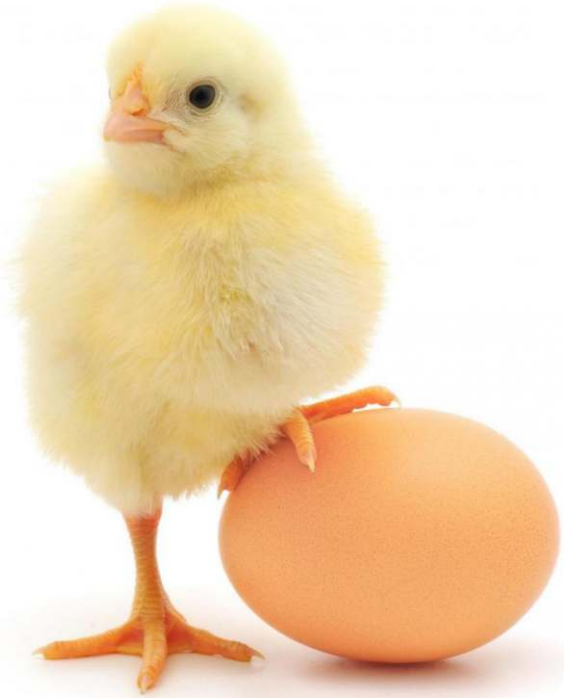
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 9 (7): 634-640, 2010
ISSN 1682-8356

Maximum Profit Feed Formulation
3. Interaction Between Energy Content and Temperature[1]

Sandro Cerrate and Park Waldroup[2]
Department of Poultry Science, University of Arkansas, Fayetteville, AR 72701, USA

Abstract: Nutritional models for comparison of environmental conditions on responses to dietary energy using data from literature were evaluated to formulate broiler diets by maximum profit feed formulation with real or simulated prices of corn and soybean meal. These diets were formulated based on Corn and Soybean Meal (C-SBM) or with Wheat and Cottonseed Meal (+W-CM) as alternative sources of energy and protein. Average body weight gain or feed intake slopes at normal temperature were significantly higher than those at heat stress. The rate of gain per calorie was two times higher at normal compared to heat stress and the rate of feed intake per calorie was half as high at normal than did at heat stress. At real or simulated prices, the economic energy content in most cases was reduced by heat stress compared to those at normal temperature. For real prices the energy reductions from normal temperature to heat stress were from 3.254 to 3.015 kcal/g for diets based on C-SBM or from 3.2 to 2.961 kcal/g for diets based on +W-CM. These economic energy reductions were around 7% from real prices, up to 10% from simulated corn prices and up to 9% from simulated SBM prices. The inclusion of +W-CM reduced the economic energy content and increased the profitability compared to those based on C-SBM diets. These data indicate that broiler diets fed during heat stress should be formulated with reduced economic energy content due to decreased rate of gain or feed intake per calorie compared to those at normal temperature.

Key words: Temperature, feed forms, energy, profit

INTRODUCTION

The profitability in the broiler industry can be improved when the income and cost are simultaneously considered in the formulation of broiler diets. Nutrient requirements of least cost feed formulation assume constant profits; however, when the prices of feed ingredients or bird meat vary, the nutrient needs can be changed according to the best profitability. In maximum profit feed formulation the broiler diets obtained for the best economic nutrient needs are the results from direct simulation of growth and feed intake. This method of formulation relies on growth or feed intake response to Dietary Nutrient Density (DND) or dietary energy. Thus, any type of interaction between the dietary energy content and temperature must be considered to produce accurate economic broiler diets.

It appears that the magnitude of growth rate is improved in either normal or heat stress environment as the energy or DND is increased but this response is greater at normal conditions than at heat stress. This effect can be observed statistically (Adams, 1961; Adams and Rogler, 1968; Mickelberry *et al*., 1966; Reece and McNaughton, 1982; Dale and Fuller, 1980; Abdelkarim, 1986; Cheng, 1991; Yalcin *et al*., 1998; Raju *et al*., 2004) or numerically (Adams *et al*., 1962; Lei and Slinger, 1970; Olson *et al*., 1972; Charles *et al*., 1981; Lott *et al*., 1992; Howlider and Rose, 1992). Therefore, there is controversy of the effect of temperature and energy on performance of broilers probably due to several reasons: 1) cyclic temperature: birds at heat stress under cyclic temperature can respond better than birds at heat stress under constant temperature. Birds fed increased energy content under cyclic temperatures can respond similarly or better than birds under normal temperatures (Dale and Fuller, 1980; Abdelkarim, 1986; Sonaiya, 1989; Belay and Teeter, 1996), showing no interaction; 2) severity of heat stress: heat stress birds with mild temperature did not present much difference as birds at normal temperature (Cheng, 1991; Charles *et al*., 1981; Lott *et al*., 1992); 3) age: for birds of early age the negative heat stress is not so pronounced (Lei and Slinger, 1970; Olson *et al*., 1972); 4) relation protein or lysine/energy ratio: when the protein or lysine is elevated, the body weight is increased significantly at heat stress as the energy content is increased (Adams *et al*., 1962; McNaughton and Reece, 1984), probably reducing the difference in performance between normal and heat stress.

