Turkish Journal of Veterinary & Animal Sciences

Volume 24 | Number 5 Article 10

1-1-2000

Effects of Environmental Temperature and Dietary Ascorbic Acid on the Diurnal Feeding Pattern of Broilers

HASAN RÜŞTÜ KUTLU

J. MICHAEL FORBES

Turk J Vet Anim Sci
24 (2000) 479-491

Effects of Environmental Temperature and Dietary Ascorbic Acid on the Diurnal Feeding Pattern of Broilers*

Hasan Rüştü KUTLU
Çukurova University, Agricultural Faculty, Department of Animal Science, 01330, Adana - TURKEY
John Michael FORBES
Leeds University, Department of Animal Physiology and Nutrition, LS2 9JT Leeds-UK

Received: 27.01.2000

Abstract : The present study was carried out to determine the diurnal feeding patterns of broiler chickens given a choice between ascorbic acid (AA) supplemented and unsupplemented feeds under heated or unheated conditions. Broiler chickens were offered supplemented (with 200 mg AA/kg feed) and unsupplemented feeds, and the feeding behaviour for each feed was monitored by continuous recording of the weight of the feed container for 4 days under unheated (UH) and the next 4 days under heated (H) conditions. The weight and timing of each meal was used to calculate cumulative feed intake, AA intake, number of meals, mean meal size and length, intermeal interval, interval length, eating time and consumption rate. The results showed that heating had a significant ($P<0.05$) effect on feed selection and AA intake; under UH, birds consumed 8.75 mg AA by selecting 70% unsupplemented and 30% supplemented feed of 152 g total intake, while under H they consumed 17.92 mg AA by eating 38% unsupplemented and 62% supplemented feed of 148 g total intake. Although under both temperature regimes the number of meals eaten from both feeds per bird per day was 55, 0.73 of those being meals from 1 food only. Under UH, 0.78 of single meals were from unsupplemented feed, and of all mixed meals 0.14 were started with unsupplemented feed. However, under H, 0.62 of single meals were taken from supplemented feed, and 0.60 of all mixed meals were initiated with supplemented feed. As a result, the eating time for unsupplemented feed was longer throughout a day under UH whereas birds spent longer consuming supplemented feed during a day under H.

It is concluded that birds can regulate their AA intake according to environmental temperature, and that the regulation occurs not only on a weekly or longer basis, but also in much shorter periods, i.e., on a daily basis as soon as birds differentiate two feeds varying in AA content.

Key Words : Diurnal Feeding Pattern, Broilers, Ascorbic Acid, Environmental Temperature

Çevre Sıcaklığı ve Yem Askorbik Asit İçeriğinin Etlik Piliçlerin Günlük Yem Tüketim Eğilimi Üzerine Etkisi

Özet : Mevcut çalışma, termonötral ve yüksek çevre sıcaklığı altında yem seçimine dayalı olarak askorbik asit içerikleri farklı yemlerle beslenen etlik piliçlerin yem tüketim eğilimindeki günlük değişimin belirlenmesi amacıyla yürütülmüştür. Çalışmada etlik piliçlere askorbik asit katkılı ve katkısız yemler aynı anda sunulmuş ve ilk 4 gün termonötral sıcaklık, daha sonraki 4 gün ise yüksek sıcaklık altında, yem tüketimleri bilgisayar sistemine bağlı elektronik teraziler aracılığıyla kaydedilmiştir. Elde edilen verilerden toplam yem tüketimi, her bir yemin tüketimi, askorbik asit tüketimi, günlük öğün sayısı, bir öğünde tüketilen yem miktarı, öğün uzunluğu, iki öğün arası süre, yemleme süresi ve günlük yem tüketim oranı hesaplanmıştır. Deneme sonunda çevre sıcaklığının etlik piliçlerin yem tüketimini etkilediği, termonötral koşullar altında etlik piliçlerin günlük toplam yem tüketimi (152 g) içinde %70 katkısız ve %30 katkılı rasyonları seçerek 8.75 mg askorbik asit tükettikleri görülürken aynı hayvanların yüksek çevre sıcaklığı altında günlük toplam yem tüketimi (148 g) içinde %62 katkılı ve %38 katkısız rasyonları seçerek 17.92 mg askorbik asit tükettikleri saptanmıştır. Her iki sıcaklık koşulu altında günlük öğün sayısı 55 olarak bulunmuş, termonötral koşullarda bunun 31'i sadece katkısız rasyondan, 9'u sadece katkılı rasyondan, 8'i katkısız+katkılı rasyonlardan karışık ve 7'si de katkılı+katkısız rasyonlardan karışık olarak alırken, yüksek çevre sıcaklığı altında toplam 55 öğünün 15'i sadece katkısız rasyonlardan, 25'i sadece katkılı rasyonlardan, 6'sı katkısız+katkılı rasyonlardan karışık, 9'u katkılı+katkısız rasyonlardan karışık olarak alındığı belirlenmiştir.

Sonuç olarak termonötral sıcaklık altında katkısız yemin tüketilmesi için bir günde ayrılan sürenin katkılı yeme oranla daha uzun olduğu görülürken, yüksek sıcaklık altında bu paternin katkılı yem lehine değiştiği ve etlik piliçlerin daha çok katkılı rasyonu tükettikleri saptanmıştır.

Anahtar Sözcükler : Yem Tüketim Eğilimi, Etlik Piliç, Askorbik Asit, Çevre Sıcaklığı

* The authors confirm that the present study was carried out at the University of Leeds, Department of Animal Physiology and Nutrition, Leeds, U.K.

Introduction

Birds are normally able to synthesize adequate amounts of ascorbic acid. However, there are many indications that under heat stress conditions they cannot produce enough ascorbic acid for their metabolic needs and they require dietary ascorbic acid (1-3). It has been reported that under heat stress conditions dietary supplemental ascorbic acid alleviates the effect of heat stress on the performance of broilers chicks (4-8). It has also been reported that excessive supplementation of the diet can reduce the performance of broiler chicks, especially in the absence of stress (4, 5). The problem arises, therefore, as to how to match the birds' requirement with appropriate levels of supplementation. Kutlu and Forbes (9) reported that the uncertainty of how much ascorbic acid to put into feed for stressed birds could be overcome by allowing them to select their own intake. They showed that broiler chicks could differentiate between feeds varying in ascorbic acid content by means of colour and they could adjust the proportion of ascorbic acid supplemented and unsupplemented feeds eaten to meet the requirements for ascorbic acid according to environmental temperature.

