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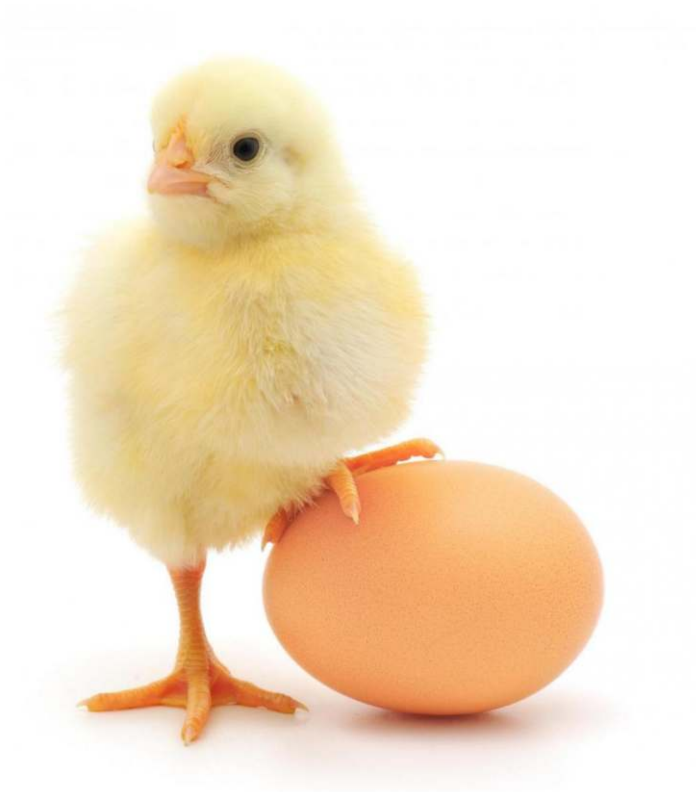

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Maximum Profit Feed Formulation of Broilers: 2. Comparison among Different Nutritional Models[1]

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Abstract: Four economic nutritional models including a constant calorie-nutrient ratio (C-E:P), a variable calorie-protein ratio (V-E:Pg), a constant protein-amino acid ratio (DBP) and a variable calorie-protein ratio for the finisher period (V-E:Pd) were compared in terms of relative performance, economic nutrient requirements and profitability based on relative performance expressed as a function of nutrients, relative or real prices of feedstuffs and broilers and maximum profit feed formulation. The relative body weight or feed intake in response to nutrient contents tended to increase or decrease respectively with particular differences for each model. The economic nutrient requirements were different for each model such as 3.139 Mcal/kg for C-E:P, 2.968 Mcal/kg and 20.7% of protein for V-E:Pg model, 22.44% of protein for DBP model, 3.167 Mcal/kg for V-E:Pd and 3.134 Mcal/kg for C-E:P-3.15 model. As the price of broilers or corn increased, the energy or protein content was increased for C-E:P, V-E:Pg and DBP models except the energy level of V-E:Pg model. However, as the Soybean Meal (SBM) or poultry oil price increased, the energy or protein content was reduced for the three models indicated above except the energy level of V-E:Pg model. Energy levels of the V-E:Pd model were kept almost constant as the broiler or ingredient price raised. Under relative price of feedstuffs and broilers the best profits depended on the model used, being more economical when the broiler or corn price increased for the C-E:P or DBP models respectively. The best profitability using real price of broiler, corn or SBM for twelve months came from the C-E:P model followed by the DBP model. From the two models, V-E:Pd and C-E:P-3.15 models, the V-E:Pd model had the best benefit but with a narrow range of growth response and economic conditions. These data suggest that the C-E:P model is the best method of formulation to maximize performance or profitability; however, for some corn price variation the DBP model can be more profitable though the carcass quality can be negatively affected.

Key words: Broiler feed, carcass quality, economic nutrient requirements

INTRODUCTION

Since it has been demonstrated that Maximum Profit Feed Formulation (MPFF) produces better broiler diets in term of profitability than least cost feed formulation (Gonzalez-Alcorta *et al.*, 1994; Guevara, 2004; Sterling *et al.*, 2005; Eits *et al.*, 2005b; Cerrate and Waldroup, 2009), it is important to compare the different nutritional models cited to date based on different methods of formulation. Nutritional models have been proposed for the formulation of broiler diets as a function of profitability; however, these approaches have not been compared to evaluate which is more suitable in terms of performances or profitability when the broiler or ingredient prices are considered under simulated or real variation.

A common way to formulate broiler diets is to consider the energy and nutrients in some ratio. As the energy and the rest of nutrients are increased, the body weight tends to increase without altering the carcass quality (Donaldson *et al.*, 1957; Combs and Nicholson, 1964; Saleh *et al.*, 2004). However, some studies have proposed that energy and protein content can vary to get the best profitability although this can negatively affect the carcass quality (Jackson *et al.*, 1982; Pesti and Fletcher, 1983; Gonzalez-Alcorta *et al.*, 1994; Pesti and Miller, 1997). Other broiler diets are based on increasing protein and essential amino acids while the energy is kept constant (Eits *et al.*, 2005a,b). In contrast, some broiler diets are based on increasing energy levels while the rest of nutrients are not varied (Leeson *et al.*, 1996; Dozier *et al.*, 2006).

These methods of formulation produce different rates of body weight and feed consumption, which are two main inputs to calculate profitability. Since the broiler responses in function of nutrient contents are expressed in absolute terms, the relative basis of body weight and feed consumption is necessary to compare among different nutritional models. The objectives of this study were to compare the different nutritional models presented currently in term of performance, nutrient contents and profitability using maximum profit feed formulation when changing the prices of broiler, corn soybean meal or/and poultry oil.

MATERIALS AND METHODS

Development of the model to predict profitability: Four models were compared in order to evaluate performance and profitability during changes of ingredient or broiler prices. The first model called the constant energy-nutrient ratio (C-E:P) was developed from the study of Saleh *et al.* (2004). The second model was proposed by Gonzalez-Alcorta *et al.* (1994) and the third model was developed from the study of Dozier *et al.* (2006), these models are called variable energy-protein ratios, V-E:Pg and V-E:Pd for the former and latter experiments. The fourth model was developed by Eits *et al.* (2005a) where the dietary protein and essential amino acids are increased at the same proportion, called Dietary Balanced Protein (DBP). For the first model, C-E:P, the absolute body weight or feed consumption was expressed in terms of the average metabolizable energy at 49 days by quadratic equations, making use of an Microsoft Excel (2003) spreadsheet. For the third model, V-E:Pd, the absolute body weight or feed consumption was also expressed in terms of the average metabolizable energy by quadratic equations, making use of an Microsoft Excel (2003) spreadsheet. The equations for the absolute body weight and feed consumption of the four nutritional models are shown in Table 1.

Relative body weight or feed consumption was calculated dividing the absolute performance of given energy or protein contents over the absolute performance fixed at 3.00 Mcal/kg of energy or 19.04% of protein for the C:E:P, V-E:Pg or DBP model. For example, the relative body weight or feed consumption of a quadratic equation was obtained from the following way:

$$rBW \text{ or } rFC = (a + bxME + cxME^2) / (a + bx3 + cx3^2)$$

Where ME = metabolizable energy, rBW = relative body weight; rFC = relative feed consumption.

The relative performance of V-E:Pd was compared to that of C-E:P model fixing at 3.15 Mcal/kg of energy since 3.0 Mcal/kg is out of the range used in the Dozier *et al.* (2006) study. For this reason the C-E:P model was called C-E:P-3.15 model in order to make comparisons with the V-E:Pd model.