The objectives of this study were to develop models for the comparison of two environmental conditions on responses to energy content using the maximum profit feed formulation in two types of broiler diets based on corn and soybean meal or wheat and cottonseed meal when real or simulated price for corn and soybean meal were used.

Corresponding Author: Park Waldroup, Department of Poultry Science, University of Arkansas, Fayetteville AR, USA

Table 1: Effect of temperature and energy on performance from literature sources

P	E	ME (Kcal/g)	CP (%)	Lys/ME (%/kcal/g)	Fat/EE (%)	Age (Days)	Temp. (C)	Body gain (g/d) Normal	Body gain (g/d) Heat	Feed intake (g/d) Normal	Feed intake (g/d) Heat
1	3	2.458	26.6*	0.616*	1.1/3.0	28-56	21vs29	26.0	23.9	83.1	74.7
		2.646	26.6	0.572	3.3/2.0			28.4	24.8	81.8	75.5
		2.756	25.8	0.536	3.2/4.5			29.8	26.2	79.8	69.8
		2.866	25.0	0.502	3.1/5.0			32.6	27.9	77.5	66.4
		2.976	25.8	0.496	7.6/9.5			31.5	26.8	74.9	64.6
		3.197	25.0	0.450	9.8/11.6			33.7	29.0	72.4	61.9
2	3	2.823	23.8	0.418*	1.0/3.6	42-70	21vs32	31.0b	24.8a	88.8	79.4
		3.289	23.0	0.352	10.0/12.2			33.3a	25.3a	94.3	69.3
		2.779	26.3	0.479	1.0/3.5			26.8b	22.8b	85.9	73.9
		3.263	25.5	0.400	10.0/12.1			29.0a	24.8a	81.6	70.1
		2.787	26.7	0.486	1.0/3.5			30.3b	26.3b	83.1	74.7
		3.269	25.9	0.407	10.0/12.0			34.8a	27.9a	83.1	64.9
3	2	2.923[m]	20.5*	0.384*	0.0/2.3	28-56	21vs29	34.9	32.8	86.1	76.1
		3.398	20.5	0.330	10.0/12.2			38.4	35.7	77.7	71.3
		3.473	20.5	0.323	10.0/12.2			39.8	35.6	78.5	71.3
		3.325	20.5	0.337	10.0/12.2			37.1	34.0	77.6	70.4
4	2	2.480	24.0	0.553*	0.0/1.6	28-56	21vs29	29.0a	28.5a	87.7	81.4
		2.770	24.0	0.495	5.9/7.4			32.6b	29.3ab	86.2	75.9
		3.070	24.0	0.447	11.8/13.2			34.0b	30.8b	79.5	72.0
		3.360	24.0	0.408	17.719.1			36.6c	30.8b	77.0	66.5
5	1	2.700	20.5	0.361*	1.0/4.1	7-21	24vs32	8.6	8.2	18.9	18.5
		3.150	23.9	0.445	11.0/12.8			10.4	9.5	17.9	16.4
6	1	2.880	19.1*	0.369*	0.0/2.8	14-28	13-24vs 27-31	11.1	9.0	33.7	23.7
		3.220	21.3	0.369	0.0/3.2			12.6	10.4	32.2	23.2
		3.690	24.7	0.396	10.0/12.6			13.4	10.5	28.9	20.7
7	1	3.190	22.0	0.362*	2.5/5.0	28-49	20vs31	49.0	37.7	103.3	82.4
		3.530	24.3	0.363	11.9/14.5			52.8	41.0	100.5	81.4
8	2	3.190	22.0	0.362*	2.5/5.0	28-49	14vs31	49.7	39.3	108.6	85.4
		3.530	24.3	0.363	11.9/14.5			53.6	41.3	104.2	82.4
9	1	2.820	19.8	0.355	0.0/1.7	21-56	18-19vs 26-27	42.8	38.8	96.2	89.3
		2.976	20.4	0.356	2.3/4.1			43.3	39.2	94.8	83.7
		3.083	20.7	0.357	5.1/6.9			43.4	39.0	93.0	82.7
		3.203	21.0	0.361	7.4/9.3			44.1	39.9	91.3	80.8
10	1	3.175	18.5	0.310	5.4/7.9	21-49	18vs27	48.4b	47.0a	106.6	101.8
		3.250	18.7	0.310	7.4/9.8			49.6ab	47.1a	105.7	99.2
		3.325	19.0	0.310	19.5/1.7			50.5a	46.8a	104.0	97.3
11	2	3.077	17.1	0.316	1.0/3.9	28-42	17vs33	50.9b	36.0a	120.3a	83.9b
		3.272	17.9	0.317	6.0/8.6			54.9a	37.2a	121.4a	83.4b
12	1	3.050	22.0	0.328	1.1/3.9	21-49	21vs29	67.7	54.4	---	---
		3.250	22.0	0.308	5.1/7.7			69.1	54.7	---	---
13	1	3.050	18.8	0.321	0.7/3.6	21-42	16vs27	104.2	99.6	192.2	183.8
		3.230	19.4	0.322	5.4/8.0			109.3	103.0	193.2	183.3
14	1	3.107	20.9	0.418	2.0/6.3	22-49	21vs29	60.0	53.9	127.0	114.6
		3.585	24.2	0.446	7.0/13.7			65.0	55.6	122.2	105.0
15	1	2.916	23.2	0.543/0.472	0.2/3.7	1-21	14-28vs 21-32	28.2c	21.5b	---	---
		3.098	23.1	0.425/0.429	3.5/6.2			30.2b	21.5b	---	---
		3.296	23.1	0.461/0.393	7.0/9.5			31.4a	22.2a	---	---
16	1	2.749	19.9	0.433	0.0/2.5	1-42	19-26vs 28-37	30.0b	29.6	65.6b	65.1a
		2.892	20.0	0.413	0.0/2.8			32.1a	30.2	63.6b	62.2b
16	24	average	g/d				40.1	34.5	88.2	76.8	
				Proportions (%)				100.0	86.1	100.0	87.1

