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Dietary Selection of Fat by Heat-stressed Broiler Chickens

I. Zulkifli*, Nwe Nwe Htin, A. R. Alimon, T. C. Loh and M. Hair-Bejo[1]
Department of Animal Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

ABSTRACT : A total of 160 d-old male broiler chicks (Cobb) were brooded for three weeks and then maintained at 24±1°C. Commencing from d 21, chicks were assigned to one of four feeding regimens: (1) diet with 8% palm oil (PO), (2) diet with 8% soybean oil (SO), (3) diet without added fat (control), (4) a choice of PO, SO and control (CH). The diets were formulated to maintain a constant ratio of energy and protein. From d 28 to 41, all birds were exposed to 34±1°C. The PO, SO and CH birds had greater body weight than controls on d 42. The PO but not SO diet reduced mortality rate, body temperature and serum creatine kinase level of broiler chickens during heat exposure. Although the total intake of control, PO and SO diets was not significantly different during heat exposure, the CH birds had lower creatine kinase activity and mortality rate than those provided SO diet but not significantly different from the birds fed control and PO diets. The relative abdominal fat weight and breast intramuscular fat content percentage were significantly lower in the control birds than those of PO, SO and CH groups. There were no significant differences in both parameters among the three latter groups. These findings suggest that the uncertainty of how much dietary fat to put into diets for heat stressed broilers can be overcome by allowing them to select their own consumption. (**Key Words :** Dietary Selection, Dietary Fat, Heat Stress, Broiler Chickens)

INTRODUCTION

There is considerable evidence that a higher dietary fat content contributes to improved heat tolerance in broiler chickens (Daghir, 1995). Zulkifli et al. (2003) reported that providing diets containing high levels of palm oil enhanced growth performance and survivability of heat-stressed broiler chickens. However, the addition of high level of fat to broiler rations may result in excessive visceral fat, loss of vitamin A and E by oxidation and changes in the flavour of poultry meats (Patrick and Schaible, 1980). Fat sources with high level of free fatty acids, polyunsaturated fatty acids, and low levels of antioxidant are especially susceptible to oxidative rancidity (Klasing, 1997). Hence, the problem arises as to how to match the birds' requirements with the appropriate level and source of dietary fat under heat stress conditions.

There is considerable evidence that birds have appetites for specific nutrients and can regulate their intake according to their nutritional requirements (Forbes, 1995; Zulkifli et al., 2001). Kutlu and Forbes (1993) reported that choice feeding of ascorbic acid may allow the birds to match their physiological requirements. The authors noted that birds kept in an "unstressful" environment consumed significantly lower proportion of the ascorbic acid supplemented food than those maintained under heat-stressed conditions. There is the question whether birds can be trained to adjust their intake of high dietary fat to meet the requirements for dietary fat according to ambient temperature. Earlier studies (Dale and Fuller, 1978; 1979) showed that choice-fed broilers preferred high fat diets over rations containing high carbohydrate or low fat irrespective of ambient temperature, feed texture and location of feeders. Dale and Fuller (1978) reported that birds provided a single high fat diet had greater weight gains but similar feed conversion ratios and feed intake as compared to those given a choice of high fat and high carbohydrate diets. To the authors' knowledge, there are no published data on the effects of dietary self-selection of fat on the physiology of broiler chickens exposed to high ambient temperatures. In the present study, the ability broiler chickens to select adequate proportion of high dietary fats with varying fatty acids saturation under heat stress conditions and its effect on performance, physiology and fat deposition were investigated.

