EFFECTS OF SEQUENTIAL FEEDING ON PERFORMANCES OF BROILER IN HOT AND HUMID CLIMATE

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ABSTRACT

Fast-growing broilers are still recording poor growth performances under tropics. Thus, this experiment aimed to evaluate the appropriate method to feed broilers under hot and humid climate. A total of 770 10-day-old Cobb broilers were assigned to 7 treatment groups having 5 replicates of 22 birds each. The birds of control group (CONT) fed complete diet with constant energy ($E_{standar}$) and protein ($P_{standar}$) levels and sequential groups which received two types of diet alternated in morning and afternoon respectively: B group with $E_{standar}$/high protein and $E_{standar}$/low protein, C group with $P_{standar}$/low energy and $P_{standar}$/high energy, D group with E_{low} P_{low} and E_{high} P_{high} and E, F and G group with E_{low} P_{high} and E_{high} $P_{low,}$ respectively in 24H, 12H and 48H cycles feeding. Chickens were fed twice a day: at 6.30 AM and 6.00 PM in all groups except F group served 7.30 AM and 1.00 PM. At 45 days of age, 6 chickens per replication were slaughtered for carcass evaluation, ultimate pH (pHu) and water holding capacity (WHC) of meat. Results showed that overall feed intake in the morning was significantly higher ($p<0.05$) than that of evening in all groups. Daily feed intake, feed conversion ratio, mortality, carcass weight and pHu were similar ($p>0.05$) across the treatment groups. However, final body weight and WHC were significantly improved in C group birds and abdominal fat significantly reduced in birds of B, C, E and F group ($p<0.05$). On the whole, the variation in energy levels of diet improve growth and water holding capacity of the meat of broilers under tropics. The feed distribution cycle of 24H (E) and 12H (F) had only impacted abdominal fat in chickens.

Keywords : Sequential feeding, fast-growing broilers, meat quality, tropical climate.

EFFETS DE L'ALIMENTATION SEQUENTIELLE SUR LES PERFORMANCES DES POULETS DE CHAIR DANS UN CLIMAT CHAUD ET HUMIDE

RÉSUMÉ

Sous les tropiques, les performances des poulets de chair à croissance rapide sont encore faibles. Ainsi, cet essai a été conduit afin d'étudier la meilleure manière de les alimenter. Au total, 770 poulets de chair Cobb âgés de 10 jours ont été répartis en 7 traitements de 5 répétitions de 22 poulets. Le lot témoin (CONT) nourri avec l'aliment complet Estandar/Pstandar et les autres lots nourris avec deux aliments alternés dans la journée: lot B : $E_{standar}$/P_{haute} et $E_{standar}$/ P_{faible}, lot C : $P_{standar}$/E_{haute} et $P_{standar}$/ E_{faible}, le lot D : E_{faible}/P_{faible} et E_{haute}/ P_{haute} et les lots E, F et G : E_{faible} P_{haute} et E_{haute} $P_{faible,}$ alternés respectivement en 24H, 12H et 48H. Les poulets ont été servis à 6h30 et 18h00 sauf ceux du groupe F servis à 7h30 et 13h00. À 45 jours d'âge, 6 poulets par répétition ont été abattus pour l'étude de la carcasse, le pH ultime (pHu) et la capacité de rétention en eau (CRE) de la viande. Les résultats ont montré globalement une consommation alimentaire plus élevée dans la matinée que dans la soirée ($p<0,05$). Cependant, la consommation journalière d'aliment, l'indice de consommation, le taux de mortalité, le poids de la carcasse et le pHu étaient similaires ($p>0,05$). Le poids vif final et le CRE des poulets du groupe C étaient plus élevés avec une teneur en graisse faible pour les poulets des lots B, C, E et F ($p<0,05$). La variation de l'énergie de l'aliment a permis d'améliorer la croissance et la capacité de rétention en eau de la viande des poulets de chair en climat tropical. Le cycle de distribution d'aliment de 24H (E) et de 12H (F) n'a eu d'effet que sur la graisse abdominale des poulets.

Mots-clés : Alimentation séquentielle, poulets de chair à croissance rapide, qualité de la viande, climat tropical.