The profitability (MP) was calculated considering income over total costs.

$$MP = Income - Costs$$

Where MP = Maximum Profit, $/birds at 49 days, Income = weight, 2.7 kg x rBW x Price of live weight and Costs = 5.2 kg x rFC x cost of the diet ($/kg).

The programming model: The four models were formulated using Maximum Profit programming 3.0. This program has nonlinear programming and conventional linear programming 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.

Each model has its own nutritional constraints which were used to formulate the broiler diets in order to have accurate feed cost. The nutritional constraints are shown in Table 2. In the C-E-P model the minerals, 105% amino acids and the energy:protein ratio as suggested by NRC (1984), Thomas *et al.* (1992) and Saleh *et al.* (2004) respectively were used. These nutrients represent the average of the different feeding phase presented in the Saleh *et al.* (2004) study. In the V-E:Pg model the amino acids and minerals as suggested by Pesti *et al.* (1986) and NRC (1994) respectively were used. In the V-E:Pd model the protein, amino acids, calcium and available phosphorus according to Dozier *et al.* (2006) and the sodium and chlorine from NRC (1994) were used. In the DBP model the energy was fixed at 3.1 Mcal/kg, a value intermediate between the 3.2 Mcal/kg from NRC (1994) and 3.0 Mcal/kg from CVB (2000), amino acid requirements according to the ideal protein profile from Mack *et al.* (1999) and the protein calculated from the proportion lysine:protein ratio, 55 g of total lysine per kg of crude protein, as suggested by Surisdiarto and Farrell (1991) were used.

The composition matrix of ingredients in the four models is shown in Table 3. It has three main ingredients which are corn, soybean meal and poultry oil. The maximum values for poultry oil were set according to their experimental studies. For example, the C-E:P, V-E:Pg, V-E:Pd and BDP had 9, 16 and 9 and 5% for maximum levels of poultry oil, respectively.

The Live Weight Equivalent Prices (LEP) were derived from Ready to Cook (RTC) prices published by USDA between September of 2006 and August of 2007 and using the following equation:

$$LEP = (RTC\text{-processing cost}) \times \text{dressing percentage} = (RTC-0.319) \times 0.774$$

The nutritional models identify the combinations of feed ingredients to find the level of energy or protein that maximize the profitability. These models require the static nutrient requirements or nutrient constrains, cost of ingredients, price of the product and levels of energy or/and protein which are entered as an extra ingredient. Further the response functions of body weight and feed consumption were expressed in terms of energy or/and protein.

Design of the analysis: Before the four models were compared in Maximum Profit Feed Formulation (MPFF), a simulation process was developed in order to estimate the performance or profitability for each model as the nutrients increased. A wide range of energy or/and protein content, from 2.9-3.35 Mcal/kg of energy or

Table 1: Equations for the absolute body weight or feed consumption of the nutritional models

Sources	R^2	Equations
C-E:P	0.7083	BW = -18.9978+13.45123 x ME -2.07873 x ME^2
	0.5459	FI = -27.3673+21.04293x ME - 3.39631x ME^2
V-E:Pg	0.9999	BW= - 3.5008 + 0.8897xME - 0.1279xME^2 +5.1743xCP - 9.1854xCP^2 + 0.0568x49
	0.9876	FI= - 4.0688 - 0.1661xME + 4.2641xCP - 8.7674xCP^2 + 0.1672x49
DBP	0.9790	BW = 0.98x78+0.02x78x(1-EXP(-0.61x(CPx0.55-(-172.9-0.1xA+0.0935x2003-0.024x1))))
	0.9700[1]	FI= [1.02x1.95-0.02x1.95x(1-EXP(-0.538x(CPx0.55-(-97.8-0.0936xA+0.0562x2003+0.0679x1))))] x BW
V-E:Pd	0.5022	BW = -291.747+186.3932xME - 29.46008xME^2
	0.9742	FI = 82.01018 - 45.5963xME + 6.733734xME^2

Where: BW = actual body weight; FI = actual feed consumption; ME = metabolizable energy level, Mcal/kg; CP = crude protein level, in g/kg for V-E:Pg and in % for DBP; A = average broiler age for the feeding period, 1 - 49 d, A = 24.5d; C-E:P = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio proposed by Gonzalez-Alcorta *et al.* (1994); V-E:Pd = variable energy-protein ratio developed from Dozier *et al.* (2006) data; DBP = dietary balanced protein model proposed by Eits *et al.* (2005a). [1]Coefficient of determination (R^2) for feed conversion

Table 2: Nutritional constraints for each model

	C-E:P	V-E:Pg	DBP	V-E:Pd
ME, Mcal/kg[1]	3.0-3.4	2.4-3.6	3.1	3.1-3.2
CP,%[2]	ME/0.158	15 - 30	11 - 29	19.7
Lys T,%	ME/2.904	CPx0.052	CPx0.055	1.04
Met T,%	ME/6.369	CPx0.026		
TSAA T,%	ME/3.84	CPx0.041	Lys Tx0.75	0.83
Thre T,%	ME/4.177		Lys Tx0.63	0.76
Calcium,%	ME/3.507	0.913	0.913	0.83
Available P,%	ME/8.533	0.375	0.375	0.41
Sodium,%	ME/19.845	0.161	0.161	0.161
Chlorine,%	ME/19.845	0.161	0.161	0.161

Where: [1,2]The nutrient range represents the minimum and maximum value used in the models; ME = metabolizable energy level; CP = crude protein contwnt; Lys T = total lysine; Met T = total methionine; TSAA T = total methionine + cystine; Thre T = total threonine. C-E:P= constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio proposed by Gonzalez-Alcorta *et al.* (1994); V-E:Pd = variable energy-protein ratio developed from Dozier *et al.* (2006) data; DBP = dietary balanced protein model proposed by Eits *et al.* (2005a); The average of nutrients contents from V-E:Pd model were obtained from the average of starter, grower and finisher nutrient contents which the starter and grower ones were acquired upon request from Dozier *et al.* (2006)

from 18.4-21.3% of protein at a constant ratio, 0.15786 ME (Mcal/kg) / CP (%), was used for the C-E:P, V-E:Pg, V-E:Pd and C-E:P-3.15 models. Further, a range from 18.4 -22.85% of protein was used for the DBP model. The feed costs were calculated in the linear programming by setting the fixed value of energy or/and protein for each model. On the other hand, using the non-linear programming, the profits were calculated and the output nutrients were found for each model.

A simulated variation of price for broilers, corn, soybean meal and poultry oil in increments of 25% in relation to reference prices was evaluated to compare the nutrient outputs or economic nutrient requirements and profitability among the nutritional models. The prices of broiler, soybean meal and corn from September, 2006 to August, 2007 published by the USDA were used to formulate diets among the four nutritional methods and compare their profits assuming a typical broiler complex slaughtering of 1,250,000 broilers per week.