* Corresponding Author: I. Zulkifli. Tel: +603-89466908, Fax: +603-89432954, E-mail: zulkifli@agri.upm.edu.my
[1] Department of Veterinary Pathology and Microbiology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
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Table 1. Compositions of starter diet (day 1 to 20) (% unless otherwise stated)

Ingredients	%
Corn	60.60
Soy meal	10.73
Broken rice	5.00
Corn gluten 60% protein	17.00
Fish meal	3.00
Common salt	0.20
Vitamin-mineral mix[1]	0.20
DCP	1.32
Lime stone	1.35
Methionine	0.04
Lysine	0.30
60% choline chloride	0.25
Antioxidant	0.01
Total	100
Calculated analysis	
ME (kcal/kg)	3,158.41
Crude protein (%)	23.13
ME/CP	136.55
Ether extract (%)	3.15

[1] Supplied per kg diet: Fe 100 mg; Mn 110 mg; Cu 20 mg; Zn 100 mg; I 2 mg; Se 0.2 mg; Co 0.6 mg; santoquin 0.6 mg; vitamin A 6,667 IU; vitamin D 1,000 IU; vitamin E 23 IU; vitamin K_3 1.33 mg; cobalamin 0.03 mg; Thiamin 0.83 mg; riboflavin 2 mg; folic acid 0.33 mg; biotin 0.03 mg; pantothenic acid 3.75 mg; niacin 23.3 mg; pyridoxine 1.33 mg.

Table 2. Compositions of finisher diets[1] (% unless otherwise stated) (day 21-41)

Ingredients	Diets		
	Control	PO	SO
Corn	64.00	49.00	4.00
Soy meal	10.98	26.48	31.48
Broken rice	5.00	6.00	50.00
Corn gluten 60% protein	14.00	4.00	0.00
Fish meal	3.00	3.00	3.00
Palm oil	-	8.00	-
Soy bean oil	-	-	8.00
Common salt	0.20	0.20	0.20
Vitamin-mineral mix[2]	0.10	0.20	0.20
DCP	1.15	1.15	1.15
Lime stone	1.00	1.00	1.00
Methionine	0.10	0.20	0.20
Lysine	0.20	0.50	0.50
60% choline chloride	0.25	0.25	0.25
Antioxidant	0.02	0.02	0.02
Total	100	100	100
Calculated analysis			
ME kcal/kg	3,166.81	3,164.41	3,151.71
Crude protein (%)	21.68	21.77	21.76
ME/CP	146.06	145.31	144.84
Ether extract (%)	3.21	8.71	9.09

[1] Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil.
[2] Supplied per kg diet: Fe 100 mg; Mn 110 mg; Cu 20 mg; Zn 100 mg; I 2 mg; Se 0.2 mg; Co 0.6 mg; santoquin 0.6 mg; vitamin A 6,667 IU; vitamin D 1,000 IU; vitamin E 23 IU; vitamin K3 1.33 mg; cobalamin 0.03 mg; Thiamin 0.83 mg; riboflavin 2 mg; folic acid 0.33 mg; biotin 0.03 mg; pantothenic acid 3.75 mg; niacin 23.3 mg; pyridoxine 1.33 mg.

MATERIALS AND METHODS

Birds, husbandry and experimental procedure

In total, 160 d-old male chicks of a commercial broiler strain (Cobb) were purchased and randomly assigned in groups of 5 to 32 cages with wire floors in an environmentally controlled chamber. Ambient temperature was set at 32±1°C and then gradually decreased until 24±1°C on d 21. A standard starter diet (Table 1) without added fat was given to the chicks from arrival until 20 d of age. Feed and water were available at all times. Continuous lighting was provided. All birds were vaccinated against Newcastle disease via intraoccular route on d 7 and d 21. From d 21 onwards equal numbers of chicks were assigned to one of four feeding regimes (8 cages/feeding regime). The feeding regimens were: (1) control diet (without added fat), (2) diet supplemented with 8% palm oil (PO), (3) diet supplemented with 8% soybean oil (SO), and (4) a choice of control, PO and SO diets (CH). The diets were formulated to maintain a constant ratio of energy and protein to meet the minimum requirement of NRC (1994). Compositions of the finisher diets are shown in Table 2.

In cages in which choice feeding was provided, each diet was randomly assigned in one of the troughs (3 troughs per cage) and the positions were not changed during the experiment. The troughs were attached to the front of each cage. Sufficient space (15 cm/chick) was allowed so that all chicks could eat each diet simultaneously. In cages where birds were received a single diet, the feed was also provided in three troughs attached to each cage. The period from d 21 to 27 was considered as a training period for the chicks to adapt to the physiological effects of each diet.