In a further study, Kutlu and Forbes (10) assessed the effects of changes in environmental temperature on self-selection of ascorbic acid in coloured foods by broiler chicks. After an 8-day training period under a constant 29°C, the chicks were tested for 10 days, during which choices of either green supplemented (with 200 mg ascorbic acid/kg feed)/red unsupplemented (G+/R-) or red supplemented (with 200 mg ascorbic acid/kg feed)/green unsupplemented (R+/G-) were given. Three groups from each colour combination were exposed to treatment 1, which consisted of a hot environment (10 h; 37°C:14 h 26°C per day) from day 1 to 5 and an unheated environment (constant 26°C) from 6 to 10, while the other 3 groups were given treatment 2, which was unheated from day 1 to 5 and heated from day 6 to 10. They found that changes in environmental temperature had significant ($P<0.05$) effects on intakes of the supplemented and the unsupplemented feeds. Birds receiving treatment 1 continuously increased their ascorbic acid intake by consuming an increasing proportion of the supplemented feed (0.56, 0.62, 0.66, 0.67, 0.66; $P<0.05$ from day 3), whereas the same birds lowered their ascorbic acid intake gradually by eating a reduced proportion of the supplemented feed (0.53, 0.45, 0.37, 0.34, 0.35; $P<0.05$ from day 8) during the second 5 days. The birds receiving treatment 2 were also affected by the environmental temperature in a similar manner as those receiving treatment 1; during the first 5 days birds reduced their ascorbic acid intake by a eating reduced proportion of the supplemented feed (0.42, 0.37, 0.38, 0.30, 0.34; $P<0.05$ from day 2). The same birds increased their ascorbic acid intake by consuming an increased proportion of the supplemented feed (0.46, 0.54, 0.60, 0.59, 0.58; $P<0.05$ from day 8) for the second 5 days. With this study Kutlu and Forbes (10) showed that broiler chicks are able to regulate their ascorbic acid intake according to the environmental temperature by associating ascorbic acid supplementation with feed colour and the association is developed or reversed by the third day of a new environment.

However, how broiler chicks behave to regulate their ascorbic acid intake under a choice feeding situation between ascorbic acid supplemented and unsupplemented feeds (whether they do this by eating several meals of 1 feed and then switching to the other feed for the next few meals or mix meals from both feeds) is not known. The present study was conducted to determine the ascorbic acid intake regulation of broiler chickens on a meal-to-meal basis under thermoneutral or heat stress conditions and also during changes in environmental temperature. In order to determine the ascorbic acid intake regulation, the feeding behaviour of broiler chickens was assessed by automatic recording of the diurnal meal pattern when the birds were given ascorbic acid supplemented and unsupplemented feeds as a choice under thermoneutral and heat stress conditions.

Materials and Methods

Six, 4-week-old female broiler chicks were divided into 2 groups of similar mean weight (1432 g, SED: 61), comprising 3 birds each. Coloured feeds were prepared by mixing 10 ml of red and green food colouring agents (Gold Seal Liquid Colour, Clayton and Jawett Ltd., Runcorn, Cheshire, U.K.) with 40 ml of tap water and spraying onto 1 kg of the plain feed (Broiler Grower Feed, obtained from E.B.Bradshaw and Sons Ltd., Bell Mills, Driffield, U.K.). The coloured feed was then allowed to dry at room temperature. When 200 mg ascorbic acid (coated Ascorbic Acid, BP, Roche Ltd, P.O. Box 8, Welwyn Garden City, AL7 3AY, U.K.) was added to 1 kg of the coloured feed, it was dissolved in 50 ml of tap water sprayed onto and thoroughly mixed with the feed, in addition to the colouring agent. Coloured feed containing no supplemental ascorbic acid was only mixed with 50 ml of tap water for 1 kg of the feed. Thus, 4 feeds were prepared: ascorbic acid supplemented green feed (G+), ascorbic acid supplemented red feed (R+), unsupplemented green feed (G-) and unsupplemented red feed (R-). The experimental feeds were prepared freshly every day throughout the study. At the end of the day the feed analysis for ascorbic acid (11) showed that the actual levels of ascorbic acid were 7(±2) and 192(±7) in the unsupplemented and supplemented feeds, respectively.

In order to eliminate the effects of colour on feed selection the birds were divided into 2 groups and housed in a room, where half of the birds (group 1) received G+/R- and the other half (group 2) were offered R+/G- as a choice in individual cages (570 mm high, 510 mm wide and 520 mm deep) for 14 days prior to the recording procedure. They were then transferred to a special room and housed in individual cages (660 mm high, 520 mm wide and 520 mm deep). Each cage was equipped with 2 electronic balances (Mettler-BB600) side by side in front. Following a 1-day-acclimatization period, first 4 days under thermoneutral (daily constant 21°C) and next 4 days under heated (10 h (from 1000 hours to 2000 hours); 35°C: 14 h; 21°C) conditions of eight days recordings were obtained for each chicken during a free choice between G+/R- (group 1) or R+/G- (group 2) for 24 h per day. Feeds and water were available ad libitum with 24 h lighting throughout the recording period. Feeding activity was recorded automatically from the balances, on top of which feed cups of each feed of a pair were positioned firmly 5 cm from the cage, 17 cm apart.

The computer program recorded the balance number, starting weight, finishing weight, starting time, finishing time of each meal every 10 seconds. A computer (IBM Portable Personal Computer, 5155) continually recorded the output of each balance and stored the meal data on a floppy disk from 1000 hours every day for 24 hours.

At the end of the 8-day-recording period, the data files created for each day were uploaded to the Amdahl 5860 mainframe computer using a microcomputer linked to the University network. Each day's data file was sorted according to bird, using the Statistical Analysis System SAS (12). The sorted data were then scanned by means of a program, in order to determine which consecutive meals should be merged according to a minimum intermeal interval. SAS was then used again for summary statistics of meal pattern which was assessed by calculating feed intake (g/day), meal size (g), meal length (min), interval length (min), eating time (min/day), consumption rate (feed intake, g / eating time, min), number of meals as single unsupplemented (taken from only unsupplemented feed within true intermeal interval), single supplemented (taken from only supplemented feed within true intermeal interval), mixed unsupplemented (taken from unsupplemented feed first and supplemented feed second within true intermeal interval), mixed supplemented (taken from supplemented feed first and unsupplemented feed second within true intermeal interval), and ascorbic acid intake (mg/day) as means per bird.