RESULTS

The relative performance and profitability for each nutritional model are shown in Fig. 1, 2 and 3 and Table 4. The relative body weight and feed intake for each model were affected by the energy and/or protein content. The relative Body Weight (rBW) of the C-E:P model showed a curvilinear fashion as the energy levels increased where the highest rBW was 104.3% at 3.25 ME Mcal/kg. The rBW for both models, V-E:Pg and DBP, showed a similar linear trend as the energy and/or protein contents raised. The rBW of V-E:Pd or C-E:P-3.15 models had also a curved line but the rBW of V-E:Pd was smaller than that of C-E:P-3.15 at energy levels lower than 3.15 or higher than 3.20 Mcal/kg. The highest rBW for V-E:Pd and C-E:P-3.15 were 100.05% and 101% respectively assuming 100% at 3.15 ME Mcal/kg. These peaks of body weights were found at 3.175 ME Mcal/kg for V-E:Pd and 3.25 ME Mcal/kg for C-E:P-3.15. The relative Feed Intake (rFI) of V-E:Pg and DBP tended to decrease linearly when the energy or protein levels increased but the feed intake by DBP model was reduced more marked than by V-E: Pg model. Moreover, the rFI of V-E:Pd model tended to reduce severely as the energy levels enhanced. However, the rFI of both C-E:P and C-E:P-3.15 models had a curved line peaked at 3.175 Mcal/kg of energy.

In these simulations the maximum profits for each model had the following energy or protein contents: 3.150 ME Mcal/kg for C-E:P, 3.00 ME Mcal/kg and 19.04% of protein for V-C:Pg, 22.53% of protein for DBP, 3.175 ME Mcal/kg for V-E:Pd and 3.125 ME Mcal/kg for C-E:P-3.15. Profits by C-E:P model were higher than by DBP or V-C:Pg models during a wide range of energy. Only at energy levels lower than 2.95 or higher than 3.25 Mcal/kg the DBP model produced higher profits than did C-E:P model. The V-E:Pg model produced higher profits than did the C-E:P model at energy contents lower than 3.025 or higher than 3.325 Mcal/kg. The C-E:P-3.15 model estimated higher profits than those in the V-C: Pd model during a wide range of energy except during a narrow range of energy around 3.175 Mcal/kg of energy. However, using the Maximum Profit Feed Formulation (MPFF) more accurate values of profits and nutrients output were found than by the simulation process. For example, 3.139 ME Mcal/kg for C-E:P, 2.968 ME Mcal/kg

Table 3: Composition matrix of ingredients in the nonlinear programming models[1]

Ingredient[3]	ME (kcal/g)	CP (%)	Calcium (%)	Nonphytate phosphorus (%)	Sodium (%)	Lysine (%)	Meth-ionine (%)	TSSA (%)	Threonine (%)	Cost[2] $/kg	Minimum (%)	Maximum (%)
Corn	3.35	8.5	0.02	0.08	0.02	0.26	0.18	0.36	0.28	0.125	0	100
Soybean meal	2.44	48.5	0.27	0.22	0.02	2.96	0.67	1.39	1.81	0.218	0	100
Poultry oil	8.25	-----	-----	-----	-----	-----	-----	-----	-----	0.419	0	PO[4]
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
ME											ME_1	ME_2
Crude protein											CP_1	CP_2

[1]The metabolizable energy ($ME_{1,2}$) or/and crude protein ($CP_{1,2}$) were allowed to vary depending of the used model as showed in Table 2. [2]Reference prices for corn and soybean meal were obtained from the month of August of 2007. [3]The nutritional composition for the ingredients was obtained from the NRC (1994) and the nutrient constrains was used as showed in Table 2. [4]PO = Poultry oil, value that differ depending of used model, such as C-E:P, V-E:Pg, V-E:Pd and BDP had 9, 16, 9 and 5% as maximum value respectively

and 20.07% of protein for V-C:Pg, 22.44% of protein for DBP, 3.167 ME Mcal/kg for V-E:Pd and 3.134 ME Mcal/kg for C-E:P-3.15. C-E:P model had a better profit than did V-E:Pg or DBP models. The V-E:Pd model had slightly higher economic return than did the C-E:P-3.15 model due to its reduced relative feed intake and total cost. The output nutrients obtained from the above nutritional models by the MPFF were similar as those calculated by the fixed nutrients of each model during the simulations; however, the protein of the V-E:Pg model from the MPFF was higher (20.07% vs 19.04%) than obtained from simulations.

The effect of price variations of broiler, corn, soybean meal or poultry oil for the C-E:P, V-E:Pg and BDP models on diet formulation and profitability is shown in Table 5. As the broiler price increased, the energy and protein contents were increased in the C-E:P model, whereas the energy level was reduced and the protein level increased in the V-E:Pg model. Similarly, the protein content of DBP model was increased as the broiler price increased. The profits were better for the C-E:P model than for the other models except at the -25% broiler price. At this price the V-E:Pg model had the highest profitability because this model allowed a greater reduction in the protein level, reducing the feed intake and total cost. All the models produced an increase of nutrients as response to increasing body weight since the broiler price was increased. It is interesting to note that only the V-E:Pg model decreased the energy content in order to reduce the total cost as the broiler price increased. Changes of corn, Soybean Meal (SBM) and poultry oil levels were adjusted according the variation of each nutrient. Thus, the levels of corn were reduced and levels of SBM were increased when the broiler price was increased for the three models but in the C-E:P model the variation of corn was slightly reduced because the levels of poultry oil were increased. As the corn price increased, the energy and protein content were increased in the C-E:P model. In this situation, the energy content was raised because the levels of poultry oil were elevated because of the relative cheaper price of poultry oil than that of corn. Further, the protein content was increased due to the cheap relative price of protein source compared to that of energy source from corn. In the V-E:Pg model the protein content was increased while the energy level was decreased and in DBP model the protein content was also increased as the corn price increased. Since the price of corn which is the main source of energy was increased, the levels of corn for the three models were reduced and SBM levels were increased with tendencies more marked for the V-E:Pg and DBP models. The C-E:P model had the best profits at -25% corn price, whereas the DBP model had the highest profits at +25% and +50% corn price. As the SBM price increased, the protein contents were reduced for the three models, being decreased less for the C-E:P model. In contrast, in the V-E:Pg model the energy level was increased while the protein level was greatly decreased. The highest profits were observed at -25% SBM price for the DBP model, at +25% SBM price for the C-E:P model and at +50% SBM price for the V-E:Pg model. As expected the levels of SBM were reduced and those of corn were increased for the three models but these changes were more drastic for the V-C:Pg and DBP models. The levels of poultry oil were reduced in the C-E:P and DBP models as the SBM price augmented. As the poultry oil price increased, the energy and consequently the protein contents were reduced in the C-E:P models. Similarly, in the DBP model the protein content was reduced. Both, C-E:P and DBP models reduced the energy or protein content due to the inclusion of poultry oil in the broiler diets. Though the energy content was fixed (3.1 Mcal/kg) in the DBP model, the protein content was reduced because the level of corn was increased to reach the target level of energy as the poultry oil price increased. The energy or protein

Table 4: Profits of nutritional models using simulations and non linear programming

		C-E:P		V-E:Pg		DBP		V-E:Pd		C-E:P-3.15	
ME	CP	rBW	rFI	rBW	rFI	rBW	rFI	rBW	rFI	rBW	rFI
Kcal/g	%	relative terms									
Input nutrients[1]											
2.900	18.40	0.955	0.981	0.989	1.002	0.988	1.006	0.34	1.23	0.92	0.98
3.000	19.04	1.000	1.000	1.000	1.000	1.000	1.000	0.75	1.12	0.96	0.996
3.050	19.36	1.017	1.005	1.005	0.999	1.005	0.997	0.88	1.07	0.98	1.000
3.100	19.67	1.029	1.0063	1.009	0.998	1.010	0.995	0.96	1.03	0.99	1.002
3.125	19.83	1.034	1.0058	1.011	0.997	1.012	0.994	0.99	1.02	0.996	1.001
3.150	19.99	1.038	1.004	1.013	0.996	1.014	0.993	1.0000	1.00	1.00	1.000
3.175	20.15	1.041	1.002	1.015	0.996	1.016	0.992	1.0005	0.99	1.00	0.998
3.200	20.31	1.0425	0.999	1.017	0.995	1.017	0.991	0.99	0.97	1.00	0.99
3.250	20.63	1.0434	0.991	1.020	0.994	1.021	0.989	0.93	0.95	1.01	0.99
3.300	20.94	1.040	0.980	1.023	0.993	1.024	0.987	0.82	0.94	1.00	0.98
3.350	21.26	1.033	0.965	1.026	0.991	1.026	0.985	0.67	0.93	1.00	0.96
	21.58					1.029	0.984				
	21.90					1.031	0.982				
	22.21					1.033	0.981				
	22.53					1.035	0.980				
	22.85					1.036	0.978				
Output nutrients[2]											
3.139		1.036	1.005								
2.968	20.07			1.005	1.003						
	22.44					1.034	0.980				
3.167								1.00	0.99		
3.134										1.00	1.00