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INTRODUCTION

Hot and humid climate is a crucial limiting factor of the broiler's production under tropics (Gu *et al.*, 2008). Intensive selection in fast-growing broilers led to their higher growth potential with a decrease in resistance to tropical conditions (Tesseraud & Temim, 1999). This resulted in an increased susceptibility to heat stress induced myopathy and muscle distrophy (Sandercock *et al.,* 2006) which combined with the insulin resistance often led to a degradation of meat quality. Accordingly, the efficiency of protein retention decreases with increasing abdominal fat in broilers (Tesseraud & Temim, 1999). Ojano-Dirain & Waldroup (2002) reported that broiler's production under heat stress condition could be improved by an appropriate pattern of nutritional combinations and feed management. Diet must be adjusted to the climatic variations with appropriate feeding strategy. Thus, sequential feeding, a cyclic feeding program with two diets for one or several days can partially recreate the conditions of more varied diets (Bouvarel *et al.,* 2008a). This type of feeding program has mainly been studied for nutritional purposes (Rose *et al.*, 1995; Lozano *et al.,* 2006) but can also be used to control animal growth and also enhance motor activity (Bizeray *et al.,* 2002). In fast growing broilers, it was first used to reduce leg problems by alternating a low-lysine and a standard feed (Bizeray *et al.,* 2002) and proved to be effective in reducing mortality under acute heat challenge during the finishing period (De Basilio *et al.,* 2001). Also, Bouvarel *et al.* (2008a) had observed similar growth performances and carcass composition from 10 to 28 days of age than with complete diet when fed chickens sequentially. Feeding high and low protein diets on alternate days has been shown to induce a relatively small and insignificant reduction in body weight gain compared to complete diet and shorter sequential feeding (Rosebrough *et al.,* 1989 ; Forbes & Shariatmadari, 1996).

Broiler chickens fed low energy and low protein diet resulting in similar final live weight compared to those fed normal energy and normal protein (Dairo *et al.*, 2010). However, Bouvarel *et al.* (2004) suggested to alternate different diets within 48 hours cycles and recommended the use of a moderate difference in rich or low protein and energy to avoid a deleterious effect on growth rate in broilers. On the contrary, it has been reported that birds are able to adjust their intakes to receive a balanced amino acid intake in 6 hours periods alternate feeding than 12 hours periods which could negatively affect their growth rate (Gous & Du Preez, 1975). Furthermore, according to De Basilio *et al.* (2001) such feeding method could enhance chicken performances under tropical conditions. Therefore, the objective of this study was to find the appropriate feeding method for rearing fast-growing broilers in hot and humid climates.

MATERIALS AND METHODS

Experimental Location

The experiment was carried out at the experimental unit of Regional Center of Excellence on Poultry Sciences (CERSA) in Badja, 41 km, at from Lome. The area is characterized by a humid tropical climate. Temperature and relative humidity of poultry house were recorded twice a day (just after the first diet distribution and half hour before the second diet distribution) by thermo-hygrometers placed in the middle and corners of poultry house over experiment period. The average temperatures were 26. 87 °C ± 0.28 and 30.83 °C ± 0.95 respectively in the morning and in the afternoon while the relative humidity varied from 78.01 % ± 1.31 in the morning to 65.23 % ± 3.19 in the afternoon.