Results

Although a critical minimum intermeal interval of 1 minute was incorporated in the computer program to allow the merging of very short meals, it was necessary to define a meal by determining a critical minimum intermeal interval to separate interruptions within meals from true intermeal intervals. In order to do that, a frequency distribution of intermeal intervals was plotted for 6 birds for 8 days (48 occasions) by using the method of Duncan et al. (13). The form of the intermeal interval distributions for each of the 48 determinations was found to be similar and results from all the determinations were combined to give a pooled frequency distribution (Fig.1). Two classes of intermeal interval distribution were observed for each determination: 1 was a class of high frequency of small intervals which was very steep and quickly fell towards the base-line (1 min), and the other low frequency of large intervals. The point where these 2 distribution classes met was deemed to be the best interval to be used for defining the minimum intermeal interval. From the results of 6 birds in 8 days and a combined interval frequency distribution, an interval of 6 minutes was found to be the most appropriate under the conditions of this study. A meal was therefore defined as a period of continuous eating not interrupted by an interval of more than 6 minutes, and the results presented here are based on the 6-min intermeal interval.

An initial analysis of the data showed no colour effect on feed selection, as the group receiving G+/R- and the other group that was offered R+/G- exhibited their feed selection between supplemented and unsupplemented

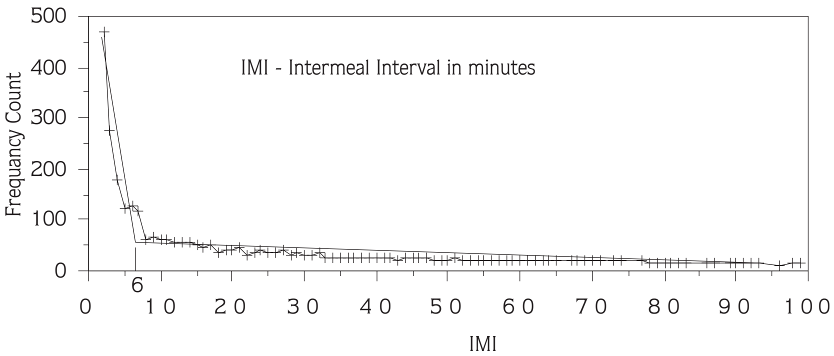

Fig. 1. Frequancy distribution of IMI of six birds on 48 occasions.

feed in a similar manner, irrespective of feed colour (Table 1). The data collected from groups 1 and 2 were, therefore, pooled and re-analyzed. The results reported here were based on choice feeding between supplemented and unsupplemented feeds, irrespective of feed colour.

Assessment of the difference between the feeding pattern of birds maintained under thermoneutral and heated conditions would be more appropriate by comparing day 4 and day 8, as by this time the birds had stabilized to the new conditions and made significant selections of 1 feed against the other. A comparative summary of the feeding pattern of birds under both temperature regimes is given in Table 2.

Figure 2 showed that on days 4 and 8 the number of meals taken from both feeds was equal. However, the distribution of the number of meals of each feed was different on these days; on day 4 the number of "single" meals, in which feed was selected exclusively from 1 feed, was 40 in 55, 31 of those being from unsupplemented feed. The predominance of unsupplemented feed selection, however, was not observed in the remaining 15 "mixed" meals, with only 8 being initiated from unsupplemented feed. On day 8 the number of "single" meals was again 40 in 55, but in this case 25 of those were from supplemented feed. The predominance of supplemented feed selection was observed again as 9 of the "mixed" meals were initiated with supplemented feed.

Figure 3 shows the feed intakes of birds from both feeds offered as a choice throughout the recording period. During the first 4 days of the experiment, birds con-

Table 1. Daily changes in self-selection of broiler chickens given a choice of G+/R- or R+/G-.

Group 1 (given a choice of G+/R-)								
Day	1	2	3	4	5	6	7	8
Food Intake (g/bird)								
Total	163±4	160±6	162±7	153±6	133±6	147±4	132±7	147±5
Sup/Unsup	58±3/105±7	54±5/106±7	47±4/115±8	43±7/110±5	39±4/94±7	51±3/96±6	63±8/69±7	96±7/51±2
%	36/64	34/66	29/71	28/72	29/71	35/65	48/52	65/35
Group 2 (given a choice of R+/G-)								
Day	1	2	3	4	5	6	7	8
Food Intake (g/bird)								
Total	132±5	142±9	145±3	150±6	128±8	137±5	147±6	148±9
Sup/Unsup	49±3/83±6	47±5/95±8	40±2/105±5	47±7/103±4	35±3/93±9	45±3/92±8	69±5/78±5	88±8/60±7
%	37/63	33/66	28/72	31/69	28/72	33/67	47/53	60/40

	Day 4			Day 8	
	Mean	SEM		Mean	SEM
Food Intake (g)					
Unsupplemented	107.00 a	8.75	*	56.14 a	5.19
Supplemented	45.00 b	4.36	*	92.34 b	6.58
AA Intake (mg)	9.39	2.2	*	18.06	1.3
Meal size (g)					
Unsupplemented	2.87 a	0.14		2.67 a	0.57
Supplemented	2.15 a	0.37	*	3.09 a	0.23
Meal Length (min)					
Unsupplemented	5.00 a	0.76		4.17 a	0.84
Supplemented	3.27 a	1.05	*	4.77 a	2.13
Interval Length (min)					
Unsupplemented	33.30 a	3.70	*	58.00 a	15.22
Supplemented	68.56 b	18.96	*	40.28 a	5.64
Eating Time (min)					
Unsupplemented	181.26 a	24.78	*	95.08 a	18.01
Supplemented	54.67 b	19.70	*	189.08 b	55.99
Consumption Rate (g/min)					
Unsupplemented	0.59 a	0.19		0.59 a	0.30
Supplemented	0.83 a	0.21		0.49 a	0.19
Number of Meals					
"Single" Unsupplemented	31	4	*	15	2
"Single" Supplemented	9	2	*	25	2
"Mixed" initiated with Unsupp	8	3		6	2
"Mixed" initiated with Supp.	7	1		9	3

a, b : in the same day for the same parameter, the difference between means of the 2 foods is significant at $P<0.05$ by t-test.

* : in any 1 row the difference between means of Day 4 and Day 8 is significant at $P<0.05$ by t-test.

Table 2. Meal pattern parameters (with SEM) of broiler chickens under thermoneutral (Day 4) and heat stress (Day 8) conditions.

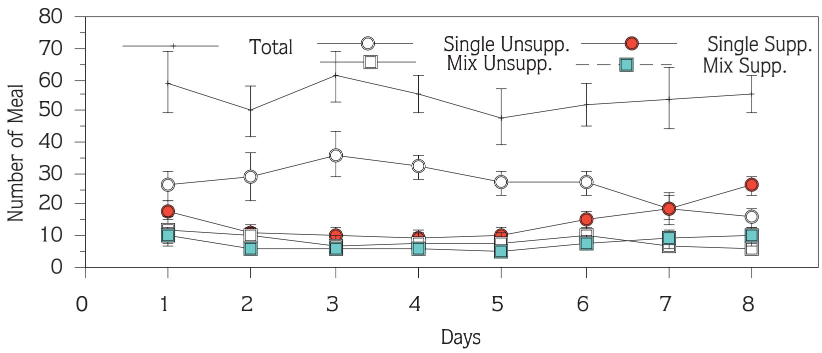

Fig. 2. Dail changes in meal number of broiler chickens offered a choice between supplemented and unsupplemented feeds.