1. Adams, 1961. Data calculated from average of trials 7, 8 and 9. 2. Adams *et al.*, 1962 and 28-56 d for the last two rows. For the heat stress of last two rows the ME, CP and lysine/ME were 2.716 and 3.199 kcal/g, 28.7 and 27.8% and 0.545 and 0.455 respectively. Data included 3 experiments. 3. Mickelberry *et al.*, 1966. Data calculated from average of trial 1 and 2. 4. Adams and Rogler, 1968. Data calculated from average of two trials. 5. Lei and Slinger, 1970. 6. Olson *et al.*, 1972. 7. Dale and Fuller, 1979. 8. Dale and Fuller, 1980. 21 vs 32 C for exp. 2. Data calculated from average of exp. 1 and 2. 9. Charles *et al.*, 1981. For the normal temperature there were three batches and at heat stress there were two batches. 10. Reece and McNaughton, 1982. 11. Abdelkarim, 1986. Data calculated from average of exp 1 and 2. 12. Cheng, 1991. Body weight gain calculated from equation published. 13. Lott *et al.*, 1992. 14. Howlider and Rose, 1992. Data average of males and females. 15. Yalcin *et al.*, 1998. The ratio of lysine/ME from the left side is from normal and right side from the heat stress. 16. Raju *et al.*, 2004.

*Estimated from NRC (1984) data. EE = Ether Extracted calculated from NRC (1984).

[m]ME of Hydrogenated Coconut Oil (HCO) from Carew *et al.*, 1964 and ME of corn oil or lard from Young (1961); ME or lysine of corn and SBM from NRC (1984). 2.923 kcal/g from control; 3.398 from +10% corn oil; 3.473 from +10% lard; 3.325 for +10% HCO.

P = Publications and E = Experiments; ME = Metabolizable Energy, CP = Crude Protein, Fat = inclusion of dietary fat

MATERIALS AND METHODS

Slopes of growth rate and feed intake from temperature: Data from literature were evaluated to quantify the growth rate and feed intake responses to dietary energy content in two environmental conditions (Table 1). It was intended to select data from literature that did not bias the real effect between temperature and energy. For example, data selected for temperature were selected for the range of temperature at heat stress approximately higher than 27^{0}C or under real cyclic temperatures, not simulated ones. Linear regression analysis was used to calculate the slopes of growth rate and feed intake in function of energy content for each set of study.

Calculation of profitability: Average daily weight gain or feed intake (A) at 49 days of male Cobb 500 (Cobb Vantress, 2008) (71.1 and 129.2 g/d), a fixed metabolizable energy (3.1 kcal/g) and average Slopes (S) for body weight or feed intake were used to calculate the Intercepts (I) of body weight gain and feed intake for normal temperature. According to the following equation:

$$I = A - S \times 3.1$$

Further Proportions (P) of heat stress/normal temperature for body weight gain and feed intake (Table 1) were multiplied by average daily weight gain or feed intake in order to calculate the intercepts of body weight and feed intake for heat stress in the following way:

$$I = AxP - S \times 3.1.$$

The predicted Body Weights (BW) or Feed Intakes (FI) were modeled by linear equations as a function of Energy Content (E) according to the following formula:

$$BW \text{ or } FI = I + S \times E$$

Two models, one for normal or heat stress, were used to calculate the profitability according to the following equation:

$$\text{Profitability (\$/bird)} = BW \times M - Fi \times C$$

Where, M is price of meat, $/kg and C is the cost of diet, $/kg; the BW and FI were multiplied by 49 and divided by 1000 to be expressed in kilograms.