		C-E:P	V-E:Pg	DBP	VE:Pd	C-E:P-3.15	C-E:P	V-E:Pg	DBP	VE:Pd	C-E:P-3.15
		Cost of diet					Profitability				
ME	CP										
Kcal/g	%	$/kg					$/bird				
Input nutrients[1]											
2.900	18.40	0.158	0.157	0.166	0.164	0.158	2.021	2.110	2.057	-0.059	1.922
3.000	19.04	0.164	0.162	0.169	0.169	0.164	2.111	2.122	2.085	1.224	2.006
3.050	19.36	0.168	0.166	0.170	0.172	0.169	2.131	2.113	2.095	1.639	2.024
3.100	19.67	0.173	0.171	0.171	0.176	0.173	2.142	2.104	2.105	1.908	2.034
3.125	19.83	0.176	0.173	0.172	0.177	0.176	2.1440	2.098	2.109	1.988	2.0359
3.150	19.99	0.178	0.175	0.172	0.179	0.178	2.1441	2.093	2.113	2.031	2.0356
3.175	20.15	0.180	0.178	0.173	0.181	0.181	2.142	2.087	2.116	2.037	2.033
3.200	20.31	0.183	0.180	0.174	0.182	0.183	2.138	2.081	2.119	2.007	2.029
3.250	20.63	0.188	0.185	0.175	0.186	0.188	2.124	2.068	2.124	1.836	2.015
3.300	20.94	0.192	0.189	0.176	0.189	0.192	2.101	2.054	2.129	1.517	1.993
3.350	21.26	0.214	0.194	0.177	0.192	0.218	1.988	2.040	2.132	1.050	1.862
	21.58	0.179					2.134				
	21.90	0.180					2.136				
	22.21	0.181					2.1366				
	22.53	0.182					2.1367				
	22.85	0.183					2.136				
Output nutrients[2]											
3.139		0.177					2.1444				
2.968	20.07		0.163					2.125			
	22.44			0.182					2.137		
3.167					0.180					2.039	
3.134						0.177					2.036

Where: [1] A wide range of simulated nutrients to obtain the maximum profitability. [2]Nutrients obtained from maximum profit feed formulation using the non linear programming. Profitability = 2.7 x rBW x 1.097-5.2 x rFI x Cost of diet; rBW = relative body weight; rFI=relative feed intake. The energy-protein ratio was 0.157567 Mcal/kg / %. The cost of corn, soybean meal and poultry oil were 0.1248, 0.2176 and 0.4189 $/kg respectively. ME = metabolizable energy level, Mcal/kg; C-E:P= constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio from Gonzalez-Alcorta *et al.* (1994); DBP = dietary balanced protein from Eits *et al.* (2005a); V-E:Pd = variable-energy protein ratio developed from Dozier *et al.* (2006) data fixed at 3.15 Mcal/kg; C-E:P-3.15 = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data fixed at 3.15 Mcal/kg

Table 5: Effect of price variations of broiler, corn, soybean meal or poultry oil for the C:EP, V-E:Pg and DBP models on diet formulations and profitability

		Use levels, %							Diet	Profit
					ME	CP	Carcass weight	Feed intake	Cost MP	Margin MP
Variables	Models	Corn	SBM	PO	Kcal/g	%	kg	kg	$/kg	$/bird
Prices changes										
Reference	C-E:P	60.14	32.37	3.97	3.139	20.91	2.798	5.227	0.177	2.144
	V-E:Pg	66.96	29.40	0.00	2.968	20.07	2.714	5.215	0.163	2.125
	DBP	56.41	36.07	3.89		22.44	2.793	5.096	0.182	2.137
Broiler price (25% -)	C-E:P	62.44	31.36	2.74	3.089	20.61	2.772	5.232	0.172	1.380
	V-E:Pg	70.43	25.88	0.00	2.999	18.67	2.692	5.196	0.160	1.383
	DBP	58.70	34.11	3.53		21.70	2.780	5.112	0.179	1.372
Broiler price (25%+)	C-E:P	58.99	32.87	4.59	3.163	21.06	2.807	5.218	0.179	2.913
	V-E:Pg	63.65	32.72	0.00	2.939	21.41	2.731	5.229	0.167	2.872
	DBP	54.61	37.61	4.16		23.03	2.800	5.085	0.184	2.904
Broiler price (50%+)	C-E:P	58.30	33.17	4.96	3.178	21.14	2.811	5.211	0.181	3.683
	V-E:Pg	61.51	34.86	0.00	2.920	22.28	2.740	5.237	0.169	3.623
	DBP	53.12	38.88	4.39		23.52	2.806	5.077	0.186	3.673
Corn (25%-)	C-E:P	61.21	31.90	3.40	3.116	20.77	2.787	5.232	0.156	2.243
	V-E:Pg	69.35	26.97	0.00	2.989	19.11	2.700	5.203	0.140	2.236
	DBP	58.77	34.05	3.52		21.67	2.780	5.113	0.161	2.229
Corn (25%+)	C-E:P	58.99	32.87	4.59	3.164	21.06	2.807	5.218	0.198	2.047
	V-E:Pg	62.76	33.61	0.00	2.931	21.77	2.735	5.233	0.187	2.020
	DBP	53.44	38.61	4.35		23.41	2.805	5.078	0.202	2.049
Corn (50%+)	C-E:P	57.73	33.42	5.27	3.191	21.22	2.813	5.203	0.218	1.952
	V-E:Pg	58.34	38.05	0.00	2.892	23.56	2.750	5.245	0.209	1.921
	DBP	50.66	40.98	4.77		24.33	2.813	5.065	0.221	1.967
SBM (25% -)	C-E:P	59.44	32.67	4.35	3.154	21.00	2.803	5.222	0.161	2.237
	V-E:Pg	59.10	37.29	0.00	2.899	23.25	2.748	5.244	0.151	2.220
	DBP	52.17	39.69	4.54		23.83	2.809	5.072	0.166	2.241
SBM (25%+)	C-E:P	60.89	32.04	3.57	3.123	20.81	2.790	5.231	0.193	2.053
	V-E:Pg	73.18	23.09	0.00	3.024	17.57	2.672	5.179	0.170	2.049
	DBP	59.34	33.56	3.43		21.49	2.776	5.118	0.196	2.040
SBM (50%+)	C-E:P	61.69	31.69	3.14	3.105	20.71	2.782	5.232	0.208	1.962
	V-E:Pg	79.57	16.60	0.00	3.081	15.00	2.613	5.129	0.170	1.995
	DBP	61.57	31.65	3.09		20.76	2.760	5.138	0.210	1.949
PO (25%-)	C-E:P	58.30	33.17	4.96	3.178	21.15	2.811	5.211	0.176	2.169
	V-E:Pg	66.95	29.40	0	2.968	20.07	2.714	5.215	0.163	2.125
	DBP	55.11	37.18	4.09		22.87	2.798	5.088	0.179	2.158
PO (25%+)	C-E:P	61.99	31.56	2.98	3.099	20.67	2.778	5.233	0.176	2.1252
	V-E:Pg	66.95	29.40	0	2.968	20.07	2.714	5.215	0.163	2.1254
	DBP	57.56	35.08	3.71		22.07	2.787	5.104	0.184	2.117
PO (50%+)	C-E:P	63.81	30.76	2.01	3.060	20.44	2.752	5.228	0.174	2.112
	V-E:Pg	66.95	29.40	0	2.968	20.07	2.714	5.215	0.163	2.125
	DBP	58.59	34.20	3.55		21.73	2.781	5.112	0.187	2.097

