CO_2 dengan menggunakan ruang respirasi sistim udara terbuka untuk lima hari periode percobaan. Hasil menunjukkan bahwa kenaikan suhu menyebabkan penuruna oksidsi protein dan lemak (P<0,05), tetapi oksidasi karbohididrat tidak berbeda (P>0,05).Lipogenesis dari karbohidrat sebagai penyumbang utama (69 -78%) retensi lemak. Sebaliknya, retensi lemak dari protein hanya menyumbangkan 8,8 – 9,6% dan tidak ada perbedaan (P>0,05) untuk semua kelompok. Selanjutnya, retensi lemak dari konversi lemak pakan meningkat dari 12,1 menjadi 21,4 seiring dengan kenaikan suhu dalam percobaan. Kesimpulan, suhu antara 21 sanpai 28^{o}C masih dalam daerah kisaran suhu yang masih dapat ditoleransi karena oksidasi lemak, protein dan karbohidrat tidak terpengaruh, namun utilisasi lebih lanjut untuk lemak dan protein terpengaruh.

Kata Kunci: oxidation zat makanan, broiler, suhu, retensi, lipogenesis, utilisasi

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Introduction

A lot of work on the use of environmental temperatures has been focused on their effects in farm animals, especially on their performances, nutrient status and physiological responses. However, a little attention has been paid to the effects of environmental temperatures on quantitative relations between digested nutrients and their final output from catabolic processes in poultry. Thus, the objectives of this study were to investigate the quantitaive of dietary carbohydrate, protein, fat and the contributin of each nutrient to fat retention in broiler chickens reared under different environmental temperature.

Material and Method

Seventy-two day-old male broiler chickens, Ross Cobb obtained from a commercially hatchery, were used in the experiment. The chickens were allocated into twelve cages with six chicks per cages during the first week and three chicks in the following five weeks of the experiment. The cages were divided into three treatments groups with four replicates each. The treatments were T0 = 21^{o}C, T1 = 24^{o}C and T2 = 28^{o}C. The temperatures in the cages were maintained at 34 - 36^{o}C for the first week with additional bulb lamp and reduced at rate of about 1 - 3^{o}C until it reached 21^{o}C, 24^{o}C, and 28^{o}C for T0, T1, and T2, respectively. The relative humidity was 60 to 70%.

The cages were equipped with feeders, and two hanging nipple drinkers supplied water through pipe positioned at the back of cages. Dropping felt through wire mesh floors into the dropping trays. The diameter of the wire used in the first period of growth was 1.0 cm while 2.0 cm was used in the later periods. Chickens were fed a commercial diet containing 16.8 MJ of gross energy (GE) and 22.5% of crude protein (CP) and given ad libitum for a five-day collection period for every week. Feed residues were weight, mixed, and used for dry matter (DM) determination to correct the differences in DM content between feed given and feed residues. Droppings were collected daily before feeding and analyzed for DM and (CP). The values of GE were obtained by means of calorimetric bombs.

A 22 to 24-hour respiration measurement was made in the middle of each five-day collection period using an open-air circulation respiration unit. In the respiration chambers, the temperature and humidity were controlled according to the treatment groups. The airflow in the system is measured by the differential pressure principle, and the composition of outgoing air is measured using an infrared gas analyzer Uras (Hartmann and Braun, Germany) for carbon dioxide and paramagnetic analyzer Magnos (Hartmann and Braun, Germany) for oxygen. The gas exchange was calculated from the difference between the concentration of atmospheric gas entering and leaving the chamber. The difference in gas concentration was multiplied by the rate of flow at which the gas was withdrawn from the chamber.