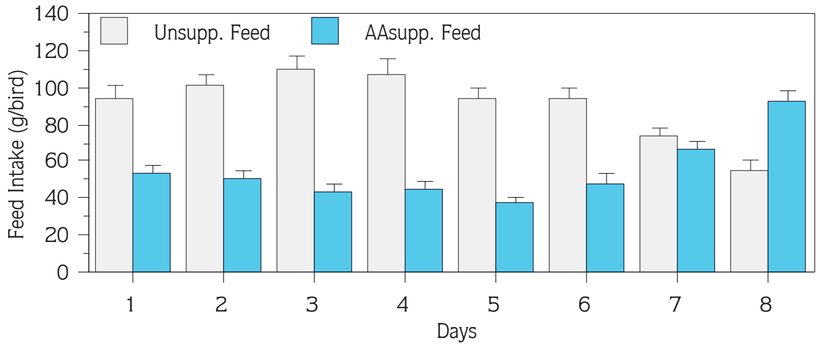

Fig. 3. Diurnal feed intake pattern of broiler chickens offered supplemented and unsupplemented feeds.

sumed greater amounts of unsupplemented feed than supplemented feed ($P<0.05$) and the daily intake of unsupplemented feed as a proportion of total intake was 0.63, 0.68, 070, 0.71. When the birds were subjected to heat from day 5, they ate decreasing proportions (0.71, 0.65, 0.47, 0.38; $P<0.05$ on day 8) of unsupplemented feed. This result showed a clear picture of feed selection changed by environmental temperature.

Figure 4 indicates that on day 4 birds greatly increased their unsupplemented feed intake as hours passed, while the cumulative supplemented feed intake increased steadily. On day 8, during the heating period, the increase in cumulative intake of both feeds was similar but rather slow in contrast to the same period on day 4. At the end of the heating period there was a sharp increase in supplemented feed intake, while the increment in unsupplemented feed intake was gradual (Fig. 5).

As far as ascorbic acid intake is concerned, birds kept their ascorbic acid intake at a stable level throughout the thermoneutral conditions. When the environmental temperature was elevated from day 5, the increase in ascorbic acid intake was gradually attained (Fig. 6). When a

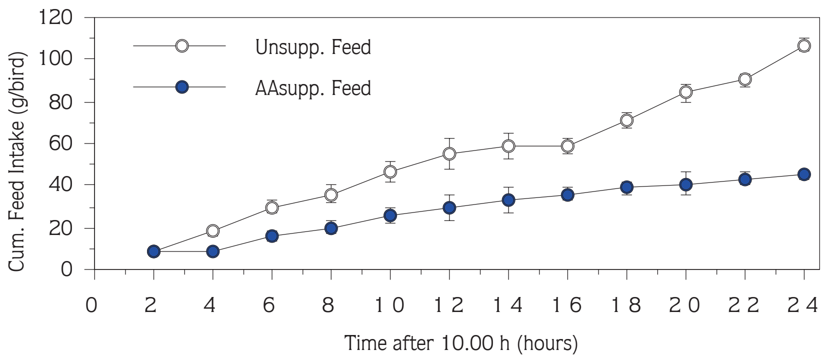

Fig. 4. Cumulative intake of supplemented and unsupplemented feeds offered as a choice throughout a day under thermoneutral conditions (on Day 4).

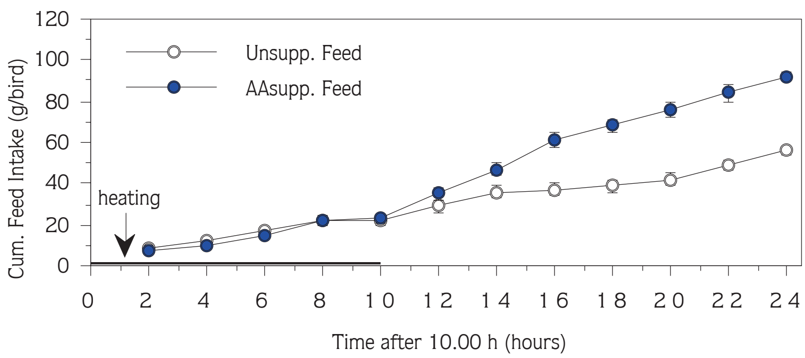

Fig. 5. Cumulative intake of supplemented and unsupplemented feeds offered as a choice throughout a day under heat stressl conditions (on Day 8).

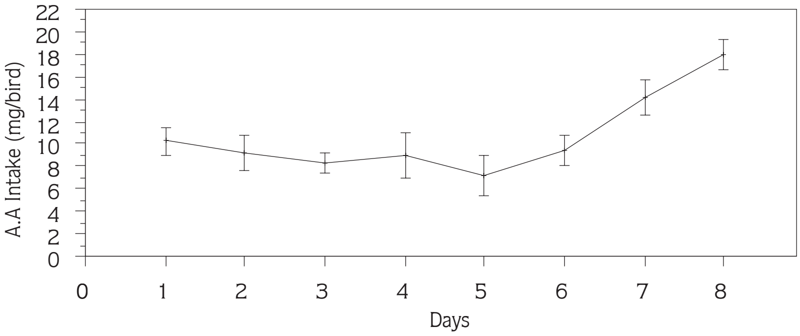

Fig. 6. Dail changes in ascorbic acid intake of broiler chickens offered supplemented and unsupplemented feeds.

comparison is made between day 4 and day 8, ascorbic acid intake was similar during the first 10 hours of both days, but the increase in ascorbic acid intake was slow for the rest of day 4 (Fig. 7). However, on day 8, at the end of the heating period, there was a sharp increase in ascorbic acid intake and the intake was doubled by the end of the day (Fig. 8)

Figure 9 shows that the size of meals taken from unsupplemented feed was greater than the meal size of supplemented feed. This pattern of meal size for both feeds was observed until day 7. Thereafter birds consumed supplemented feed in meals of greater size than unsupplemented feed. Figure 10 shows that there were sharp changes with no clear pattern in meal size in both feeds throughout day 4. On day 8 changes in meal size of unsupplemented feed fluctuated over a narrow range (Fig.11), whereas a continuous increase in meal size of supplemented feed especially after the heating period was recorded.