Where: Reference broiler price obtained from liveweight equivalent price, 1.097 $/kg; Live weight equivalent price, derived from Ready to Cook (RTC) prices from the month of August, 2007 (USDA) using the following formula = [RTC price-processing cost] x dressing percentage (0.774)] = (1.736-0.319)x0.774. Reference prices for corn, soybean meal and poultry oil were 124.8, 217.63 and 418.88 $/tons respectively from the month of August, 2007 (USDA). Profit ($/bird) = [(rBW x 2.7 x liveweight equivalent price) - (rFI x 5.2 x diet cost)]; rBW = relative body weight; rFI = relative feed intake. SBM = soybean meal; PO = poultry oil; ME = metabolizable energy level; CP = crude protein. C-E:P = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio from Gonzalez-Alcorta *et al.* (1994); DBP = dietary balanced protein from Eits *et al.* (2005a)

content of the V-E:Pg model did not vary because the poultry oil was not included in these diets as result of the low selected energy level by the program, around 3.00 Mcal/kg.

The effect of price variations of broiler, corn, soybean meal or poultry oil for the V-E:Pd and C-E:P-3.15 models on diet formulation and profitability is shown in Table 6. As the broiler, corn, SBM and poultry oil prices increased the energy level almost kept constant, 3.165-3.170 Mcal/kg, in the V-E:Pd. In contrast, in the C-E:P-3.15 model the energy contents, 3.052-3.188 mcal/kg, were varied according the variation of broiler or ingredient prices as did the C-E:P model. The major profitability from the two models was dependent upon the price variation of ingredients or broiler. At high prices for either broilers or corn (+25 or +50%) the profits by V-E:Pd model were higher than by the C-E:P-3.15 model; however, at high prices for either SBM (+50%) or poultry

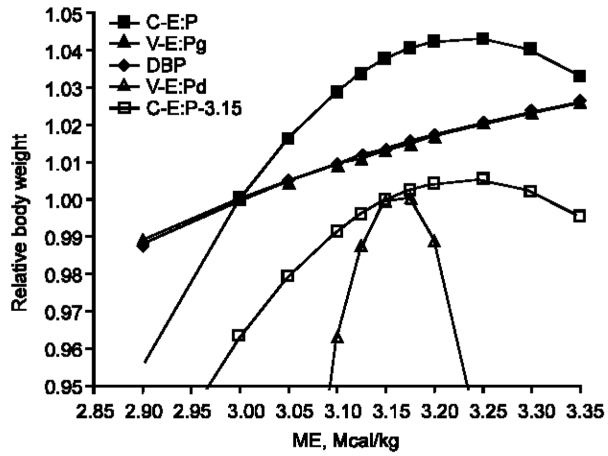

Fig. 1: Comparisons of relative body weight among different nutritional models during the increase of energy or protein.
Where: ME = metabolizable energy level, Mcal/kg; C-E:P = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio from Gonzalez-Alcorta *et al.* (1994); DBP = dietary balanced protein from Eits *et al.* (2005a); V-E:Pd = variable energy-protein ratio developed from Dozier *et al.* (2006) data fixed at 3.15 Mcal/kg; C-E:P-3.15 = constant energy-protein ratio developed from Saleh *et al.* (2004) data fixed at 3.15 Mcal/kg. The DBP model used the energy as x variable in constant energy-protein ratio, 0.157567 Mcal/kg/%, to be present in the graph

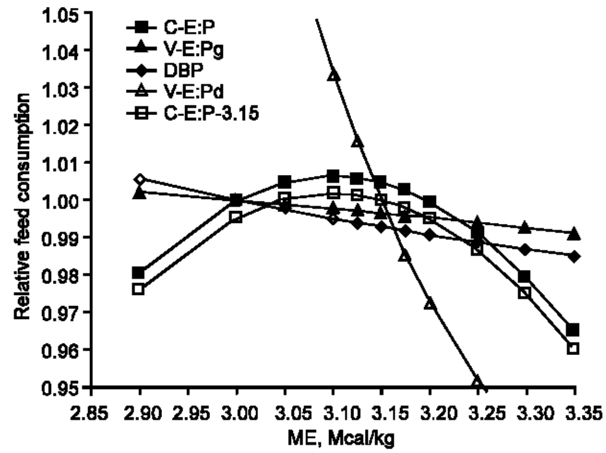

Fig. 2: Comparisons of relative feed consumption among different nutritional models during the increase of energy or protein.
Where: ME = metabolizable energy level, Mcal/kg; C-E:P = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio from Gonzalez-Alcorta *et al.* (1994); DBP = dietary balanced protein from Eits *et al.* (2005a); V-E:Pd = variable energy-protein ratio developed from Dozier *et al.* (2006) data fixed at 3.15 Mcal/kg; C-E:P-3.15 = constant energy-protein ratio developed from Saleh *et al.* (2004) data fixed at 3.15 Mcal/kg. The DBP model used the energy as x variable in constant energy-protein ratio, 0.157567 Mcal/kg/%, to be present in the graph

oil (+25 or +50%) the profits by latter model were higher than by former model.

The comparisons of profitability under real price condition among the C-E:P, V-E:Pg and DBP models are shown in Table 7. The best profits were obtained from the C-E:P model followed by the DBP model. During the twelve months of broiler production, differences of $76,097 between the C-E:P and DBP models and $951,577 dollars between the C-E:P and V-E:Pg models were observed assuming a broiler complex slaughtering 1,250,000 broilers per week.

The comparisons of profitability under real price condition between V-E:Pd and C-E:P-3.15 models are shown in Table 8. The best profits were obtained from the V-E:Pd model. During the 12 months of broiler production a difference of $178,171 was observed assuming a broiler complex slaughtering 1,250,000 broilers per week.

DISCUSSION

The best rBW obtained using the C-E:P model was probably because this model was developed using data from a strain of birds of the present decade and this response was a consequence of increasing all the nutrients. The striking fact that rBW for DBP and V-E:Pg model had similar form probably is because the DBP model came from newer data than that of the V-E:Pg model and the latter model has two nutrient inputs (energy and protein) while the former model has only one nutrient input (protein). The pronounced curvature of rBW by the V-E:Pd model compared to the C-E:P-3.15 model was probably due to the effect of the level of energy only during the finisher period. However, it is hard to define a consistent pattern in the V-E:Pd model because in the studies where only the energy level was increased, the body weight was not significantly different (Leeson *et al.*, 1996; Dozier *et al.*, 2006).