Growth performance

Prior to feeding, body weight was measured individually on d 21, 28, 35 and 42. Weekly feed consumption was recorded and feed conversion ratios (FCR) were calculated as g food ingested per g live weight gain. The feed intake of choice-fed groups was recorded daily as intake from each diet from d 21 to 41 and expressed as percentage of total intake. Mortality was recorded as it occurred.

Heat challenge

From d 28 to d 41, all the birds were exposed to 34±1°C and 60-70% relative humidity daily. Feed and water were provided throughout the heat challenge period.

Body temperature and blood collection

Prior to heat exposure (d 21) and on d 28, 35 and 41, immediately following heat challenge, 2 birds from each cage (16 birds per treatment) were randomly chosen and rectal temperatures were recorded with the aid of a digital

Table 3. Mean (±SEM) body weights, feed consumptions, feed conversion ratios (FCR) and mortality rates of broilers chickens[1] by diet

Parameters	Diet[2]			
	Control	PO	SO	CH
Body weight (g per bird)				
Day 21	435±9.24	423±8.96	449±9.93	443±7.81
Day 28	643^{c}±12.46	695^{b}±13.41	754^{a}±20.07	699^{b}±12.36
Day 35	875^{c}±16.27	998^{ab}±17.30	1056^{a}±27.34	990^{b}±20.20
Day 42	1004^{b}±18.25	1143^{a}±20.36	1133^{a}±28.06	1088^{a}±25.28
Feed consumption (g per bird)				
Day 21-27	533^{ab}±19.00	508^{b}±16.33	548^{ab}±17.72	574^{a}±19.78
Day 28-34	557±19.27	563±19.59	527±14.32	573±9.43
Day 35-41	435^{ab}±17.52	470^{a}±15.91	362^{c}±22.68	399^{bc}±30.10
Total	$1,524^{a}$±38.52	$1,540^{a}$±39.18	$1,438^{ab}$±22.43	$1,546^{a}$±39.94
FCR (feed per gain)				
Day 21-27	2.56^{a}±0.07	1.86^{b}±0.09	1.80^{b}±0.08	2.50^{a}±0.05
Day 28-41	1.71^{a}±0.06	1.44^{bc}±0.04	1.33^{c}±0.03	1.53^{b}±0.04
Overall (day 21-41)	2.19^{a}±0.08	1.86^{b}±0.03	1.90^{b}±0.07	2.03^{ab}±0.03
Mortality % (day 28-41)	5^{b}	5^{b}	20^{a}	10^{ab}

[a-c] Means within a row with no common superscripts differ at p≤0.05.
[1] From day 28 to 41, all chickens were exposed to 34±1°C.
[2] Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil, CH = choice feeding.

thermometer. The probe was inserted into the cloaca to a depth of about 3 cm, for about one minute. Immediately following recording of rectal temperature, blood samples (2.5 ml) were obtained from each bird for heterophil (H) to lymphocyte (L) counts, and serum concentrations of creatine kinase, cholesterol, protein, sodium, potassium and chloride. Blood samples for H and L counts were collected in tubes containing EDTA as anticoagulant. Blood smears were prepared using May-Grünwald- Giemsa stain, and H and L were counted to a total of 60 cells (Gross and Siegel, 1983). Blood samples for serum concentrations of creatine kinase, cholesterol, protein, sodium, potassium and chloride were serum separated and stored at -20°C. Analyses for serum creatine kinase, cholesterol, protein, sodium, potassium, and chloride were conducted on an automated spectrophotometer Ultraspec® 300; Cobas-Mira, Roche Diagnostic System, CH4070 Basel, Switzerland) using a standard diagnostic kit.

Abdominal fat pad and meat samples

On d 42, 2 birds per cage (16 birds per treatment) were randomly chosen, slaughtered and plucked mechanically. Abdominal fat pads (fat surrounding the bursa of fabricius, cloaca and adjacent muscles) and their breast portions were anatomically excised for determination of weight and killed to determine relative abdominal fat pad and breast intramuscular lipids, respectively. The percentage of intramuscular breast crude fat content was conducted with the aid of 2,050 Soxtec, Auto extraction unit, Foss Tecator. The general principles were according to AOAC (1984).