The programming model: The two models were formulated using Solver, which is the default solver of Excel (Frontline Systems, Inc., 1999). It uses the generalized reduced gradient method to solve nonlinear problems. The options, which are specified by the user, were set as follows: iterations = 1000, precision = 0.000000001, convergence = 0.000001, estimates = tangent, derivatives = forward and search = Newton.
The composition matrix of ingredients and nutrient needs is shown in Table 2.

Design of analysis: Two types of diets were formulated, one based on corn and soybean meal and the other based on wheat and cottonseed meal as alternatives sources. The fixed maximum level for wheat was 40% and for cottonseed meal 20% according to studies by Partridge and Wyatt (1995) and Watkins and Waldroup (1995) respectively. Prices of main feed ingredients from

Table 2: Composition matrix of ingredients and nutrient needs in the nonlinear programming models[1]

Ingredients	ME (Kcal/g)	CP (%)	Ca (%)	NPP (%)	Na (%)	Lys (%)	Met (%)	TSSA (%)	Thr (%)	Cost[2] ($/kg)	Min (%)	Max (%)
Corn	3.35	8.5	0.02	0.08	0.02	0.26	0.18	0.36	0.28	0.135	0	100
Soybean meal	2.44	48.5	0.27	0.22	0.02	2.96	0.67	1.39	1.81	0.267	0	100
Wheat	3.120	11.50	0.05	0.00	0.06	0.35	0.17	0.42	0.36	0.124	0	40
Cottonseed meal	2.135	44.7	0.15	0.37	0.00	1.79	0.72	1.49	1.44	0.250	0	20
Poultry oil	8.25	....	....	....	....	....	....	....	....	0.350	0	6
Limestone	....	....	38	....	....	....	....	....	....	0.034	0	100
Phosphorus	....	....	21	16	....	....	....	....	....	0.281	0	100
Common salt	....	....	....	....	39	....	....	....	....	0.061	0	100
Vitamin premix	....	....	....	....	....	....	....	....	....	3.700	0.1	0.1
Mineral premix	....	....	....	....	....	....	....	....	....	1.746	0.1	0.1
DL-Methionine	3.68	57.52	....	....	....	....	98	0.98	....	2.533	0	100
L-Lysine HCl	4.60	94.4	....	....	....	74.42	....	....	....	1.762	0	100
L-Threonine	3.150	73.5	....	....	....	....	....	....	99.00	3.500	0	100
ME[3]											2.6	3.4
Nutrient needs[4]	3.115	18.71	0.928	0.463	0.195	1.086	0.436	0.833	1.103			
Maximum		23.00	1.100		0.400							

[1]The nutritional composition for the ingredients was obtained from the NRC (1984).
[2]Reference prices for corn and soybean meal were obtained from the month of November of 2008 and wheat and cottonseed meal from Feedstuffs, Nov, 2008.
[3]The Metabolizable Energy (ME) represents the dietary nutrient density. The energy/nutrient ratio was kept constant during its variation.
[4]Nutrient needs from average of 0-49d of Cobb 500, 2008 was used kept the energy/nutrient ratio.
Live Weight Equivalent Price (LWP) was 1.092 $/kg calculated from the following equation: LWP = (Wholecarcass price - processing cost) x dressing percentage = (1.73-0.319) x 0.774. Wholecarcass price from November, 2008 USDA.
ME = Metabolizable Energy, CP = Crude Protein, Ca = Calcium, NPP = Nonphytate Phosphorus, Na = Sodium, Lys = Total Lysine, Met = Total Methionine, TSSA = Total Sulfur Amino Acids, Thr = Threonine

November, 2008 were used to formulate broiler diets and predict performance for each model. Further increments of corn or soybean meal prices at -25%, +25%, +50%, +75% or +100% from real prices were simulated to calculate the economic energy contents for each model.

Statistical analysis: The slopes of the linear regressions for body weight gain or feed intake for the two environmental conditions were compared by paired t-test. Linear regressions and comparisons by paired t-test were obtained using JMP Software (JMP, version 7).

RESULTS

The slopes of body weight gain and feed intake for temperature are showed in Table 3. There were significant differences among the slopes. The average slopes of body weight or feed intake at normal temperature were significantly greater than those at heat stress. The predicted body weight gain and feed intake in function of energy content from 2.8-3.3 kcal/g for temperature are showed in Fig. 1.