Experimental design

A total of 770 10-day-old, unsex Cobb broiler chickens, with similar average body weight, were selected and assigned to seven treatments of five replicates of 22 chickens each: control group (CONT) fed complete diet with constant energy ($E_{standar}$) and constant protein ($P_{standar}$) levels (ME =3084.10 kcal/kg and PB= 19.01 %); B birds fed with $E_{standar}$ and high protein level (P_{high} : 21.63 %) diet in morning and with $E_{standar}$ and low protein level (P_{low}: 16.39%) in the afternoon; C birds fed diet with $P_{standar}$ and low energy level (E_{low} : 2953.56 kcal/kg) in morning and with $P_{standar}$ and high energy level (E_{high} : 3216.33 kcal/kg) in the afternoon; D birds fed diet with low energy level (E_{low}: 2932.73 kcal/kg) and low protein level (P_{low}: 16.40 %) in morning and thereafter high energy level (E_{high}: 3233.18 kcal/kg) and high protein level (P_{high}: 21.63%) in the afternoon; E birds received diet with low energy level (E_{low}: 2960.56 kcal/kg) and high protein level (P_{high}: 22.02 %) in morning and subsequently with high energy level (E_{high} : 3207.14 kcal/kg) and low protein level (P_{low} : 16.01 %) in the afternoon (24H cycles). F and G birds received the same feeding treatment than E birds respectively in 12H and 48H cycles. Diets alternated in birds were formulated to be isoenergetic and/or isoprotenic to control diet at the end of period cycles (Table 1). Broiler chickens received the same starter diet (ME: 3071.34 kcal/kg and 22 % CP) from 0 to 10 days old. The experiment lasted for 5 wk. Feed (Table 1) was provided two times daily : 6.30 AM and 6.00 PM in all groups except group F which was served diets 7.30 AM and 1.00 PM. Water was supplied *ad libitum*. The lighting program was reduced from daily 24 L : 0 D to 23 L : 1D from 10 to 15 d of age of chickens. The chickens were raised on deep litter system at the density of 5 birds/m^2. Temperature and relative humidity were recorded twice daily (morning and afternoon). Daily feed intakes according to the day time (morning or afternoon), daily mortalities, and weekly body weight were recorded.

Day time feed intake and growth parameters evaluation

The amount of feed offered and the left over were weighed (twice a day) before distribution of each diet. Feed intake was recorded according to the day time. The birds were weighed weekly to determine absolute body weight and weight gain. In order to determine carcass and organs relative weights, 6 selected birds having the average weight were slaughtered at 45-d old and abdominal fat, emptied gizzard, liver, heart, kidney and intestine were weighed while intestinal length were also measured.

Ultimate pH evaluation and water holding capacity of meat

Breast meat was sample and cooled at 4°C and 24 hours postmortem, ultimate pH (pHu) at 24 hours postmortem, was measured with a pH meter by inserting a glass electrode directly into the thickest part of the pectoralis major muscle using a pH meter OARTON pH 700 (with precision of 0.01). A piece of 6*6 cm of filter paper was placed on a plexiglass plate and 0.3 g of meat was placed in its centre. A second plexiglass plate was put on top and pressed by a weight of 50 kilogram for 5 min (Hamm, 1960).

Gait Score

Observations were made on the gait score of the birds at 41 d of age using the method of Bizeray *et al.* (2002). Gait score was determined using a five-point scales performed by Kestin *et al.* (1992) : 0 corresponding to a bird that walked normally with no detectable abnormality, to 4 designating a bird that had a severe gait defect but was still capable of walking with difficulty and only when strongly motivated. Birds with a gait score of 3 and 4 were considered to have abnormal gait. A score of 5 was not included because birds with such a gait score were able to walk and would have been culled before.

Statistical analysis

Data were analyzed by ANOVA using the GLM procedure of R software 3.5.2 version. Sequential feeding was used as the independent variable in a completely randomized design. When differences among the parameters were significant ($p < 0.05$), means were separated using Tukey's HSD test. Pearson correlation coefficient was used to analyze mortalities. Since abnormal scores are ordinal variables, their analysis was done following the Kruskall–Wallis test followed by the Mann–Whitney U test. The significant effect of feeding system on variables was reported when P–value < 0.05. Data are presented as mean ± SEM.

RESULTS

Day time feed intake, total daily feed intake and growth performance

Overall, broiler chickens consumed higher ($p < 0.05$) feed in the morning than in the afternoon across all treatment groups (Table 2). Also, as shown in Table 3, total daily feed intake of birds fed sequentially was similar ($p > 0.05$) compared to those in control (CONT) group.