The result with respect to meal length showed that the meals taken from unsupplemented feed were longer according to their size. This pattern continued until day 7 (Fig. 12). The meal length pattern of birds on day 4 is plotted in Figure 13. From day 7 birds spent a longer

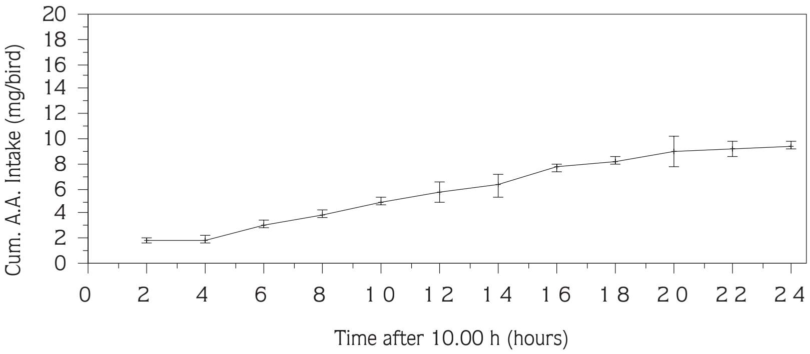

Fig. 7. Cumulative ascorbic acid intake of broiler chickens throughout a day under thermoneutral conditions (on Day 4).

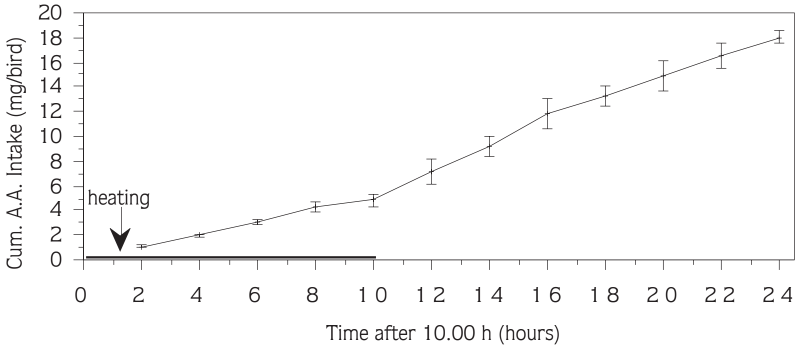

Fig. 8. Cumulative ascorbic acid intake of broiler chickens throughout a day under heat stress conditions (on Day 8).

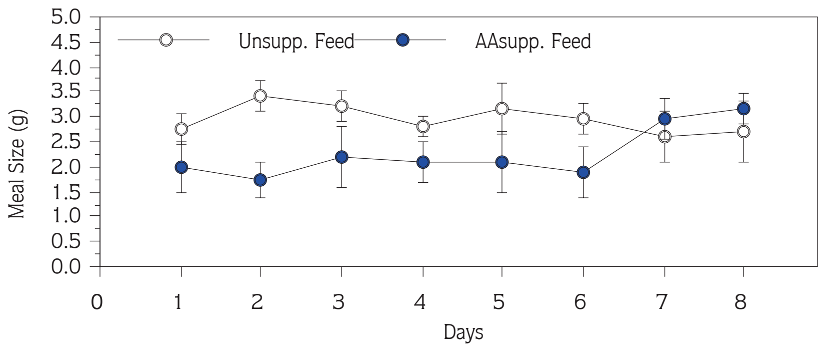

Fig. 9. Daily changes in meal size of broiler chickens given a choice between supplemented and unsupplemented feeds.

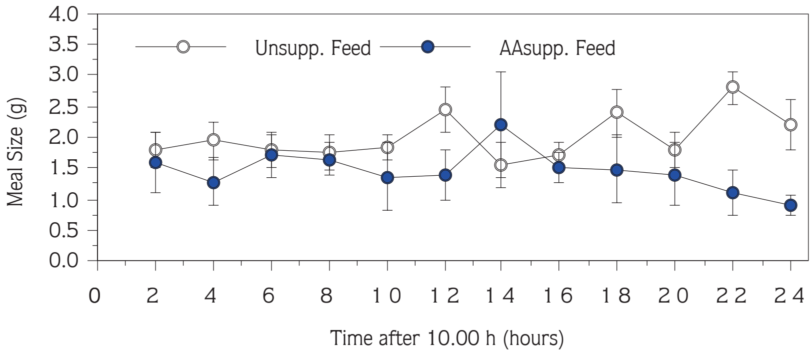

Fig. 10. Meal size of supplemented and unsupplemented feeds offered as a choice throughout a day under thermoneutral conditions (on Day 4).

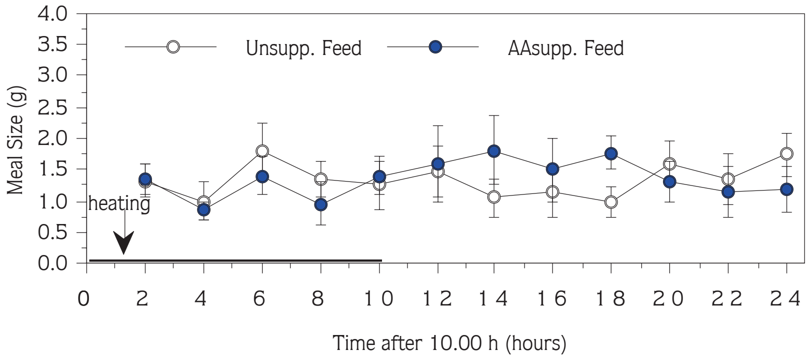

Fig. 11. Meal size of supplemented and unsupplemented feeds offered as a choice throughout a day under heat stress conditions (on Day 8).

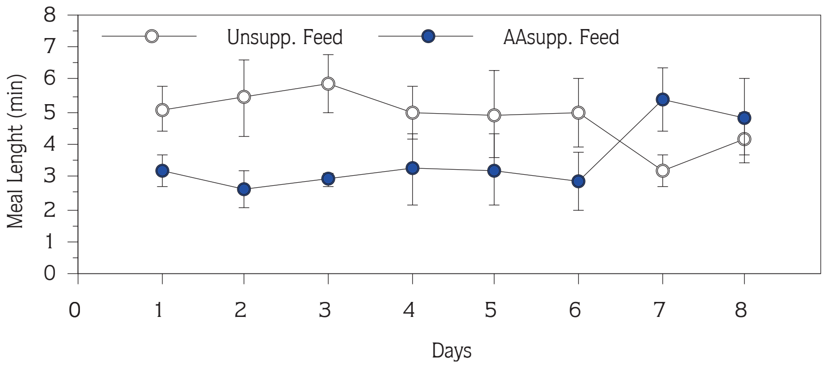

Fig. 12. Daily changes in meal length of broiler chickens given a choice between supplemented and unsupplemented feeds.