Statistical analysis

Data were subjected to ANOVA using General Linear Model procedure of SAS® (SAS® institute Inc., 1991). Performance, relative abdominal fat weight and breast intramuscular fat content percentage data were analysed with diet as the main effect. Weights of abdominal fat pads were expressed relative to body weight and transformed to arc sine square roots prior to analyses. The H/L ratio, body temperature, and serum level of blood metabolites data were tested for the effect of diet, age and their interactions. When interactions between main effects were significant, comparisons were made within each experimental variable. Diet preference in choice fed birds was measured by the consumption of each diet expressed as a ratio of total intake. Percentages were transformed to arc sine square roots, and analysed separately for each week. When significant (p≤0.05) effects were found, comparisons among multiple means were model by Duncan's Multiple Range Test. Mortality was analysed by Chi-Square test.

RESULTS

The effect of feeding regimen on performance is shown in Table 3. In general, irrespective of feeding regimen, two weeks of heat exposure resulted in a dramatic retardation of body weight. On d 28, the SO chicks had greater body weights than those of PO, CH and controls. However, on d 42, the body weight of SO, PO and CH chicks did not differ significantly. The control diet depressed body weight on d 28, 35 and 42. From d 28 to 34, feed consumption was not affected by feeding regimen. The PO chicks consumed significantly more feed than those fed SO and CH from d 35 to 41. Feeding regimen had no significant effect on total feed consumption. Feed conversion ratios of PO and SO chicks were significantly better than their control and CH

Table 4. Mean (±SEM) proportional intake of each diet by choice fed broiler chickens[1] by diet

	Diet[2]		
	Control	PO	SO
Day 21-27	0.44^{a}±0.04	0.28^{b}±0.05	0.28^{b}±0.05
Day 28-35	0.37±0.04	0.29±0.03	0.34±0.04
Day 35-41	0.29±0.04	0.31±0.05	0.40±0.04
Total	0.37±0.10	0.30±0.11	0.33±0.13

a, b Means within a row with no common superscripts differ at p≤0.05.
1 From day 28 to 41, all chickens were exposed to 34±1°C.
2 Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil, CH = choice feeding.

counterparts from d 21 to 27. During the heat exposure period (d 28 to 41), the control chicks showed the poorest FCR than the other three groups of birds. The FCR of PO, SO and CH chicks did not differ significantly during the heat challenge period. The overall FCR of PO and SO chicks were significantly better than control birds, but did not differ significantly from their CH counterparts. The heat exposure resulted in higher mortality rates among SO birds but not those fed PO and control diets. The mortality rates of CH birds were not significantly different to the other three groups.

From d 21 to 27, the CH birds consumed significantly more control than PO and SO diets (Table 4). The diet selection among three different diets did not differ significantly, thereafter.

Significant feeding regimen×age interactions were noted for body temperature (Table 5). Prior to heat exposure (d 21) and on d 28, the mean body temperatures of all birds were not significantly different. On d 35, SO and CH chicks were more hyperthermic than their control counterparts.

Table 6. Mean (±SEM) heterophil/lymphocyte ratios in broiler chickens[1] where diet×age interactions were significant

Age	Diet[2]			
	Control	PO	SO	CH
Day 28	0.45^{ay}±0.05	0.36^{aby}±0.03	0.34^{aby}±0.04	0.30^{by}±0.02
Day 35	0.33^{bcy}±0.01	0.30^{cy}±0.02	0.41^{ay}±0.03	0.38^{aby}±0.03
Day 41	0.64^{bx}±0.06	0.81^{ax}±0.03	0.89^{ax}±0.06	0.72^{abx}±0.03

a, b Means within a row with no common superscripts differ at p≤0.05.
x, y Means within a column with no common superscripts differ at p≤0.05.
1 From day 28 to 41, all chickens were exposed to 34 ± 1ºC.
2 Control = without added fat, PO = 8% palm oil, SO 8% soybean oil, CH = choice feeding.