Nevertheless, final body weight of C group birds fed alternate high and low energy diets were significantly higher ($p < 0.05$) than those of CONT, B, D, E, F and G birds (Table 3). Despite this improvement, sequential feeding had no significant effect ($p > 0.05$) on weight gain, mortality and feed conversion ratio

Table 1. Ingredients and chemical composition of broiler diets as formulated and fed

	Complete diet	**Alternated diets**							
	CONT	LOT B		LOT C		LOT D		LOT E, F and G	
Ingredients	Control	$E P^{+}$	$E P^{-}$	$E^{-}P$	$E^{+}P$	$E^{-}P^{-}$	$E^{+}P^{+}$	$E^{-}P^{+}$	$E^{+}P^{-}$
Maize (%)	59.3	56.3	69.3	56.3	59.4	62.5	51.7	48.7	66.3
Wheat bran (%)	6.5	2	3	12.4	4.4	13.8	2.1	9.1	4
Soybean (%)	19.5	25.5	12	17.5	22	12.5	25.5	24.5	10
Lysine (%)	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
Methionine (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Oyster shell (%)	1	1	1	1	1	1	1	1	1
Salt (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Concentrate 5%	6.5	8.5	5.5	8	5	4.5	8.5	8.5	7.5
Palm oil (%)	1	0	0	0.5	2.5	0	3	0	3
Bier dresh (%)	5.5	6	8.5	3.5	5	5	7.5	7.5	7.5
Diet chemical composition									
EM (kcal/kg)	3084.10	3084.40	3084.10	2953.56	3216.33	2932.73	3233.18	2960.56	3207.14
Crude Protein (%)	19.01	21.63	16.39	19.02	19.03	16.40	21.63	22.02	16.01

CONT : $E_{standar}/P_{standar\ diet}$ (control) ; $E^{-}P$: $E_{low}/P_{standar}$ diet; $E^{+}P$: $E_{high}/P_{standar}$ diet; $P^{+}E$: P_{high} /$E_{standar}$ diet; $P^{-}E$: P_{low} /$E_{standar}$ diet; $E^{-}P^{-}$: E_{low}/P_{low} diet; $E^{+}P^{+}$: E_{high}/P_{high} diet; $E^{-}P^{+}$: E_{low} /P_{high} diet; $E^{+}P^{-}$ diet: E_{high} /P_{low} diet. CONT: Chicken fed complete diet $E_{standar}/P_{standar}$; B birds fed $E_{standar}/P_{high}$ diet in morning and $E_{standar}/P_{low}$ diet in the afternoon; C birds received $P_{standar}/E_{low}$ diet in the morning followed by $P_{standar}/E_{high}$ diet in the afternoon; D birds fed E_{low}/P_{low} diet in the morning and E_{high}/P_{high} diet in the afternoon; E, F and G birds received E_{low}/P_{high} diet in the morning followed by E_{high}/P_{low} diet in the afternoon respectively in 24H, 12H and 48H cycles.

Table 2. Feed intake according to day time (distribution in the morning and distribution in the afternoon) in 24 H cycles sequential feeding treatments

Treatments	Day time		
	Morning	Afternoon	$p < 0.05$
CONT	42.77 ± 2.09^a	34.63 ± 2.45^b	0.04
B	43.58 ± 2.44^a	32.56 ± 1.25^b	0.02
C	46.52 ± 3.18^a	38.69 ± 2.77^b	0.03
D	41.62 ± 3.52^a	35.44 ± 0.99^b	0.02
E	43.7 ± 2.80^a	29.76 ± 0.80^b	0.008
F	40.28 ± 2.30^a	30.93 ± 1.49^b	0.03

^{a,b}Means within row values with different superscript differ significantly ($p < 0.05$).
CONT: Chicken fed complete diet $E_{standar}/P_{standar}$; B birds fed $E_{standar}/P_{high}$ diet in morning and $E_{standar}/P_{low}$ diet in the afternoon; C birds received $P_{standar}/E_{low}$ diet in the morning followed by $P_{standar}/E_{high}$ diet in the afternoon; D birds fed E_{low}/P_{low} diet in the morning and E_{high}/P_{high} diet in the afternoon; E and F birds received E_{low}/P_{high} diet in the morning followed by E_{high}/P_{low} diet in the afternoon respectively in 24H and 12H cycles

Carcass composition evaluation

Tables 4 and 5 show the effects of sequential feeding system on carcass weights, digestive organ weights and intestinal length of broiler chickens. No significant difference ($p > 0.05$) was observed in breast, thigh, pancreas, gizzard, heart, tenderloin weights among all treatment groups. Similarly, intestinal length and weight were not significantly impacted ($p > 0.05$) by sequential feeding strategy. However, abdominal fat was significantly increased in control, D and G birds ($p < 0.05$) than those of the other treatment groups.