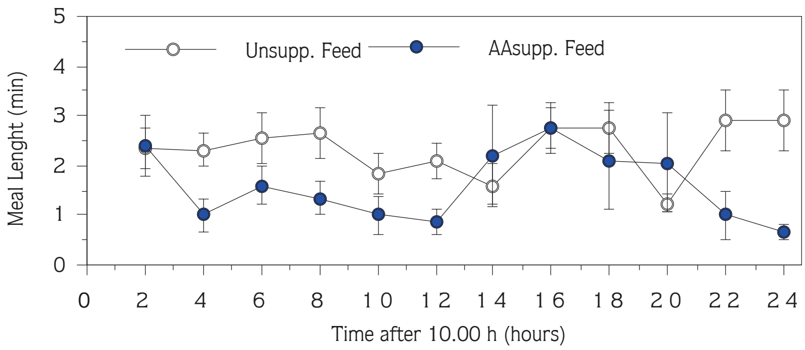

Fig. 13. Meal length supplemented and unsupplemented feeds offered as a choice throughout a day under thermoneutral conditions (on Day 4).

period for each meal from supplemented feed than the meal from unsupplemented feed. The result obtained on day 8 showed a sharp increase in meal length of supplemented feed at the end of the heating period (Fig. 14) and this increase was concomitant with the rise in meal size of supplemented feed.

Intervals of the meals taken from supplemented feed were longer than intervals between the meals from unsupplemented feed until day 8 (Fig. 15). Throughout day 4 changes in interval length for unsupplemented feed were gradual (Fig. 16), while intervals of the meals from the supplemented feed were longer ($P<0.05$) and changed sharply throughout the day. Figure 17 indicates that during the heating period of day 8 interval length of the meals from both feeds was increased and the increase was much greater for unsupplemented feed. However, after the heating period the interval lengths decreased sharply for both feeds, as birds increased their feed intake.

The result with respect to consumption rate showed that birds consumed greater ($P>0.05$) amounts of supplemented feed than unsupplemented feed in a minute during the first 5 days of the recording period (Fig. 18). Thereafter consumption rate of unsupplemented feed was greater than the consumption rate of supplemented feed. The result also showed that during the first 6 days of the experiment, birds spent more time consuming unsupplemented feed than supplemented feed ($P<0.05$). As birds changed their preference in favour of supplemented feed from day 7, the eating time for supplemented feed gradually increased (Fig. 19) and birds spent longer eating supplemented feed than unsupplemented feed ($P<0.05$).

Discussion

The results obtained in this study confirmed our previous studies (9, 10), in which broiler chicks were reported to be able to differentiate between 2 feeds, 1 supplemented with ascorbic acid, and the other inadequate in ascorbic acid content, by means of colour and they can regulate their ascorbic acid intake according to the environmental temperature to which they are exposed. The precision of the feeding pattern throughout the day under thermoneutral or heated (10 h/day) conditions indicates that the ascorbic acid intake regulation occurs not only on a weekly or longer basis, but also in much shorter periods, i.e,. on a daily basis as soon as birds differentiate between 2 feeds varying in ascorbic acid content. For the regulation of ascorbic acid intake, birds mostly consumed unsupplemented feed singly in greater meal size, longer meal length with shorter intervals and spread supplemented feed intake in smaller meal size, shorter meal length with longer intervals under thermoneutral conditions, while the opposite occurred under the heated conditions, especially during the time following the 10 h heating period.

In fact, the results reported here were obtained on the basis of a 6-min intermeal interval. The determination of this interval was based essentially on the principle used by Duncan et al. (13). The 6-min level derived from the frequency distributions differed from that of 2-min level chosen by Duncan et al. (13). Duncan and co-workers used Brown Leghorn hens from 10 to 16 weeks of age and based feed intake on pecking responses at a disc for feed reward rather than actual consumption of feed. However, the 6-min intermeal interval chosen in this study is close to the level reported by Azahan (14), who

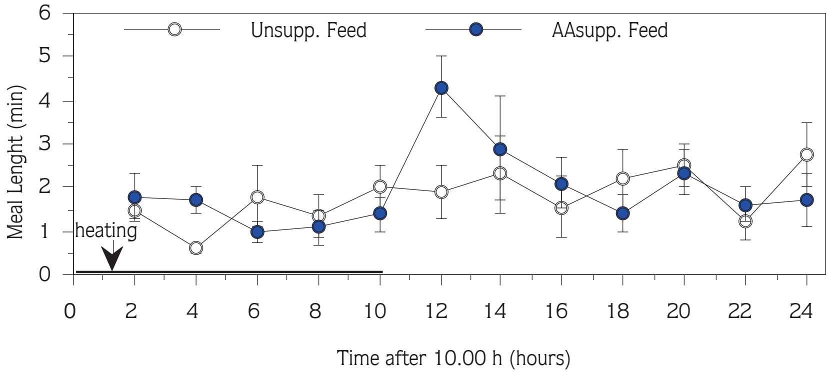

Fig. 14. Meal length of supplemented and unsupplemented feeds offered as a choice throughout a day under theat stress conditions (on Day 8).

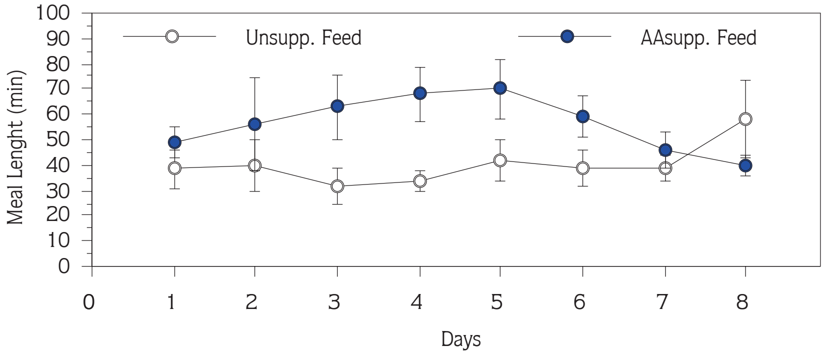

Fig. 15. Daily changes in meal interval length of broiler chickens given a choice between supplemented and unsupplemented feeds.

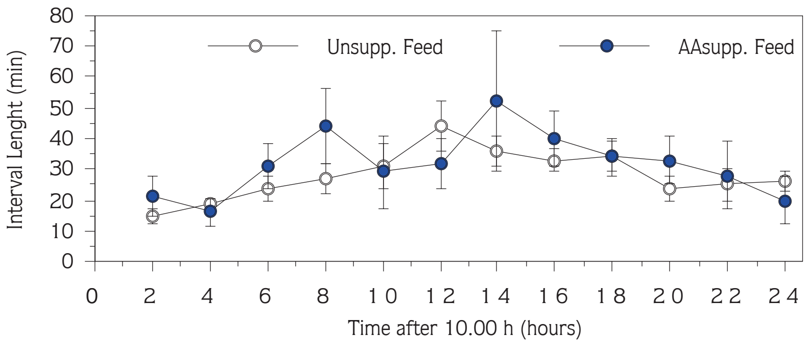

Fig. 16. Meal interval length of supplemented and unsupplemented feeds offered as a choice throughout a day under thermoneutral conditions (on Day 4).