Using real feed ingredient prices, the economic energy contents or dietary nutrient density obtained in the maximum profit feed formulation at heat stress were lower than at normal temperature, around 7% less for both types of diets (Table 4). For example at heat stress the broiler diets had 239 kcal/kg or 1.4% of protein less than did at normal temperature. The inclusion of alternative feed ingredients reduced the dietary nutrient density and increased the profitability compared to corn and soybean meal diets. This reduction of nutrients was equivalent around 2% less. These broiler diets had 40% of wheat, the fixed maximum level, whereas the cottonseed meal was not taken due to the lower soybean meal price. As expected the profitability at normal temperature was greater than did at heat stress.

In order to show the magnitude of difference for temperature, extra broiler diets were formulated at fixed energy levels assuming no interaction between energy and temperature on diets based with corn and soybean meal. For example if at heat stress the dietary energy is increased from 3.015 to 3.254 kcal/g, the same economic energy content at normal temperature, the profitability is reduced from 2.1542 to 2.1317 $/bird, the diet cost is increased from 0.1972 to 0.2179 $/kg, the body weight is increased from 2.978 to 3.033 kg and the feed intake is reduced from 5.567 to 5.417 kg. Thus at heat stress the reduction of feed intake or increment of body weigh did not compensate the high cost of 3.254 kcal/g diet.

The variations of economic energy contents as changing the price of corn or soybean meal in corn-soybean meal or corn-soybean meal with alternative ingredients are showed in Table 5. The economic energy content was different as changing the corn or Soybean Meal (SBM) prices. In general at heat stress the economic energy content was lower than did at normal temperature. This economic energy reduction was up to 10% for corn variation and up to 9% for SBM variation. However, this difference disappeared in corn-soybean meal diets at +75% corn price and at +50%, +75% or +100% soybean meal price. In general as the corn price was increased,

Table 3: Regression slopes (g gain or feed intake/kcal/g) of the effects of temperature on responses to energy content or dietary nutrient density

P	Gain: Normal	Gain: Heat stress	Feed intake: Normal	Feed intake: Heat stress
1	10.4	6.9	-15.7	-20.2
2	6.6	2.0	1.7	-14.5
3	8.0	5.3	-15.3	-9.7
4	8.2	2.9	-13.3	-16.5
5	4.0	2.9	-2.2	-4.6
6	2.8	1.8	-6.0	-3.8
7	11.2	9.7	-8.4	-2.8
8	11.6	5.9	-12.8	-8.8
9	3.3	2.3	-13.0	-21.8
10	14.0	-1.0	-17.4	-30.2
11	20.9	6.4	5.9	-2.6
12	7.1	1.5	---	---
13	28.3	18.8	5.5	-3.1
14	10.5	3.5	-10.1	-20.1
15	8.4	2.0	---	---
16	14.4	3.8	-13.8	-19.9
Average	10.6	4.7	-8.2	-12.8
Mean difference	-5.938		-4.553	
Standard error	1.122		1.714	
T-ratio	-5.294		-2.656	
Prob<t	<0.0001		0.009	

P = Publications. 1. Adams, 1961; 2. Adams *et al.*, 1962; 3. Mickelberry *et al.*, 1966; 4. Adams and Rogler, 1968; 5. Lei and Slinger, 1970; 6. Olson *et al.*, 1972; 7. Dale and Fuller, 1979; 8. Dale and Fuller, 1980; 9. Charles *et al.*, 1981; 10. Reece and McNaughton, 1982; 11. Abdelkarim, 1986; 12. Cheng, 1991; 13. Lott *et al.*, 1992; 14. Howlider and Rose, 1992; 15. Yalcin *et al.*, 1998; 16. Raju *et al.*, 2004

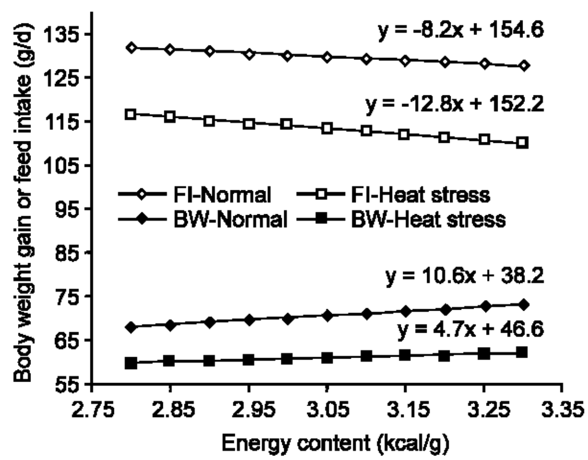


Fig. 1: Linear equations of Body Weight Gain (BW) and Feed Intake (FI) for environmental conditions