Gait score of chickens, ultimate pH evaluation and water holding capacity (WHC) of meat

Abnormal gait study highlights the issue of animal welfare in the rearing of fast-growing broiler chickens. As shown in Table 6, sequential feeding system had no significant ($p > 0.05$) effect on gait score. Additionally, ultimate pH (pHu) of breast meat of the chickens was not affected by the treatments ($p > 0.05$). However, C bird's meat showed a significant higher water holding capacity (WHC) than those of the other dietary treatment groups ($p < 0.05$).

Table 3. Effect of sequential feeding system on growth performances in broilers

Parameters	Traitements							$p < 0.05$
	CONT	Lot B	Lot C	Lot D	Lot E	Lot F	Lot G	
Total daily feed intake (g)	76.88 ± 6.69	75.63 ± 6.91	84.36 ± 8.55	76.50 ± 7.51	72.95 ± 6.79	70.67 ± 6.93	79.31± 6.45	NS
Final body weight (g)	1886 ±73.68[b]	1868 ± 12.11[b]	2143 ± 40.25[a]	1854 ± 35.10[b]	1838 ± 17.84[b]	1765 ±47.27[b]	1841 ±47.40[b]	0.02
weight gain (g)	49.29 ± 6.89	48.77 ± 6.75	56.64 ± 9.11	48.36 ± 7.31	47.94 ± 7.64	45.81 ± 7.41	48.00 ± 7.21	NS
Mortality (%)	0.00	0.04 ± 0.04	0,04 ± 0.04	0,09 ± 0.05	0,04 ± 0.04	0,00	0,09 ± 0.05	NS
FCR	1.65 ± 0.13	1.70 ± 0.17	1.69 ± 0.20	1.80 ± 0.21	1.87 ± 0.31	1.96 ± 0.38	1.88 ± 0.22	NS

[a,b]Means within row values with different superscript differ significantly ($p < 0.05$).
CONT: Chicken fed complete diet $E_{standar}/P_{standar}$; B birds fed $E_{standar}/P_{high}$ diet in morning and $E_{standar}/P_{low}$ diet in the afternoon; C birds received $P_{standar}/E_{low}$ diet in the morning followed by $P_{standar}/E_{high}$ diet in the afternoon; D birds fed E_{low}/P_{low} diet in the morning and E_{high}/P_{high} diet in the afternoon; E, F and G birds received E_{low}/P_{high} diet in the morning followed by E_{high}/P_{low} diet in the afternoon respectively in 24H, 12H and 48H cycles

Table 4. Effect of sequential feeding system on carcass composition in broilers

Parameters	Traitements							$p < 0.05$
	CONT	Lot B	Lot C	Lot D	Lot E	Lot F	Lot G	
Breast	22.60 ± 1.34	21.54 ± 0.20	23.89 ± 1.84	22.74 ± 0.17	21.17 ± 0.67	20.67 ± 1.21	22.08 ± 0.78	NS
Thigh	23.41 ± 1.65	21.86 ± 0.32	16.06 ± 5.36	21.04 ± 0.53	20.59 ± 0.73	21.62 ± 0.06	21.29 ± 0.80	NS
Fillet	6.06 ± 0.54	5.84 ± 0.08	6.11 ± 0.27	5.88 ± 0.20	5.91 ± 0.29	5.41 ± 0.22	5.87 ± 0.27	NS
Carcass	69.19 ± 0.60	66.51 ± 0.79	70.55 ± 0.64	70.67 ± 3.47	58.26 ± 11.89	69.81 ± 3.04	69.48 ± 1.38	NS
Abd. Fat	1.61 ± 0.12[a]	1.01 ± 0.15[b]	0.96 ± 0.1[b]	1.42 ± 0.21[a]	0.80 ± 0.10[b]	0.97 ± 0.12[b]	1.51 ± 0.15[a]	0.03
Gizzard	2.16 ± 0.12	2.47 ± 0.22	2.11 ± 0.10	2.34 ± 0.18	2.67 ± 0.29	2.67 ± 0.09	2.17 ± 0.11	NS
Heart	0.47 ± 0.01	0.47 ± 0.01	0.42 ± 0.02	0.46 ± 0.03	0.45 ± 0.04	0.48 ± 0.02	0.51 ± 0.03	NS
Liver	1.89 ± 0.07	1.96 ± 0.07	1.74 ± 0.08	1.81 ± 0.09	1.35 ± 0.44	1.83 ± 0.04	2.07 ± 0.10	NS
Pancréas	0.31 ± 0.02	0.24 ± 0.05	0.28 ± 0.02	0.31 ± 0.02	0.18 ± 0.06	0.33 ± 0.02	0.27 ± 0.02	NS