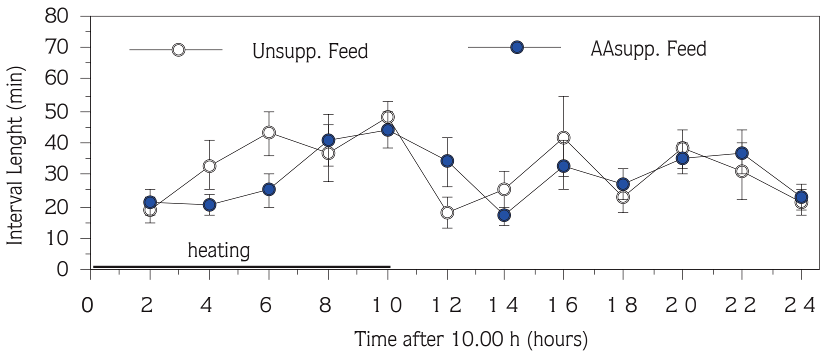

Fig. 17. Meal interval length of supplemented and unsupplemented feeds offered as a choice throughout a day under heat stress conditions (on Day 8).

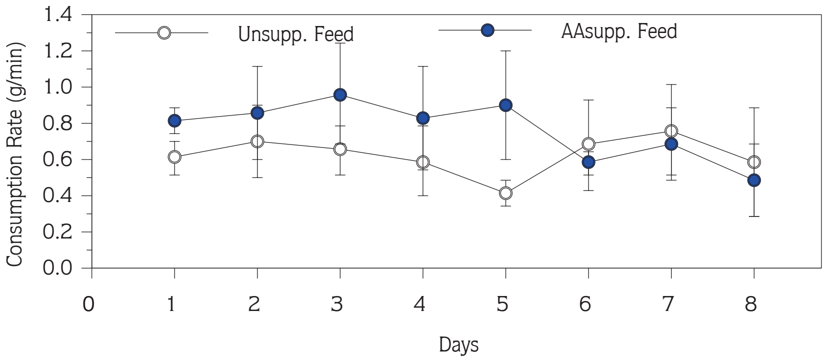

Fig. 18. Daily changes in consumption rate of broiler chickens offered a choice between supplemented and unsupplemented feeds.

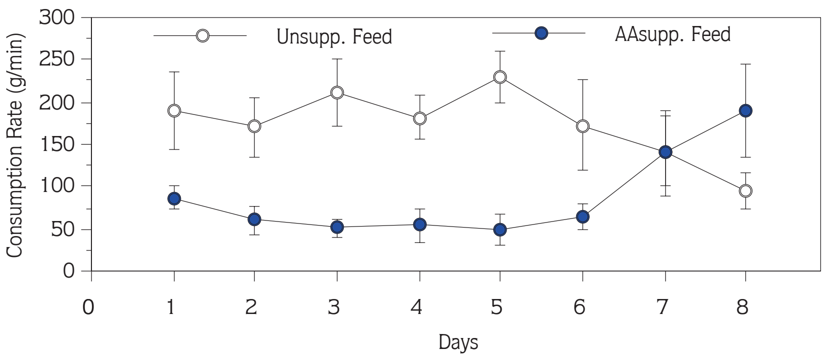

Fig. 19. Daily changes in eating time of broiler chickens offered a choice between supplemented and unsupplemented feeds.

determined a 5-min intermeal interval using layer cockerels from 12 to 20 weeks of age by applying the same method used in this study. The relationship between the size of meal and the intermeal interval before and after the meal is of considerable interest in poultry farming (13). The slopes of the regression lines relating the intermeal interval to meal consumption from each of 6 birds showed that there was no correlation between the premeal interval and the amount of feed taken in a meal nor with the length of the following interval. This may indicate that if a chicken consumes a meal containing either feed, it cannot be predicted when or how long later it will eat from either of the feeds again.

The results obtained with respect to feed intake showed that from the first day of the recording period birds consumed greater amounts of unsupplemented feed than supplemented feed. This was expected because the birds were offered a choice between the 2 feeds for a 2-week period under thermoneutral conditions prior to the recording period. Under thermoneutral conditions birds kept their daily ascorbic acid intake almost constant by adjusting the proportion of the 2 feeds. During this period birds consumed unsupplemented feed in meals of greater size with longer length. Therefore, birds spent more time consuming unsupplemented feed, as is consistent with the pattern of eating time. However, during this period the consumption rate was lower for unsupplemented feed than supplemented feed. This indicates that birds consumed unsupplemented feed slowly in contrast to supplemented feed. This may suggest that as meal length is increased, the feeding activity of bird s slowdown relatively as a result of fullness or tiredness due to the long-term eating. When the birds were exposed to 10 hours heating from day 5, there was a slow change in feed selection. Birds responded to heat by increasing supplemented feed intake and reducing unsupplemented feed intake as the days passed and developed feed selection in favour of supplemented feed. Thus, birds considerably increased their ascorbic acid intake. The increase in supplemented feed intake was greater with bigger meal size and longer meal length for at least 6 hours after the heating period, although birds consumed similar amounts of feed during the heating period. This result shows that birds do not consume supplemented or unsupplemented feeds in great amounts during the heating period, but at the end of the heating period, when the environmental temperature returns to normal, birds mostly consume supplemented feed.

There was no difference between the number of meals consumed under heated and thermoneutral conditions, although feed intake was depressed by heating, as heating induced a considerable reduction in meal size and meal length. The results also suggest that birds can partly compensate for the depression in feed intake by increasing meal size and meal length with shorter intervals as soon as the environmental temperature returns to normal.

Although the mechanism by which birds can regulate their ascorbic acid intake is not clear, it is conceivable that there could be a pre-existing recognition system for ascorbic acid. However, it is evident that birds can only distinguish 2 different levels of ascorbic acid in feeds by means of colour (9). This indicates that learning plays a key role in the differentiation process and birds paired the physiological effect of each feed with its colour, meaning that the preference is expressed for the colour, not for ascorbic acid.

The feed preference observed in this study may be explained by the Feed-Preference Learning theory suggested by Richter and Eckert (15). The theory proposed that an animal deficient in nutrient X presumably feels sick. It searches for alternative feed until it finds it and eats some. The animal starts feeling better and is thus reinforced for eating X; hence a preference for X develops. But the paradigm of feed preference conditioning can only apply to experiments where the animal has to select a diet between a set of feeds to meets its requirements. This implies that the animal gets a sufficient amount of nutrient(s) and at the same time will avoid excesses of nutrient intake. In the case of dietary self-selection of ascorbic acid under heat stress, when birds learn to increase their supplemented feed they are probably responding to the effect of ascorbic acid in producing a generalized improvement in their metabolism.