Table 4: Performance of environmental based on Corn and Soybean Meal (C-SBM) diets and Wheat (W)

	Environmental condition			
	Normal		Heat stress	
Characteristics	C-SBM	+W	C-SBM	+W
Profitability ($/bird)	2.5241	2.5373	2.1542	2.1772
Diet cost ($/kg)	0.2179	0.2101	0.1972	0.1894
Body weight (kg)	3.562	3.534	2.978	2.9653
Feed intake (kg)	6.268	6.290	5.567	5.601
ME (kcal/g)	3.254	3.200	3.015	2.961
Crude protein (%)	19.55	19.22	18.11	17.79
Lysine (%)	1.134	1.116	1.051	1.032
Met + Cys (%)	0.870	0.856	0.806	0.792
Threonine (%)	1.152	1.133	1.068	1.048
Nonphytate P (%)	0.484	0.476	0.448	0.440
Calcium (%)	0.969	0.953	0.898	0.882
Corn (%)	60.79	24.71	72.04	35.96
Wheat (%)	---	40.00	---	40.00
Soybean meal (%)	28.24	24.25	23.31	19.32
Poultry oil (%)	6.0	6.0	0.0	0.0
Ground limestone (%)	1.03	0.88	0.99	0.84
Calcium phosphate (%)	2.33	2.52	2.12	2.31
Sodium chloride (%)	0.48	0.43	0.44	0.39
L-Threonine (%)	0.48	0.49	0.44	0.46
L-Lysine HCl (%)	0.19	0.26	0.23	0.30
DL-Methionine (%)	0.26	0.27	0.23	0.23

Standard price, $/kg: corn (C) = 0.135, SBM = 0.267, Wheat (W) = 0.124. Live weight equivalent price = 1.092 $/kg

Table 5: Variations of corn and soybean meal prices in environmental on economic energy contents of broiler diets

	Environmental condition			
	Normal		Heat stress	
Price variation ($/kg)	C-SBM	+W,CM	C-SBM	+W,CM
Standard prices	3.254	3.200	3.015	2.961
Corn, -25%, 0.101	3.254	3.254[y]	3.015	3.015[y]
Corn, +25%, 0.169	3.254	3.200	3.015	2.895
Corn, +50%, 0.203	3.254	3.200	3.213[z]	3.143[z]
Corn, +75%, 0.236	3.213	3.143	3.213	3.130[2]
Corn, +100%, 0.270	3.173[1]	3.109[1]	3.159[1,2]	3.075[1,2,3]
SBM, -25%, 0.200	3.213	3.173	2.964	2.895
SBM, +25%, 0.334	3.254	3.142[x]	3.015	2.904[x,o]
SBM, +50%, 0.401	3.015[s]	2.917[o]	3.015	----
SBM, +75%, 0.467	3.015	-----	3.015	----
SBM, +100%, 0.534	3.015	-----	3.015	----

Standard prices, $/kg: corn (C) = 0.135, soybean meal (SBM) = 0.267, wheat = 0.124, cottonseed meal = 0.250, poultry oil = 0.350. [1]Fixed maximum level: 23% of crude protein. [2]Fixed maximum level: 1.1% of calcium. [3]Fixed maximum fixed level: 0.4% of sodium. [y]Only at this level the wheat (W) is not taken. [x]After this SBM price, the Cottonseed Meal (CM) is taken 20% for normal temperature and 19.7% for heat stress. [o]After this SBM price, SBM is not taken. [z]After this corn price, the poultry oil is taken until its maximum level, 6%. [s]After this SBM price, the poultry oil is not taken

the economic energy content tended to decrease. The wheat was taken 40% replacing mainly corn as the corn price increased except at -25%. When the program allowed the inclusion of poultry oil, the economic energy content was elevated and then the energy also tended to reduce as corn price increased. This reduction in some case was allowed at the expense of increments of protein, calcium or sodium sources due to the lack of bulkiness. Likewise, as the Soybean Meal (SBM) price was increased the economic energy content tended to reduce except at diets based on corn and SBM after +50% SBM prices. After +25% SBM price, the cottonseed meal was taken 19.7% for heat stress and 20% for normal temperature.