[a,b]Means within row values with different superscript differ significantly ($p < 0.05$). Abd. Fat: abdominal fat.

CONT: Chicken fed complete diet $E_{standar}/P_{standar}$; B birds fed $E_{standar}/P_{high}$ diet in morning and $E_{standar}/P_{low}$ diet in the afternoon; C birds received $P_{standar}/E_{low}$ diet in the morning followed by $P_{standar}/E_{high}$ diet in the afternoon; D birds fed E_{low}/P_{low} diet in the morning and E_{high}/P_{high} diet in the afternoon; E, F and F birds received E_{low}/P_{high} diet in the morning followed by E_{high}/P_{low} diet in the afternoon respectively in 24H, 12H and 48H cycles

Table 5. Effect of sequential feeding system on intestinal sections weight and length in broilers

	Traitements							
Paramètres	CONT	Lot B	Lot C	Lot D	Lot E	Lot F	Lot G	*p* < 0.05
Duodenum weight (%)	0.75 ± 0.05	0.78 ± 0.09	0.72 ± 0.03	0.77 ± 0.17	0.72 ± 0.15	0.99 ± 0.06	0.76 ± 0.15	NS
Jejunum weight (%)	1.15 ± 0.05	1.18 ± 0.09	1.15 ± 0.02	0.93 ± 0.21	1.10 ± 0.23	1.36 ± 0.07	1.09 ± 0.24	NS
Ileum weight (%)	0.99 ± 0.03	1.07 ± 0.07	0.98 ± 0.04	0.89 ± 0.19	0.90 ± 0.18	1.12 ± 0.06	0.94 ± 0.20	NS
Rectum weight (%)	0.10 ± 0.02	0.17 ± 0.02	0.14 ± 0.01	0.08 ± 0.03	0.10 ± 0.03	0.32 ± 1.26	0.10 ± 0.02	NS
Duodenum length (cm)	29.07 ± 1.08	28.41 ± 1.66	27.40 ± 0.65	30.43 ± 2.09	25.02 ± 5.06	32.12 ± 1.36	25.03 ± 5.15	NS
Jejunum length (cm)	47.45 ± 2.38	46.40 ± 2.36	48.05 ± 2.31	44.17 ± 2.89	43.84 ± 9.33	53.08 ± 3.41	33.95 ± 10.79	NS
Ileon length (cm)	55.60 ± 1.49	57.92 ± 2.39	55.77 ± 1.53	53.19 ± 4.43	49.11 ± 10.02	60.98 ± 2.80	42.14 ± 13.43	NS
Rectum length (cm)	6.32 ± 0.25	6.96 ± 0.53	5.86 ± 0.67	5.12 ± 0.55	5.99 ± 1.26	18.78 ± 13.62	4.12 ± 1.31	NS

CONT: Chicken fed complete diet $E_{standar}/P_{standar}$; B birds fed $E_{standar}/P_{high}$ diet in morning and $E_{standar}/P_{low}$ diet in the afternoon; C birds received $P_{standar}/E_{low}$ diet in the morning followed by $P_{standar}/E_{high}$ diet in the afternoon; D birds fed E_{low}/P_{low} diet in the morning and E_{high}/P_{high} diet in the afternoon; E, F and F birds received E_{low}/P_{high} diet in the morning followed by E_{high}/P_{low} diet in the afternoon respectively in 24H, 12H and 48H cycles