An outline of measurements and calculations is shown in Figure 1. The quantitative data measurements of substrate oxidation were calculated from the measurements of gaseous exchange and, nitrogen excretion in urine and fat retention based on Brouwer's equation (1958) and later validated by Chwalibog and Thorbek (1992). All measurements are reported in relation to metabolic body weight (W, kg$^{0.75}$), and the following terminology and calculation are used:

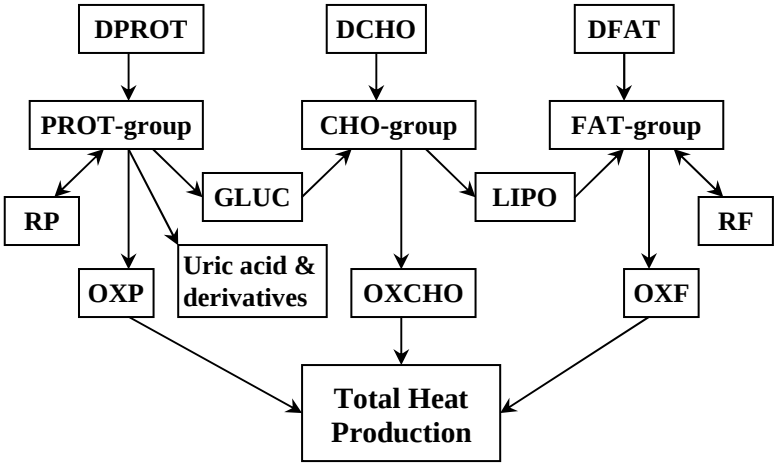

Figure 1. Model of nutrient oxidation and retention (Chwalibog, 1997)

Protein metabolism

IP, g (ingested protein) = IN, g (ingested nitrogen) x 6.25
DRP, g (dropping protein) = DRN, g (dropping nitrogen) x 6.25
RP, g (retained protein) = IP – DRP
FN, g (faecal nitrogen) = IN x 0.20, assuming digestibility is 80%
UN, g (urinary nitrogen) = DRN – FN
DP, kJ (digested protein) = IP x 0.80 x 23.86
PROT-group, kJ (protein group) = DP
OXP, kJ (oxidized protein) = UN, g x 6.25 x 18.42
RP, kJ = RP, g x 23.86
GLUC, kJ (gluconeogenesis) = DPROT, kJ – OXP, kJ –RP, kJ

Carbohydrate metabolism

DCHO, kJ (digested carbohydrate) = ME x 1.05 –DPROT, kJ – (DFAT, g (digested fat) x 39.76), assuming DE is 5% higher than ME
OXCHO, kJ (oxidized carbohydrate) = (-2.968 x O_2, l - CO_2, l - 2.446 x UN, g) x 17.58
CHO-group, kJ (carbohydrate group) = DCHO, kJ +GLUC, kJ
LIPO, kJ (lipogenesis) = CHO-group, kJ – OXCHO, kJ

Fat metabolism

DFAT, kJ (digested fat) = DFAT, g x 39.76
FAT-group, kJ (fat group) = DFAT, kJ + LIPO, kJ
OXF (oxidized fat), kJ = (1.719 x O_2, l – 1.719 x CO_2, l – 1.963 x UN, g) x 39.76
RF, kJ (retained fat) = Fat-group, kJ – OXF, kJ

Heat production

HE(RQ), kJ = 16.18 x O_2, l + 5.02 x CO_2, l – 5.99 x UN, g

Contribution of each nutrient metabolism to fat retention

RF(P), % retained fat from protein = (DP, kJ – OXP, kJ – RP, kJ)/RF, kJ
RF(CHO), % retained fat from carbohydrate = (DCHO, kJ – OXCHO, kJ)/RF, kJ
RF(F), % retained fat from fat = (DF, kJ – OXF, kJ)/RF, kJ

The statistical analysis was unbalanced ANOVA procedure in completely randomized block design using the GLM procedure, and Duncan's multiple range test was used to compare treatment means (SAS Institute, 1988). The mathematical description of an observation is given by:

$Y_{ijk} = \mu + \beta_i + \tau_j + (\beta\tau)_{jk} + \varepsilon_{(ij)k}$

μ = treatment mean

β_i = effect of period $_i$

τ_j = effect of treatment $_j$

$(\beta\tau)_{jk}$ = interaction between period and treatment

$\varepsilon_{(ij)k}$ = experimental error

Result and Discussion

The summary of protein utilization is shown in Table 1. OXP and GLUC were significantly different (P<0.05), whereas, DP and RP were not significantly different (P>0.05). The results showed that the increase of temperature from 21 to 24°C did not give any differences in OXP and GLUC, but further increase up to 24°C gave significant difference for both of them.