DISCUSSION

The two times higher growth slope of birds at normal temperature compared to birds at heat stress could be increased if studies where the effect of temperature and energy at early age were omitted (Lei and Slinger, 1970; Olson *et al.*, 1972) because at this early age the negative effect of heat stress on performance is small. However, at early age Yalcin *et al.* (1998) showed big differences on growth rate between normal temperature and heat stress as energy increased. Probably this new broiler strain of fast growth rate have responded more in normal condition but less at heat stress. Fisher and Wilson (1974) showed that birds of fast growth rate responded with higher energy needs compared to slow growth rate. Otherwise, this difference can be more marked when the dietary protein or lysine are not elevated as the energy content is increased. Studies have showed that birds at heat stress fed increased energy content with lower lysine/energy ratio the body weight is not increased, whereas with higher lysine/energy ratio the body weight is improved (Adams *et al.*, 1962; McNaughton and Reece, 1984). Further it has been showed that birds at cyclic temperature tend to increase the energy intake and consequently improve the body weight reducing the difference between normal temperature and heat stress (Dale and Fuller, 1980; Abdelkarim, 1986; Sonaiya, 1989; Belay and Teeter, 1996). The lower rate of feed intake per calorie of birds at heat stress compared to normal conditions shows that birds under heat stress tend to regulate the energy intake decreasing the feed consumption as dietary energy is increased probably in order to dissipate better the heat production. However, it seems that under cyclic temperature this rate is higher than did at normal temperature (Dale and Fuller, 1980; Olson *et al.*, 1972) probably because the heat stress birds at hours of normal temperature tend to ingest more feed due to a compensatory factor.

The linear equations presented in this study are suitable to demonstrate differences between two temperature as energy is increased; however, accurate estimations of body weight or feed intake are needed by non linear equations (Pesti and Miller, 1997; Guevara, 2004; Eits *et al.*, 2005a,b; Cerrate and Waldroup, 2009). Thus it is recommended feasible equations for particular conditions using non linear equations between energy content and normal temperature or heat stress.

As the corn price was increased, the alternative energy sources were included and the economic energy contents were increased or decreased depending on the energy content of substitute sources such as poultry oil or wheat. Similarly, as the Soybean Meal (SBM) price was increased, the Cottonseed Meal (CM) was included and the economic energy content was slightly reduced due to the smaller metabolizable energy of CM compared to that of SBM.

The marked difference of growth or feed intake slopes for two environmental condition shows that the energy needs should be reconsidered in order to be used for least cost feed formulation. Furthermore, the maximum profit feed formulation produces broiler diets with a wide range of economic energy content or dietary nutrient density according to feed ingredient prices or alternatives feed ingredients. In this study in most cases reduced economic energy contents at heat stress have been observed. Unfortunately it is believed that diets should be increased in energy, along with other nutrient except protein, under heat stress in order to compensate the reduced feed intake. However, this small increment in weight gain on response to increased dietary density or energy did not offset the high cost diet. Moreover, the high mortality observed in heat stress birds fed high energy diet (Belay, 1991) suggests that the energy content or dietary nutrient density should be reduced.

The results of this study showed that the energy needs should be reconsidered for environmental conditions in order to be used in maximum profit feed formulation or even in least cost feed formulation. In general at heat stress reduced economic energy content due to the decreased rate of gain or feed intake per calorie is recommended compared to those at normal temperature.

REFERENCES

Abdelkarim, M.R., 1986. A Study of the Interrelationships between Dietary Energy and Protein on Performance of Broilers during Heat Stress. PhD. Thesis, University of Arkansas, Fayetteville, AR.

Adams, R.L. and J.C. Rogler, 1968. The effects of environmental temperature on the protein requirements and response to energy in slow and fast growing chicks. Poult. Sci., 47: 579-586.

Adams, R.L., 1961. Effect of Environmental Temperature Upon the Nutrition of Young Chickens. Ph.D. Thesis, Purdue University, Lafayette, IN.

Adams, R.L., F.N. Andrews, E.E. Gardiner, W.E. Fontaine and C.W. Carrick, 1962. The effects of environmental temperature on the growth and nutritional requirements of the chick. Poult. Sci., 41: 588-594.

Belay, T., 1991. Nutritional and Water Balance Considerations for Development of Broiler Heat Distress Therapeutic Techniques. Ph.D. Thesis, Oklahoma State University, Stillwater, OK.

Belay, T. and R.G. Teeter, 1996. Virginiamycin and caloric density effects on live performance, blood serum metabolite concentration and carcass composition of broilers reared in thermoneutral and cycling ambient temperatures. Poult. Sci., 75: 1383-1392.

Carew, L.B., D.T. Hopkins, and M.C. Nesheim, 1964. Influence of amount and type of fat on metabolic efficiency of energy utilization by the chick. J. Nutr., 83: 300-306.

Cerrate, S. and P. Waldroup, 2009. Maximum profit feed formulation of broilers: 1. Development of a feeding program model to predict profitability in a non linear programming. Int. J. Poult. Sci., 8: 205-215.

Charles, D.R., C.M. Groom and T.S. Bray, 1981. The effects of temperature on broilers: Interactions between temperature and feeding regime. Br. Poult. Sci., 22: 475-481.

Cheng, T.K., 1991. Feeding and Managing Broilers at High Temperatures. Ph.D. Thesis, University of Minnesota, St. Paul, MN.