It seems that the modern broiler and especially strains selected for rapid growth do not adjust the feed intake to meet a fixed energy need; rather, these birds tend to eat more energy as the energy content increased (Wells, 1963; Petersen, 1971, 1975; Fisher and Wilson, 1974; Waldroup *et al.*, 1976; Hidalgo *et al.*, 2004; Saleh *et al.*, 2004). This is true especially when the energy is elevated with the protein as well as essential amino acids; however, when only the energy level is increased,

Table 6: Effect of price variations of broiler, corn, soybean meal or poultry oil for the V-E:Pd and C-E:P-3.15 models on diet formulations and profitability

Variables	Models	Use levels, % Corn	SBM	PO	ME Kcal/g	CP %	Body weight Kg	Feed intake Kg	Diet cost MP $/kg	Profit Margin MP $/bird
Prices changes										
Reference	V-E:Pd	58.73	33.15	4.66	3.167		2.704	5.149	0.180	2.039
	C-E:P-3.15	60.22	32.29	3.91	3.134	20.88	2.694	5.205	0.177	2.036
Broiler price (25% -)	V-E:Pd	58.70	33.16	4.69	3.168		2.704	5.146	0.180	1.298
	C-E:P-3.15	62.65	31.23	2.61	3.082	20.57	2.667	5.208	0.172	1.300
Broiler price (25%+)	V-E:Pd	58.74	33.15	4.65	3.166		2.705	5.150	0.180	2.781
	C-E:P-3.15	59.00	32.83	4.56	3.160	21.04	2.703	5.196	0.179	2.776
Broiler price (50%+)	V-E:Pd	58.75	33.15	4.64	3.166		2.705	5.152	0.180	3.523
	C-E:P-3.15	58.28	33.14	4.95	3.176	21.13	2.708	5.189	0.181	3.518
Corn (25%-)	V-E:Pd	58.77	33.14	4.63	3.165		2.705	5.153	0.162	2.134
	C-E:P-3.15	61.32	31.81	3.32	3.110	20.74	2.683	5.209	0.155	2.135
Corn (25%+)	V-E:Pd	58.69	33.16	4.70	3.168		2.704	5.144	0.199	1.945
	C-E:P-3.15	59.02	32.82	4.56	3.160	21.03	2.703	5.196	0.197	1.939
Corn (50%+)	V-E:Pd	58.65	33.16	4.73	3.170		2.704	5.139	0.217	1.851
	C-E:P-3.15	57.70	33.40	5.26	3.188	21.20	2.710	5.182	0.218	1.845
SBM (25% -)	V-E:Pd	58.74	33.15	4.65	3.166		2.705	5.151	0.162	2.132
	C-E:P-3.15	59.48	32.62	4.31	3.150	20.97	2.700	5.200	0.160	2.128
SBM (25%+)	V-E:Pd	58.71	33.15	4.68	3.168		2.704	5.146	0.198	1.947
	C-E:P-3.15	61.01	31.95	3.49	3.117	20.78	2.686	5.208	0.192	1.945
SBM (50%+)	V-E:Pd	58.69	33.16	4.69	3.168		2.704	5.144	0.216	1.854
	C-E:P-3.15	61.86	31.58	3.03	3.099	20.67	2.677	5.209	0.208	1.855
PO (25%-)	V-E:Pd	58.68	33.16	4.70	3.168		2.704	5.144	0.175	2.065
	C-E:P-3.15	58.29	33.14	4.95	3.176	21.13	2.708	5.189	0.175	2.060
PO (25%+)	V-E:Pd	58.77	33.14	4.63	3.165		2.705	5.154	0.185	2.014
	C-E:P-3.15	62.15	31.45	2.87	3.093	20.63	2.673	5.209	0.176	2.018
PO (50%+)	V-E:Pd	58.81	33.14	4.59	3.163		2.705	5.159	0.190	1.989
	C-E:P-3.15	64.04	30.62	1.86	3.052	20.39	2.646	5.202	0.173	2.005

Where: Reference broiler price obtained from liveweight equivalent price, 1.097 $/kg; Live weight equivalent price, derived from Ready to Cook (RTC) prices from the month of August, 2007 (USDA) using the following formula = [RTC price-processing cost] x dressing percentage (0.774)] = (1.736-0.319)*0.774. Reference prices for corn, soybean meal and fat were 124.8, 217.63 and 418.88 $/tons respectively from the month of August, 2007 (USDA). Profit ($/bird) = [(rBW x 2.7 x liveweight equivalent price) - (rFI x 5.2 x diet cost)]; BW relative = relative body weight; rFI = relative feed intake. SBM = soybean meal; PO = poultry oil; ME = metabolizable energy level; CP=crude protein. V-E:Pd = variable energy-protein ratio developed from Dozier *et al.* (2006) data fixed at 3.15 Mcal/kg; C-E:P-3.15 = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data fixed at 3.15 Mcal/kg

the feed intake is proportionally reduced to normalize the energy intake (Leeson *et al.*, 1996; Dozier *et al.*, 2006). Thus, rFI of the C-E:P model had a greater feed intake from 3.0-3.225 Mcal/kg than did the DBP or V-E:Pg model. The reduced rFI of DBP model compared to that of V-E:Pg model was probably because the DBP model was developed with modern strains of chicken and thus the feed conversion was better than did V-E:Pg model. The severely reduced rFI of V-E:Pd model may be accounted for by increasing the energy level during the finisher period. This severe reduction is in agreement with the finding of Leeson *et al.* (1996).

With the reference broiler or ingredient prices, the economic nutrient requirement for energy varied, for example: 3.139 Mcal/kg for C-E:P model and 2.968 Mcal/kg for V-E:Pg model. The latter model estimated a reduced energy level probably because the body weight had responded less to the increased of energy level. On the other hand, the estimated protein contents for both models, C-E:P or V-E:Pg, were almost similar, around 20%. However, the increased protein content (22.4%) from DBP model compared with both C-E:P and V-E:Pg models was probably due to the fact that the protein level selected in DBP model is originated from three main variables such as feeding period (24.5 d), sex (male) and strain (year = 2003). This high value for protein may be accounted for by the findings of Wijtten *et al.* (2004) which showed that increasing of protein and essential amino acids gave a better response than increasing only lysine. The protein and essential amino acids were raised simultaneously for the three models, C-E:P, V-E:Pg and DBP; however, the increased range of protein and amino acids by C-E:P model were lower than by DBP model and not all the data of V-E:Pg model included the essential amino acids as a variable of this model. The best profit obtained by C-E:P model from 3.025-3.25 Mcal/kg was a consequence of their higher rBW than by DBP and V-E:Pg models after 3.00 Mcal/kg, even though the rFI from 3.0-3.225 Mcal/kg and diet cost after 3.1 Mcal/kg from the C-E:P model were higher than

Table 7: Effects of changing prices on nutrients and profitability for the C-E:P, V-E:Pg and DBP models