Table 1. Means of Retained Protein (RP), Oxidized Protein (OXP), Gluconeogenesis (GLUC) and Their Proportions to Digested Protein (DP)

	T0 (21°C)	T1 (24°C)	T2 (28°C)
DP, kJ	500.3	497.1	495.7
RP, kJ	374.0	371.5	370.9
OXP, kJ	90.7[a]	91.6[a]	82.4[b]
GLUC, kJ	35.6[a]	34.0[a]	42.4[b]
RP/DP, %	74.8	74.7	74.8
OXP/DP, %	18.1	18.4	16.6
GLUC/DP, %	7.1[a]	6.8[a]	8.6[b]

[a-b] *Means within a row followed by superscript is significantly different (P<0.05).*

The proportions of RP and OXP to DP were not significantly different (P>0.05), but the proportion of GLUC to DP was significantly different (P<0.05). The proportion of GLUC to DP was higher at the temperature of 28°C. Heat stress generally had no significant effect on amino acid digestibility except for His and Lys digestibility. Histidine digestibility was higher during the heat stress period

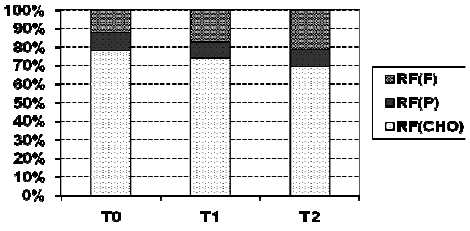

Figure 2. Retained fat (RF) from dietary carbohydrate (CHO), protein (P) and fat (F) in percentage of total RF

than during the initial and recovery thermoneutral periods, whereas Lys digestibility was higher during the heat stress period than during the initial thermoneutral period. These results indicated that acute heat stress (8 d) had no adverse effects on dietary amino acid digestibility in laying hens (Koelkebeck et al., 1998). However, Nitrogen retention was significantly reduced in 32°C birds compared to 22°C birds, irrespective of the diet (Bonnet et al.,1997)

Consistent with acute heat stress induced alterations in thermoregulatory indices and muscle membrane integrity were changes in breast muscle glycolytic metabolism as indicated by lower muscle pH immediately posts-laughter (Sandercock et al., 2001). Moreover, this is in agreement with the study that has demonstrated partial protein efficiency was higher in the birds with lower growth hormone, especially at low temperature (Buys dkk, 1999).

Table 2. Means of Digested Carbohydrate (DCHO) and the Proportions of Oxidized Carbohydrate (OXCHO) and Lipogenesis (LIPO) to Carbohydrate Group (CHO-group)

	T0 (21°C)	T1 (24°C)	T2 (28°C)
DCHO, kJ	851.4	846.9	849.3
CHO-group, kJ	887.0	880.9	891.7
OXCHO, kJ	562.3	562.4	539.7
LIPO, kJ	324.7	318.5	352.0
OXCHO/CHO-group, %	63.4	63.8	60.5
LIPO/CHO-group, %	36.6	36.2	39.5

The results of carbohydrate utilization are given in Table 3. Values for DCHO, CHO-group, OXCHO, and the use of the CHO-group for oxidation and lipogenesis were not significantly different (P>0.05). The mean value of LIPO was numerically increased in T2 but was not statistically different.