Body temperature of PO chicks did not differ from their other counterparts on d 35. Feeding regimen, however, had no significant effect on body temperature on d 42.

There were significant diet×age interactions for HLR (Table 6). The effect of feeding regime on HLR was inconsistent with age. Following 7 d of heat treatment (d 35), PO birds had significantly lower HLR than those of SO and CH. On d 42, however, the HLR of PO, SO and CH birds were similar.

Interaction of diet x age was significant for serum levels of creatine kinase (Table 7). The significant effect of diet was only noted on d 21 and 42. On d 21 (prior to heat exposure), provision of control diet increased serum levels of creatine kinase as compared to those PO and SO chicks. Following two weeks of heat exposure (d 42), the creatine kinase concentrations of SO birds were significantly higher than the other groups.

Table 8 shows the effects of feeding regimen and age on serum levels of cholesterol, protein, potassium and chloride. There was no significant feeding regimen by age interaction

Table 5. Mean (±SEM) body temperatures of broiler chickens[1] where diet x age interactions were significant (°C)

Age	Diet[2]			
	Control	PO	SO	CH
Day 21	39.24^{z}±0.11	39.14^{z}±0.14	39.16^{z}±0.16	39.14^{y}±0.21
Day 28	42.68^{y}±0.18	42.70^{y}±0.16	42.68^{y}±0.20	42.85^{x}±0.17
Day 35	42.71^{by}±0.19	42.97^{aby}±0.13	43.28^{ax}±0.10	43.31^{ax}±0.11
Day 41	43.33^{x}±0.12	43.47^{x}±0.11	43.33^{x}±0.12	43.27^{x}±0.08

a, b Means within a row with no common superscripts differ at p≤0.05.
x-z Means within a column with no common superscripts differ at p≤0.05.
1 From day 28 to 41, all chickens were exposed to 34±1°C.
2 Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil, CH = choice feeding.

Table 7. Mean (±SEM) levels of serum creatine kinase in broiler chickens where diet×age interactions were significant (IU/L)

Age	Diet			
	Control	PO	SO	CH
Day 21	$2,363^{a}$±278	$1,413^{by}$±115	$1,920^{aby}$±146	$1,656^{by}$±151
Day 28	1,983±215	$2,997^{x}$±562	$2,521^{xy}$±324	$2,204^{xy}$±321
Day 35	2,422±274	$2,400^{xy}$±223	$2,320^{y}$±260	$2,856^{x}$±324
Day 41	$1,872^{b}$±291	$2,066^{bxy}$±295	$3,479±519^{ax}$	$2,403±326^{bxy}$

a, b Means within a row with no common superscripts differ at p≤0.05.
x, y Means within a column with no common superscripts differ at p≤0.05.
1 From day 28 to 41, all chickens were exposed to 34±1°C.
2 Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil, CH = choice feeding.

Table 8. Mean (±SEM) serum levels of cholesterol, protein, sodium, potassium and chloride in broiler chickens[1] by diet and age (m mol/L)

	Blood parameters				
	Cholesterol	Protein	Sodium	Potassium	Chloride
Diet[2]					
Control	3.98±0.10	24.54±0.42	137.86±0.99^{xy}	4.02±0.15	107.14±0.86
PO	3.73±0.10	25.25±0.51	140.45±1.27^{x}	3.95±0.19	108.60±1.13
SO	3.86±0.11	24.45±0.54	135.47±1.46^{y}	3.80±0.17	105.79±1.76
CH	3.89±0.08	24.23±0.42	137.50±1.33^{xy}	3.66±0.15	106.56±1.01
Age					
Day 21	4.07±0.09^{x}	24.14±0.49	141.05±0.97^{x}	4.08±0.09^{x}	111.34±1.56^{x}
Day 28	3.92± 0.10^{xy}	24.77±0.44	135.61±1.72^{y}	4.34±0.20^{x}	105.09±1.37^{y}
Day 35	3.73±0.08^{y}	24.47±0.30	133.79±0.84^{y}	4.47±0.14^{x}	102.78±0.63^{y}
Day 41	3.73±0.11^{y}	25.11±0.62	140.85±1.22^{x}	2.53±0.07^{y}	108.89±0.90^{x}

$^{x, y}$ Means within a column with no common superscripts differ at $p \leq 0.05$.