	Price changes, $/kg					Use levels, %		
Variables	WC	LEP	Corn	SBM	Models	Corn	SBM	PO
Months								
August	1.736	1.097	0.125	0.218	C-E:P	60.14	32.36	3.97
					V-E:Pg	66.95	29.40	0.00
					DBP	56.41	36.06	3.89
July	1.777	1.129	0.121	0.221	C-E:P	60.14	32.36	3.97
					V-E:Pg	67.1	29.29	0.00
					DBP	56.7	35.86	3.85
June	1.792	1.140	0.146	0.230	C-E:P	59.34	32.72	4.41
					V-E:Pg	65.3	31.01	0.00
					DBP	55.1	37.20	4.09
May	1.784	1.134	0.142	0.199	C-E:P	59.12	32.81	4.52
					V-E:Pg	61.56	34.82	0.00
					DBP	53.13	38.87	4.39
April	1.731	1.093	0.136	0.189	C-E:P	59.38	32.70	4.38
					V-E:Pg	61.37	35.01	0.00
					DBP	53.24	38.78	4.38
Mar	1.734	1.095	0.151	0.205	C-E:P	59.03	32.85	4.57
					V-E:Pg	61.67	34.71	0.00
					DBP	52.96	39.02	4.42
February	1.673	1.048	0.154	0.209	C-E:P	59.18	32.79	4.49
					V-E:Pg	62.3	34.09	0.00
					DBP	53.25	38.77	4.37
January	1.553	0.955	0.145	0.191	C-E:P	59.80	32.51	4.16
					V-E:Pg	61.78	34.59	0.00
					DBP	53.35	38.68	4.36
December	1.466	0.887	0.137	0.181	C-E:P	60.46	32.23	3.80
					V-E:Pg	62.16	34.21	0.00
					DBP	53.91	38.21	4.27
November	1.454	0.878	0.133	0.191	C-E:P	60.94	32.02	3.55
					V-E:Pg	64.95	31.41	0.00
					DBP	55.44	36.90	4.04
October	1.437	0.865	0.110	0.178	C-E:P	61.84	31.62	3.06
					V-E:Pg	66.66	29.70	0.00
					DBP	56.93	35.62	3.81
September	1.503	0.917	0.079	0.169	C-E:P	62.43	31.36	2.75
					V-E:Pg	67.06	29.29	0.00
					DBP	58.7	34.12	3.53
Yearly profit					C-E:P			
					V-E:Pg			
					DBP			
Differences					C-E:P-DBP			
					C-E:P-V-E:Pg			

Variables	ME Kcal/g	CP %	Body weight Kg	Feed intake Kg	Diet Costs MP $/kg	Profit Margin MP $/bird	Monthly Additional Profit
Months							
August	3.139	20.91	2.798	5.227	0.177	2.144	11612603
	2.968	20.07	2.714	5.215	0.163	2.125	11510517
		22.44	2.793	5.096	0.182	2.136	11571965
July	3.139	20.91	2.798	5.227	0.178	2.239	12127174
	2.969	20.02	2.714	5.215	0.162	2.219	12020005
		22.36	2.792	5.097	0.181	2.230	12078340
June	3.156	21.01	2.804	5.221	0.195	2.179	11800573
	2.954	20.72	2.723	5.222	0.183	2.151	11650004
		22.88	2.799	5.087	0.200	2.175	11779760
May	3.161	21.04	2.806	5.219	0.183	2.228	12066022
	2.921	22.26	2.740	5.237	0.173	2.201	11924420
		23.51	2.806	5.077	0.188	2.229	12075186
April	3.155	21.01	2.804	5.221	0.176	2.144	11615263
	2.919	22.33	2.741	5.237	0.166	2.123	11497849
		23.48	2.805	5.077	0.181	2.146	11625667

Table 7: Continue

Variables	ME Kcal/g	CP %	Body weight Kg	Feed intake Kg	Diet Costs MP $/kg	Profit Margin MP $/bird	Monthly Additional Profit
Mar	3.163	21.05	2.806	5.218	0.190	2.080	11265637
	2.922	22.21	2.740	5.236	0.181	2.054	11127057
		23.57	2.806	5.076	0.195	2.083	11284509
February	3.159	21.03	2.805	5.220	0.193	1.931	10461712
	2.927	21.97	2.737	5.234	0.184	1.908	10335969
		23.48	2.805	5.077	0.198	1.935	10482174
January	3.146	20.95	2.801	5.225	0.181	1.729	9368031
	2.923	22.17	2.739	5.236	0.172	1.715	9291139
		23.44	2.805	5.078	0.186	1.734	9393625
December	3.132	20.87	2.795	5.229	0.172	1.581	8562975
	2.926	22.01	2.738	5.235	0.164	1.572	8517658
		23.26	2.803	5.081	0.178	1.585	8583056
November	3.122	20.81	2.790	5.231	0.171	1.553	8413256
	2.950	20.88	2.725	5.224	0.162	1.546	8372931
		22.76	2.797	5.090	0.178	1.553	8410752
October	3.102	20.69	2.780	5.233	0.152	1.612	8729453
	2.965	20.19	2.716	5.217	0.142	1.609	8716409
		22.27	2.790	5.099	0.158	1.605	8695952
September	3.090	20.61	2.772	5.232	0.128	1.870	10129893
	2.969	20.02	2.714	5.215	0.118	1.871	10134975
		21.70	2.780	5.112	0.135	1.856	10054872
Yearly profit							114539990
							113588413
							114463894
Differences							76097
							951577

Where: Reference prices for corn, soybean meal and fat were 124.8, 217.63 and 418.88 $/tons respectively from the month of August (2007). Liveweight Equivalent Price (LEP), 1.097 $/kg; wholecarcass = WC. Live weight equivalent price, derived from Ready to Cook (RTC) prices using the following formula = [RTC price-processing cost] x dressing percentage (0.774)] = (1.736-0.319) x 0.774. Assuming a typical broiler complex slaughtering 1250000 broilers per week Profit ($/bird) = [(BW relative x 2.7 x liveweight equivalent price) - (FI relative x 5.2 x diet cost)]. SBM = soybean meal; PO = poultry oil; ME = metabolizable energy; CP = crude protein

did the BDP and V-E:Pg models. The DBP model had better economic return than did the V-E:Pg model after 3.1 Mcal/kg or 19.67% of protein due to its reduced diet cost and rFI, whereas the latter model had better profit than did the former model before 3.1 Mcal/kg or 19.67% of protein due to its reduced diet cost.

The increases in nutrients as the broiler or corn price increased for each model except in energy level for V-E:Pg model are in agreement with previous studies (Guevara, 2004; Eits *et al*., 2005b; Cerrate and Waldroup, 2009). With corn as a unique main energy source, the energy level should be reduced as the corn price increased; however, with corn and poultry oil as main energy sources, the energy level is increased because in the C-E:P model the protein and energy content are fixed and for this reason the energy level was increased due to increasing protein content. Further, the cheap relative price of the protein source compared to that of energy source from corn makes that program selects increased amounts of soybean meal and poultry oil. On the other hand, the increased protein level and reduced energy levels as the corn price increased by the V-E:Pg model are in agreement with the findings from Gonzalez-Alcorta *et al*. (1994). Likewise, the increased protein content for the DBP model as the corn price increased had a similar pattern as shown by Eits *et al.* (2005b). This is the best method of formulation in term of profit when the corn price is increased but when the corn price is decreased, the carcass quality can be negatively affected due to the reduced protein content. The decreased nutrient content of the C-E:P model as the SBM price raised is in agreement with the result of Cerrate and Waldroup (2009), although the nutrient contents can be increased when another source of protein such as fish meal is used in the maximum profit feed formulation (Guevara, 2004). The reduced protein contents for both DBP and V-E:Pg models and the increased energy level for V-E:Pg model as the SBM price increased are in agreement with the results in the literature (Jackson *et al*., 1982; Gonzalez-Alcorta *et al*., 1994; Eits *et al*., 2005b). Even though these models can be more profitable at -25% or +50% SBM price for the DBP or V-E:Pg model respectively, the carcass quality can be negatively affected by reduced protein or increased energy levels. It has been observed that reducing protein level or increasing energy level increases the carcass or abdominal fat (Bartov *et al*., 1974; Mabray and Waldroup, 1981; Skinner *et al*., 1992).