There are possibilities concerning to carbohydrate metabolism, especially in the form of glucose. Such the result from this study showed that neither the digestibility nor the utilization of carbohydrate was different. These results may be due to the temperatures used are still in the tolerable hot zone. This reason can be explained that when the chickens are under heat stress, the plasma glucose concentration can decrease. The decrease can be due to the decrease in concentration of insulin and thyroxin but can be due to the increase in glucose utilization in order to produce more energy for greater muscular expenditure required for respiratory activity (Phillips and Piggins, 1992). The decrease can also due to the decrease of glucose utilization, the depression of both anabolic and catabolic enzyme secretions and the increase in glucocorticoid hormones or the subsequent reduction in metabolic rate.

Table 3. Means of digested fat (DF) and the Proportions of Oxidized fat (OXF) and Retained fat (RF) to Fat Group (Fat-group)

	T0 (21°C)	T1 (24°C)	T2 (28°C)
DF, kJ	199.2	194.6	198.3
Fat-group, kJ	523.9	513.1	550.3
OXF, kJ	154.4[a]	127.7[b]	102.5[c]
RF, kJ	369.5 [a]	385.4 [a]	447.8 [b]
OXF/Fat-group, %	29.5 [a]	24.9 [ab]	18.6 [b]
RF/Fat-group, %	70.5 [a]	75.1 [ab]	81.4 [b]

[a-c] *Means within a row followed by superscript is significantly different (P<0.05).*

The results of fat utilization are given in Table 3. The results showed that the environmental temperature resulted in an increase (P<0.05) in OXP in spite of there being no effect on the DF and Fat-group. Therefore, the temperature increased RF, and the response seemed to be in linear. The proportion OXP/Fat-group decreased as the temperature was increased (P<0.05), but adverse response was shown in RF/Fat-group.

A chemical analysis of the chicken meat showed significantly higher fat content in thigh muscles of the males in the group of day average temperature 38 and night average temperature 30°C and average relative humidity of 55% compared to the other groups of broiler chickens exposed to lower constant

ambient temperatures (Blaha dkk, 2000). The increase in plasma T(3) concentration at low temperatures was accompanied by a decrease in relative fat deposition from the increased energy expenditure(Buys dkk,1999)

Table 4. Means of respiratory quotient (RQ), metabolizable energy (ME), and the proportion of oxidized protein (OXP), oxidized carbohydrate (OXCHO) and oxidized fat (OXF) to heat production (HE)

	T0 (21°C)	T1 (24°C)	T2 (28°C)
RQ	0.92[a]	0.93[ab]	0.96[b]
HE, kJ	807.19 [a]	780.83 [a]	724.30 [b]
ME, kJ	1495	1474	1455
OXP/HE, %	11.22	11.73	11.38
OXCHO/HE, %	69.66	72.00	74.50
OXF/HE, %	19.12 [a]	16.28 [b]	14.14 [c]

[a-c] *Means within a row followed by superscript is significantly different (P<0.05)*

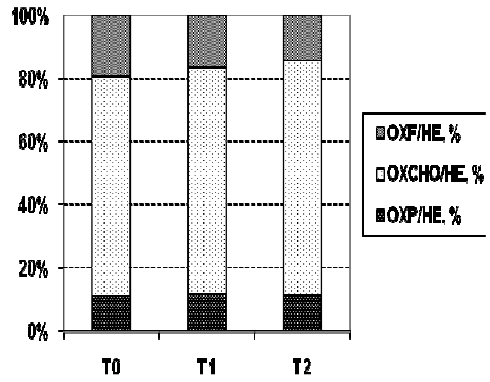

Figure 3. Proportion of oxidized protein (OXP) oxidized carbohydrate (CHO) and oxidized fat (OXF) to heat production (HE).

In conclusion, the temperature range of 21 to 28°C used is still in the tolerable hot zone since the digestibility of protein, carbohydrate and fat were not influenced. However, the utilization of protein and fat depends on the environmental temperature. In addition, carbohydrate is always the main source of nutrient utilized for heat production since there were no differences in its oxidation.

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