[1] From day 28 to 41, all chickens were exposed to 34±1°C.

[2] Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil, CH = choice feeding.

Table 9. Mean (±SEM) relative abdominal fat pad weights and breast intramuscular fat concentration of broiler chickens[1] by diet on day 42

	Diet[2]			
	Control	PO	SO	CH
Relative abdominal fat pad weight (g fat/g body weight)	0.094±0.009^{b}	0.117±0.002^{a}	0.112±0.006^{a}	0.113±0.006^{a}
Breast intramuscular fat (%)	3.740±0.23^{b}	4.670±0.11^{a}	4.010±0.33^{a}	4.670±0.36^{a}

$^{a, b}$ Means within a column with no common superscripts differ at $p \leq 0.05$.

[1] From day 28 to 41, all chicks were exposed to 34±1°C.

[2] Control = without added fat, PO = 8% palm oil, SO = 8% soybean oil, CH = choice feeding.

for the blood parameters. Except for sodium, feeding regimen had no significant effect on the measured blood parameters. The effect of age was significant for levels of serum cholesterol, sodium, potassium and chloride of broiler chicks. Serum levels of cholesterol and potassium declined with age. The effect of age on serum levels of sodium and chloride was inconsistent.

The relative abdominal fat weight and breast intramuscular fat content percentage were significantly lower in the control birds (Table 9) than those of PO, SO and CH groups. There were no significant differences in both parameters among the three latter groups.

DISCUSSION

This experiment confirmed previous findings (Fuller and Rendon, 1977; Zulkifli et al., 2003) that high fat diet alleviates the detrimental effects of heat stress on performance of broiler chickens. Following two weeks of heat exposure, the PO and SO birds had grater body weight and better FCR than those of controls. It has been documented that diets without added fat have lower energetic efficiency (lower energy gain and higher energy losses) with respect to those with added fat (Carew et al., 1964; Fuller and Rendon, 1977; 1979; Nitsan et al., 1997). The addition of fat to the diet has also been shown to decrease the rate of feed passage and thus increase nutrient utilisation (Mateos et al., 1982).

The final body weight and overall FCR of PO and SO chicks did not differ significantly. This could be attributed to the similar energetic efficiency of SO and PO diets as unsaturated fatty acids to saturated fatty acids ratio of these two diets were almost the same (2.15 and 2.05 respectively). Ketel and De Groote (1989) indicated that the degree of saturation (UNSFA/SFA) directly affected fat utilization parameters. Although based on growth performance, body temperatures and H/L ratios, both PO and SO chicks appear to have similar ability to withstand high temperature, significantly higher number of the latter succumbed to the heat challenge. The observed elevated levels of serum creatine kinase, a useful indicator of myopathy, in the SO birds also suggests their susceptibility to heat distress. A large increase in total plasma creatine kinase activity has been reported in poultry following transportation and heat exposure (Mitchell and Sandercock, 1995). Damage to muscle leads to an increase in membrane permeability and leakage of enzymes and other markers into the blood. Thus, it appears that the PO diet which contains more monounsaturated fatty acids is more beneficial to combat the adverse effects of heat stress than that of SO diet which is richer in polyunsaturated fatty aids. Polyunsaturated fatty acids are prone to be easily oxidised and thus may lead to oxidative cell damage (Dibner et al., 1996; Jensen et al., 1997). Stressful conditions, particularly those related to high ambient temperatures, are well known to increase vitamin E requirements in poultry (Cheville, 1979). Generally, vitamin E protects against free-radical-mediated oxidation (Turchetto and Pignatti, 1982) and thus contributes to the integrity of the endothelial cells of the circulatory system. In work with laying hens (Njoku and Nwazota, 1989; Bollengier-Lee et al., 1998; 1999; Puthpongsiriporn et al., 2001), vitamin E supplementation was shown to improve egg production. Refined palm oil contains larger amount of vitamin E (350-450 ppm; Sambanthamurthi et al., 2000) as compared to soybean oil (Goh et al., 1985).