Table 8: Effects of real prices for broiler, corn and soybean meal on nutrients and profitability for the V-E:Pd and C-E:P-3.15 models

	Price changes, $/kg					Use levels, %		
Months	WC	LEP	Corn	SBM	Models	Corn	SBM	PO
August	1.736	1.097	0.125	0.218	V-E:Pd	58.73	33.15	4.66
					C-E:P-3.15	60.22	32.29	3.91
July	1.777	1.129	0.121	0.221	V-E:Pd	58.73	33.15	4.66
					C-E:P-3.15	60.22	32.29	3.91
June	1.792	1.140	0.146	0.230	V-E:Pd	58.70	33.16	4.69
					C-E:P-3.15	59.38	32.66	4.36
May	1.784	1.134	0.142	0.199	V-E:Pd	58.71	33.15	4.67
					C-E:P-3.15	59.14	32.76	4.49
April	1.731	1.093	0.136	0.189	V-E:Pd	58.72	33.15	4.67
					C-E:P-3.15	59.42	32.64	4.34
Mar	1.734	1.095	0.151	0.205	V-E:Pd	58.70	33.16	4.69
					C-E:P-3.15	59.06	32.80	4.53
February	1.673	1.048	0.154	0.209	V-E:Pd	58.69	33.16	4.70
					C-E:P-3.15	59.21	32.73	4.45
January	1.553	0.955	0.145	0.191	V-E:Pd	58.70	33.16	4.69
					C-E:P-3.15	59.88	32.44	4.09
December	1.466	0.887	0.137	0.181	V-E:Pd	58.70	33.15	4.68
					C-E:P-3.15	60.57	32.14	3.72
November	1.454	0.878	0.133	0.191	V-E:Pd	58.71	33.15	4.68
					C-E:P-3.15	61.07	31.92	3.45
October	1.437	0.865	0.110	0.178	V-E:Pd	58.75	33.15	4.65
					C-E:P-3.15	62.01	31.51	2.95
September	1.503	0.917	0.079	0.169	V-E:Pd	58.80	33.14	4.60
					C-E:P-3.15	62.59	31.25	2.64
Yearly profit					V-E:Pd			
					C-E:P-3.15			
Difference								

Months	ME Kcal/g	CP %	Body weight Kg	Feed intake Kg	Diet Costs MP $/kg	Profit Margin MP $/bird	Monthly Additional Profit
August	3.167		2.704	5.149	0.180	2.039	11044497
	3.134	20.88	2.694	5.205	0.177	2.036	11026362
July	3.167		2.705	5.149	0.179	2.131	11540521
	3.134	20.88	2.694	5.205	0.175	2.127	11523107
June	3.168		2.704	5.145	0.196	2.072	11220722
	3.152	20.99	2.701	5.199	0.195	2.066	11192067
May	3.167		2.704	5.147	0.184	2.121	11487110
	3.157	21.02	2.702	5.197	0.183	2.115	11458846
April	3.167		2.704	5.148	0.177	2.041	11056597
	3.151	20.98	2.700	5.200	0.176	2.036	11030428
Mar	3.168		2.704	5.145	0.191	1.977	10711336
	3.159	21.03	2.703	5.197	0.190	1.972	10681015
February	3.168		2.704	5.144	0.194	1.834	9934687
	3.156	21.01	2.702	5.198	0.193	1.828	9903923
January	3.168		2.704	5.145	0.183	1.641	8886711
	3.141	20.92	2.697	5.203	0.181	1.636	8860949
December	3.168		2.704	5.146	0.175	1.498	8111606
	3.127	20.83	2.691	5.206	0.172	1.494	8092868
November	3.168		2.704	5.146	0.176	1.470	7961054
	3.116	20.77	2.686	5.208	0.171	1.467	7948890
October	3.166		2.705	5.151	0.158	1.525	8262621
	3.096	20.65	2.675	5.209	0.151	1.527	8270849
September	3.164		2.705	5.157	0.137	1.774	9608521
	3.083	20.57	2.668	5.208	0.128	1.780	9640375
Yearly profit							108781487
							108603315
Difference							178171

Where: Reference prices for corn, soybean meal and fat were 124.8, 217.63 and 418.88 $/tons respectively from the month of August (2007). Liveweight Equivalent Price (LEP), 1.097 $/kg; wholecarcass = WC. Live weight equivalent price, derived from Ready to Cook (RTC) prices using the following formula = [RTC price-processing cost] x dressing percentage (0.774)] = (1.736-0.319) x 0.774.

Assuming a typical broiler complex slaughtering 1250000 broilers per week Profit ($/bird) = [(BW relative x 2.7 x liveweight equivalent price) - (FI relative x 5.2 x diet cost)]. SBM = soybean meal; PO = poultry oil; ME = metabolizable energy; CP= crude protein

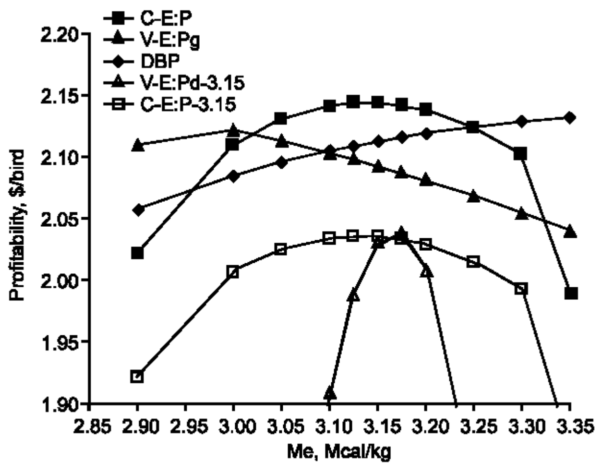

Fig. 3: Profitability of the nutritional models during the increase of energy or protein.
Where: ME = metabolizable energy level, Mcal/kg; C-E:P = constant energy-nutrient ratio developed from Saleh *et al.* (2004) data; V-E:Pg = variable energy-protein ratio from Gonzalez-Alcorta *et al.* (1994); DBP = dietary balanced protein from Eits *et al.* (2005a); V-E:Pd = variable energy-protein ratio developed from Dozier *et al.* (2006) data fixed at 3.15 Mcal/kg; C-E:P-3.15 = constant energy-protein ratio developed from Saleh *et al.* (2004) data fixed at 3.15 Mcal/kg. The DBP model used the energy as x variable in constant energy-protein ratio, 0.157567 Mcal/kg/%, to be present in the graph

Moreover, the relationship between energy and protein is most important because both affect fat synthesis with protein being a powerful inhibitor (Leveille *et al.*, 1975), whereas the energy intake is a meaningful stimulator (Leeson *et al.*, 1996).
The best profit obtained from C-E:P model under real variation of corn, SBM or broiler prices can assure a good carcass quality, whereas the DBP model can affect it especially when the corn price is reduced or the SBM price is increased.
Despite the best economic return observed in the V-E:Pd model compared to that in the C-E:P-3.15 model, the former model had a very narrow range of variation for the energy level as the relative or real price of feedstuffs and broilers varied. Moreover, the selected energy level only applies for the finisher period and the difference of profit could be reduced if the variation of poultry oil price were included in the present study.
The results of this study showed that C-E:P model is the most suitable method of formulation in terms of performance and profitability. Further, the V-E:Pd model had also the best profit but with a lack of consistency of growth response and a narrow range of economic conditions. For some price variation of corn the DBP model can produce the best economic return though the carcass quality can be negatively affected.

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