Table 6. Effect of sequential feeding system on gait score, ultimate pH and water holding capacity in broilers

	Traitements							
Parameters	CONT	Lot B	Lot C	Lot D	Lot E	Lot F	Lot G	*p* < 0.05
pHu	5,61 ± 0,10	5,41 ± 0,06	5,69 ± 0,07	5,38 ± 0,03	5,58 ± 0,05	5,70 ± 0,03	5,71 ± 0,04	NS
*WHC	29,44 ± 0,65[b]	26,58 ± 0,75[c]	34,31 ± 0,32[a]	27,08 ± 1,12[bc]	27,49 ± 0,26[bc]	24,26 ± 0,78[c]	25,32 ± 0,53[c]	0.02
Abnormal gait	1,167 ± 0,54	1,33 ± 0,49	2,00 ± 0,68	1,83 ± 0,75	0,50 ± 0,34	0,67 ± 0,49	1,17 ± 0,48	NS

[a,b]Means within row values with different superscript differ significantly ($p < 0.05$)

CONT: Chicken fed complete diet $E_{standar}/P_{standar}$; B birds fed $E_{standar}/P_{high}$ diet in morning and $E_{standar}/P_{low}$ diet in the afternoon; C birds received $P_{standar}/E_{low}$ diet in the morning followed by $P_{standar}/E_{high}$ diet in the afternoon; D birds fed E_{low}/P_{low} diet in the morning and E_{high}/P_{high} diet in the afternoon; E, F and F birds received E_{low}/P_{high} diet in the morning followed by E_{high}/P_{low} diet in the afternoon respectively in 24H, 12H and 48H cycles.

DISCUSSION

The present study aimed to find the appropriate feeding method for rearing fast-growing broilers in hot and humid climates. Broiler chickens showed similar feed intake even though that was significantly different according to the feeding day-time (Table 2). In fact, as shown in Table 2, the afternoon feed intake was low in some treatments, particularly in B, E and F birds. The reduction of feed intake was correlated to the increase of temperature and relative humidity in the afternoon. This could indicate the effect of temperature and relative humidity on chickens' feed intake. High ambient temperature stress reduces feed intake (Teeter and Belay, 1996). In general, optimal feed intake in broilers was observed in thermoneutral zone called comfort zone (Al-Aqil *et al.,* 2009) with temperature between 15 to 25°C and 60-65% humidity. Then, birds are able to regulate their heat balance relatively well and do not spend much energy on activity (Syafwan *et al.,* 2011). Feed intake increased in cooler time of the day compared to warmer time. Moreover, according to the feeding method, birds in C group fed diet with $P_{standar}$ and low energy level in morning and with $P_{standar}$ and high energy level in the afternoon consumed more feed both in the morning and in the evening. Feeding strategy therefore have played important role in the feed intake of C group broilers. Broiler production under heat stress could be improved by an appropriate combination of nutritional and management therapies (Ojano-Dirain & Waldroup, 2002). Since total daily feed intake during the experiment were similar (Table 3), the tendency to consume differently one or the other alternate served diet can be linked with the law of feeding compensation of the birds (Bouvarel *et al.,* 2008a,b ; Forbes & Shariatmadari, 1996 ; Bizeray *et al.,* 2002).

Similar body weight noticed with chickens of group B, D and E, F and G which received two types of alternate diets varying in energy and/or in protein (Table 3) while those fed in C group showed higher body weight compared to control group. First, this suggests that birds could adjust their feed intake to compensate for their nutritional needs for the day. Also, feeding model used in broilers in C group could improve broiler performances under acute heat challenge. Indeed, poultry growth performances are greatly affected by the environment conditions (Babinszky *et al.,* 2011); but nutritional practices could increase these performances (Padilha, 1995). Chicken might have eaten more energy through such feeding strategy. With the peaks and abrupt changes in temperature and/or relative humidity, metabolic disturbances would have occurred with birds in the other groups and the protein retention efficiency (ratio of proteins retained to proteins ingested) significantly decreased in chickens (Tesseraud & Temim, 1999). In this context, changes in the use of glucose occur in relation to altered insulin secretion and tissue sensitivity to this hormone (Rideau & Métayer-Coustard, 2012). Since energy is mainly provided by dietary carbohydrates, the insulin resistance induced by heat stress in warm causes a breakdown of the sensors of the muscle cells, which are unable to regulate the blood glucose (Tesseraud & Temim, 1999). Much of the glucose that should be converted into energy usable for proteosynthesis is then accumulated and subjected to lipogenesis in the liver and leads to fat formation (Rideau & Métayer-Coustard, 2012). This phenomenon would occur even when the amounts of feed consumed by the chickens were similar (Tesseraud & Temim, 1999). Alternate varied level of dietary energy could have improved energy intake efficiency leading to improve protein retention and then the growth performances through above mentioned mechanism in chickens in C group. These performances are consistent with those by Fosoul *et al.* (2016), Bouvarel *et al.* (2004, 2008a) but contradict those of Leterrier *et al.* (2008) and Bizeray *et al.* (2002).