On the other hand, birds maintained under thermoneutral conditions developed an aversion to ascorbic acid supplemented feed. This suggests that an excessive intake of ascorbic acid induces aversive events. The colour of supplemented feed becomes associated with illness or negative effects, therefore, the colour becomes an aversive instrument.

Several other appetites have been demonstrated in poultry and it is likely that these would be exhibited more quickly and more consistently by prior training using alternate exposure to the 2 feeds which are to be given as choices (16). As far as self-selection of ascorbic acid is concerned, Kutlu and Forbes (10) showed that following an 8-day-training period, broiler chicks, up to 4 weeks of age, significantly associate colour cues with the ascorbic acid content of the feed within 3 days of a change in the environmental temperature. However, in the present study the same birds at about 6 weeks of age associated colour with supplemental ascorbic acid within 4 days following a change in the environmental temperature. A reversing of learned preference has also been demonstrated in other studies (16-20). These results showed that it is possible for birds to adjust their knowledge in the face of changing circumstances. However, they do not seem to adapt as quickly as they do at an early age, as observed in this study.

It is concluded from the results reported in this study that broiler chickens can be taught to distinguish between different levels of ascorbic acid in feeds by means of their colour and they can regulate their ascorbic acid intake by adjusting the proportion of supplemented and unsupplemented feeds eaten to meet the requirement according to environmental temperature. The precision of the feeding pattern throughout the day under thermoneutral or heated (10 h/day) conditions indicates that the ascorbic acid intake regulation occurs not only on a weekly or longer basis, but also in much shorter periods, i.e., on a daily basis as soon as birds differentiate 2 feeds varying in ascorbic acid content. In order to regulate ascorbic acid intake, birds mostly consumed unsupplemented feed singly in greater meal size, longer meal length with shorter intervals and spread supplemented feed intake in smaller meal size, shorter meal length with longer intervals under thermoneutral condition, while the opposite occurs under the heated condition, especially during the time following a 10 h heating period.

References

1. Coates, M.E. Metabolic role of the vitamins. In: Physiology and Biochemistry of the Domestic Fowl. Edit. B.W. Freeman, Academic Press, London; 1984, Vol.5 pp: 27-36.

2. Hornig, D., Glatthaar, B. and Moser, U.: General aspects of ascorbic acid in domestic animals. In: Workshop. Ascorbic Acid in Domestic Animals. Edits. I. Wegger, F. J. Tagwerker, J.Moustgaard, Royal Danish Agr. Soc. Copenhagen; 1984; pp: 3-24.

3. Scott, M.L.: Environmental Influences on ascorbic acid requirements in animals. Ann. NY Acad. Sci., 1975; 258: 151-155.

4 Kafri, I. and Cherry, J.A.: Supplemental ascorbic acid and heat stress in broiler chicks. Poultry Sci., 1984; 63 (suppl.):125.

5 Kutlu, H.R. and Forbes, J.M.: Changes in growth and blood parameters in heat-stressed broiler chicks in response to dietary ascorbic acid. Livest. Prod. Sci., 1993; 36: 335-350.

6 Njoku, R.C.: Effect of dietary ascorbic acid (vitamin C) supplementation on the performance of broiler chickens in a tropical environment. Anim. Feed Sci. Tech., 1986; 16: 17-24.

7. Pardue, S.L., Thaxton, J.P. and Brake, J.: Role of ascorbic acid in chicks exposed to high environmental temperature. J. App. Physiol. 1985; 58: 1521-1516.

8. McKee, J.S., Harrison, P.C. and Riskowski, G.L.: Effects of supplemental ascorbic acid on the energy conversion of broiler chicks during heat stress and feed withdrawal. Poultry Sci., 1997; 76: 1278-1286.

9. Kutlu, H.R. and Forbes, J.M.: Self-selection of ascorbic acid in coloured foods by heat-stressed broiler chicks. Physiol. Behav., 1993; 53: 103-110.

10. Kutlu, H.R. and Forbes, J.M.: Effect of changes in environmental temperature on self-selection of ascorbic acid in coloured feeds by broiler chicks. Proc. Nutr. Soc., 1993; 52: 29A.

11. Schuep, W., Vuilleumier, J.P., Gysel, D. and Hess, D.: Determination of ascorbic acid in body fluids, tissues and feedstuffs. In: Workshop. Ascorbic Acid in Domestic Animals, In: Workshop. Ascorbic Acid in Domestic Animals. Edits. I. Wegger, F.J. Tagwerker, J. Moustgaard, Royal Danish Agr. Soc. Copenhagen; 1984; pp: 50-55.

12. SAS Institute Inc. SAS User's Guide: Statistics, version 5 Ed. SAS Ins. Inc., Cary, North Carolina; 1985.

13. Duncan, I.J.H., Horne, A.R., Hughes, B.O. and Wood-Gush, D.G.M.: The pattern of feed intake in female Brown Leghorn fowls as recorded in a skinner box. Anim. Behav., 1970; 18: 245-255.

14. Azahan, H.: Voluntary food intake of chickens and sheep in relation to energy metabolism, metabolite solutions and choice feeding. Ph.D. Thesis. The University of Leeds, Leeds, UK, 1988.

15. Richter, C.P. and Eckert, J.F.: Mineral metabolism of adrenalectomised rats studied by the appetite method. Endocrinology, 1968; 22: 214-224.

16. Kyriazakis, I., Emmans, G.C. and Whittemore, G.T.: Diet selection in pigs: choices made by growing pigs given foods of different content. Anim. Prod., 1990; 51: 189-199.

17. Covasa, M. and Forbes, J.M.: Cholocystokinin octapeptide suppresses feeding and conditions colour aversion in chicken. Proc. Nutr. Soc.,1993; 52: 30A.

18. Gous, L.S., Bradford, M.M. and Kobus, G.E.: Choice-feeding experiment with growing pigs. In: Recent Advances in Animal Nutrition in Australia. Edit. D.J. Farrel, 1989; pp: 147-154.

19. Hughes, B.O. and Wood-Gush, D.G.M.: A specific appetite for calcium in domestic chickens. Anim. Behav., 1971; 12: 255-258.

20. Mastika, M. and Cumming, R.B.: Effect of nutrition and environmental variations on choice feeding of broilers. In: recent Advances in Animal Nutrition in Australia, 1985, Proceedings of a Symposium at the University of New England, November, 1985; pp: 24-27.