Cobb-Vantress Inc., 2008. Broiler Performance & Nutrition Supplement Cobb500. Cobb-Vantress, Inc., Siloam Springs, AR.

Dale, N.M. and H.L. Fuller, 1980. Effect of diet composition on feed intake and growth of chicks under heat stress. II. Constant vs. cycling temperatures. Poult. Sci., 59: 1434-1441.

Dale, N.M. and H.L. Fuller, 1979. Effects of diet composition on feed intake and growth of chicks under heat stress. I. Dietary fat levels. Poult. Sci., 58: 1529-1534.

Eits, R.M., G.W.J. Giesen, R.P. Kwakkel, M.W.A. Verstegen and L.A. Den Hartog, 2005a. Dietary balanced protein in broiler chickens. 2. An economic analysis. Br. Poult. Sci., 46: 310-317.

Eits, R.M., R.P. Kwakkel, M.W.A. Verstegen and L.A. Den Hartog, 2005b. Dietary balanced protein in broiler chickens. 1. A flexible and practical tool to predict dose-response curves. Br. Poult. Sci., 46: 300-309.

Fisher, C. and B.J. Wilson, 1974. Response to dietary energy concentration by growing chickens. Page 151-184 in: Energy requirements of poultry. T.R. Morris and B.M. Freeman, ed. Br. Poult. Sci. Ltd., Edinburgh.

Frontline Systems, Inc., 1999. Solver User's Guide. Incline Village, NV.

Guevara, V.R., 2004. Use of nonlinear programming to optimize performance response to energy density in broiler feed formulation. Poult. Sci., 83: 147-151.

Howlider, M.A.R. and S.P. Rose, 1992. The response of growing male and female broiler chickens kept at different temperature to dietary energy concentration and feed form. Anim. Feed Sci. Technol., 39: 71-78.

JMP, Version 7. SAS Institute Inc., Cary, NC, 1989-2007.

Lei, K.Y. and S.J. Slinger, 1970. Energy utilization in the chick in relation to certain environmental stresses. Can. J. Anim. Sci., 50: 285-292.

Lott, B.D., E.J. Day, J.W. Deaton and J.D. May, 1992. The effect of temperature, dietary energy level and corn particle size on broiler performance. Poult. Sci., 71: 618-624.

McNaughton, J.L. and F.N. Reece, 1984. Factors affecting pelleting response. 1. Influence of dietary energy in broiler starter diets. Poult. Sci., 63: 682-685.

Mickelberry, W.C., J.C. Rogler and W.J. Stadelman, 1966. The influence of dietary fat and environmental temperature upon chick growth and carcass composition. Poult. Sci., 45: 313-321.

National Research Council, 1984. Nutrient Requirements of Poultry. 8th Rev. Edn., Natl. Acad. Press, Washington, DC.

Olson, D.W., M.L. Sunde and H.R. Bird, 1972. The effect of temperature on metabolizable energy determination and utilization by the growing chick. Poult. Sci., 51: 1915-1922.

Partridge, G. and C. Wyatt, 1995. More flexibility with new generation of enzymes. World Poultry-Misset, 11: 17, 19, 21.

Pesti, G.M. and B.R. Miller, 1997. Modeling for precision nutrition. J. Appl. Poult. Res., 6: 483-494.

Raju, L.N., G. Shyam Sunder, M.M. Chawak, S.V. Rama Rao and V.R. Sadagopan, 2004. Response of naked neck (Nana) and normal (nana) broiler chickens to dietary energy levels in a subtropical climate. Br. Poult. Sci., 45: 186-193.

Reece, F.N. and J.L. McNaughton, 1982. Effects of dietary nutrient density on broiler performance at low and moderate environmental temperatures. Poult. Sci., 61: 2208-2211.

Sonaiya, E.B., 1989. Effects of environmental temperature, dietary energy, sex and age on nitrogen and energy retention in the edible carcase of broilers. Br. Poult. Sci., 30: 735-745.

Watkins, S.E. and P.W. Waldroup, 1995. Utilization of high protein cottonseed meal in broiler diets. J. Appl. Poult. Res., 4: 310-318.

Yalcin, S., S. Ozkan, Z. Acikgoz and K. Ozkan, 1998. Influence of dietary energy on bird performance, carcase parts yields and nutrient composition of breast meat of heterozygous naked neck broilers reared at natural optimum and summer temperatures. Br. Poult. Sci., 39: 633-638.

Young, R.J., 1961. The energy value of fats and fatty acids for chicks. Poult. Sci., 40: 1225-1235.

[1]Published with approval of the Director, Arkansas Agricultural Experiment Station, Fayetteville AR 72701. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the University of Arkansas and does not imply its approval to the exclusion of other products that may be suitable.

[2]To whom correspondence should be addressed. Waldroup@uark.edu.