On the other hand, our findings on the carcass and organ weights results showed that the mean values of the weight of the brisket, thigh, fillet, carcass, gizzard, heart, liver and pancreas and intestine length were similar across the treatments. These results are consistent with those of Kim *et al.* (2012), which distributed energy and protein diets to chickens. The higher fat content of chickens in control group in this study indicates intense lipogenesis activity leading to increase abdominal fat and to the reduction of glucose availability for protein synthesis (Tesseraud & Temim*,* 1999 ; Rideau & Métayer-Coustard, 2012). These results contradict those of Bouvarel *et al.* (2008a) who found similar abdominal fat.

The sequential feeding strategy during the day did not improve the feed efficiency of chickens in across the treatment groups (Table 3). Similar feed conversion ratio suggested proportional feed intake according to growth rate. Our findings are in agreement with those of Fosoul *et al.* (2016), Bouvarel *et al.* (2008a) and Leterrier *et al.* (2008) over the period from 28 to 38 days of age but contradict those of Leterrier *et al.* (2008) over the period from 10 to 28 days of age and Bizeray *et al.* (2002) from 2 to 42 days of age.

The low mortality recorded in this experiment indicates there was no negative impact of such feeding method on chicken's immune responses. In practice interplay exists among nutrition, genetics, management, and diseases and nutritional management impacts immune function of the chicken (Kidd, 2004).

As the feed distribution cycles was very important (De Basilio *et al.,* 2001), among other things, the study focused on the effect of the sequential feeding method in 12 H, 24 H and 48 H cycles.

Considering the different feeding models used, the 24-hour feeding cycle was found to be the most suitable for rearing broilers in tropical conditions. This challenges the previous findings of Bouvarel *et al.* (2004) who observed that 48H cycles were preferable.

In fast-growing broiler production, the problem of bone difficulties and metabolic disorders (ascites, and others) affect their welfare (De Smit *et al.,* 2005). In this study, it was important to evaluate whether alternating diets could reduce the prevalence of these nutritional pathologies or disorder. It was observed that the incidence of foot bone abnormalities was similar across the different treatments (Table 6). Indeed, the number of chickens that had scores 3 (obvious difficulty walking) and 4 (severe injury and severe difficulty walking) was similar among the treatments. Similar results were observed by Ale Saheb Fosoul *et al.* (2016), Bouvarel *et al.* (2008a).

In addition, the ultimate pH assessment of the meat revealed that, apart from the birds in C, which had a value between 5.7 and 6 (recommended by (Berri *et al.* (2005)), chickens in the other groups had pHu values between 5.4 and 5.6, suggesting good meat quality from chickens of treatment C (fed a low-energy feed in the morning and high-energy in the evening with a similar protein level to the control) compared to other treatment groups. Furthermore, these chickens had a higher water holding capacity, indicating the improvement of their meat quality (Blond & Montupet, 1989).

CONCLUSION

The use of sequential feeding with variable energy levels (high and low) with standard protein levels in broilers improved their body weights and ultimate pH and water holding capacity and reduced abdominal fat under tropical environment. However, sequential feeding did not limit leg abnormalities. Finally, feeding $P_{standar}/E_{low}$ in the morning and $P_{standar}/E_{high}$ in the afternoon was effective in increasing final body weights, some qualities in meat and in reducing abdominal fat.

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