The main objective of the present study was to determine whether broilers are able to choose among three diets varying in dietary fat and adjust their intake to meet the requirements for dietary fat under heat stress conditions. It was noted that CH birds preferred the control diet (without added fat) over either PO or SO diet during d 21 to 27. The preference for control diet could be attributed to prior experience of food (Forbes, 1995) as birds had been fed with starter diets without added fat from d 1 to 21. The lack of preference for the control diet from d 28 to 41 suggested that the influence of prior experience on dietary self-selection is only temporary. It is interesting to note that the proportion of control diet consumed by the CH birds appears to decline with the period of heat exposure.

The present findings clearly suggest that the CH regimen had no detrimental effect on performance of broilers exposed to high ambient temperature. Following two weeks of heat exposure, the body weight (d 42) and overall FCR (d 21-42) of CH birds were not significantly different from their PO and SO counterparts. Thus, it appears that the CH birds are able to select each proportion of diets adequately to obtain similar body weights with those fed single high fat diets. These findings are not in accordance with those of Dale and Fuller (1978) that birds provided a single high fat diet had greater weight gains than those given a choice of high fat and high carbohydrate diets. However, because the birds in the present study were exposed to high ambient temperature, inferences should be made with caution.

The preceding discussion suggests that the PO diet can dampen adverse physiological reactions to heat exposure. The mortality and serum creatine kinase concentration data presented here clearly indicate that the CH birds were equally tolerant to high temperature stress as their PO counterparts. It is interesting to note that the enhanced heat tolerance among the CH birds was acquired without showing significant preference for PO diet. From d 28 to 41 (heat challenge period), the CH birds consumed 33%, 30% and 47% of control, PO and SO diets, respectively. Hence, feeding a single diet with high addition of palm oil which may lead to over consumption of dietary fat is not necessary to alleviate heat stress problems in broiler chickens.

We hypothesised that CH birds are able to select high fat diet according to their physiological requirements and as such have less fat deposition than those provided a single high fat diet. In the present study, however, despite consuming less high fat diet, the relative abdominal fat weights and the breast intramuscular fat content of the CH birds were not significantly different from those of PO and SO chicks. The phenomenon could be attributed to hormonal control of lipid metabolism in heat stressed chickens. Geraert et al. (1996) reported that heat-exposed birds exhibited lower plasma triiodothyronine and higher corticosterone concentrations, which can enhance fat deposition. There is a possibility that the enhanced fatness attributed to the hormonal alterations has masked the possible differences in fat deposition among PO, SO and CH chickens.

Literature regarding the influence of high ambient temperature on plasma electrolyte status in chickens is conflicting. While Khone and Jones (1975) reported increased blood potassium level in response to heat stress, Huston (1978), and Ait-Boulahsen et al. (1989) noted otherwise. Lin et al. (2000) reported wide variations in plasma biochemical indices; chloride content was increased by high temperature and potassium content was decreased by high or low temperature and increased by moderate temperature. In this study, the significant effect of d of heat exposure on blood metabolites was observed. Serum levels of sodium and chloride were significantly higher and serum potassium were significantly lower on d 41 (14 d after heat exposure) as compared to d 28 and d 35. In the present study, however, birds were exposed continuously to high ambient temperature for 14 d, thus adaptive responses to chronic heat exposure may have affected the level of blood biochemical indices.

In conclusion, this experiment suggests that broiler chickens were able to adjust the proportion of diets with no added fat, high addition of palm oil and high addition of soybean oil to support optimum thermoregulation under heat stress conditions. Choice feeding of dietary fat was proved to be as effective as providing a single diet with high addition of palm oil in alleviating the detrimental effects of high ambient temperature in broiler chickens. Considering the negative consequences of over consuming dietary fat, dietary self selection may offer a feasible feeding regimen to combat chronic heat stress problems in broiler chickens.

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