

Maximising broiler profit using the EFG Model: A comparative case study

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Abstract

1. The EFG Model is described as a mechanistic model and has been used in this case study as a nutritional and management tool to make changes to feeds and suggest new temperature profiles.
2. Three integrators were compared with Cobb 500 broilers in one tropical environment and Ross 308 broilers in a second tropical climate and in a temperate climate.
3. In the temperate climate of New Zealand, the EFG model has been used for many years and the suggested improvements to the temperature profiles of the sheds predicted a small improvement in performance of Ross 308 broilers. The predicted improvements and realised savings when expressed as a feed cost per kg of liveweight gain to 2.0 kg's was 2.9 %.
4. In the first tropical climate with Ross 308 broilers (Papua New Guinea) the cost savings were substantial with reduction of tallow in feed. For this integrator, the feed cost savings to a 2.0 kg liveweight broiler was predicted to be 8.4 %.
5. In the second tropical climate of Fiji using Cobb 500 broilers, broiler performance is hampered by Inclusion Body Hepatitis in broilers at 18 to 24 days of age that are hatched from eggs imported from New Zealand. However, the climate is not quite as humid as Papua New Guinea and sheds are equipped with cooling pads. The EFG Model predicted an 11.3 % improvement in feed costs per kg of liveweight and the integrator realised an actual improvement of 5.3 % per kg of liveweight gain to 2.0 kg's due to capital constraints on improving shed ventilation.

INTRODUCTION

Thornley and France (1984) introduced the term “mechanistic” to describe models which are quantitative and aim to represent the underlying mechanisms that produce predicted end results. If a model estimates only a single value for a specific age or period based on the data input and output without explanations of the process, the model can be classified as static, deterministic and empiric. However, if the model can predict values as a function of time or age corresponding to the data probability distribution describing the processes involved, within the constraints of environment and management, this model can be categorised as dynamic, stochastic and mechanistic (Baldwin, 1995; Black, 1995).

The EFG² (Emmans, Fisher and Gous) model is an example of a mechanistic model and describes the changes in bird growth mathematically with the use of the Gompertz function as the best fit for broiler growth (Lehmann, 1980; Tzeng and Becker, 1981; Gous, 1986; 1998; Emmans, 1995; Hruby *et al.*, 1996). The Gompertz equation utilized in the EFG model (and other broiler models) is given in the form:

$$W_t = W_o e^{(L/K)(1-e^{-Kt})}$$

Where:

- W_t = Weight at time t,
- W_o = Hatch weight,
- L = Initial growth rate,
- K = Rate of exponential decay of L.

In this form, the mature weight is described as $A = W_o e^{(L/K)}$ (Hruby *et al.*, 1994)

In poultry, the primary goal of the poultry nutritionist has been to predict the response of growing broilers to a given set of nutrients. This task is complicated by many factors other than feed nutrient content and the first serious attempt to integrate information about the animal, its feed and the environment in which it was kept, with a view to simulating its performance was the Edinburgh Pig Model (Whittemore, 1976; Whittemore and Fawcett,

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² EFG Software (Natal). www.efgsoftware.com

1976). Whittemore (1983), before the regular use of broiler models, suggested that nutrient requirements should not be stated in fixed terms but should rather describe levels of energy, protein, amino acids and other nutrients that are required to satisfy a target response in the animal that is consistent with the genetic potential and environmental constraints placed on the animal.

In the determination of the optimum amino acid contents in feeds used by broilers, Fisher *et al.* (1973) showed that there was an advantage in seeing the requirements of animals as variable, dependent on the marginal cost of the amino acid and the marginal returns of the product rather than fixed values. Many factors have to be integrated before the optimum economic feeding schedule can be determined. This is especially true of feeding programmes for growing animals. Factors to be considered include the potential protein growth rate of the genotype; differences between individuals at any time and within individuals over time; the effect of different nutrient concentrations and energy-to-protein ratios on food intake; carcass composition and protein gains; the effects of differences between genotypes in the amount of excess energy that may be stored as body lipid and the maximum rate at which this can take place; the effects of high or low environmental temperatures on all of the above and the constraints placed on the animal by the environment and by the feed, which prevent the birds from consuming the necessary amount of a feed to grow at their potential. Therefore, to accurately drive an “objective function” such as maximum margin/m²/annum, maximum breast meat yield, lowest feed conversion ratio (FCR) or even maximum margin over feed cost requires simultaneous consideration of all interacting factors in determining both the feed specification and the amount of each phase to be fed to the growing broiler.

Subsequent to the development of the Edinburgh Model, Emmans (1981) proposed a theory that accurately predicted feed intake in poultry and pigs and this raised the value of models considerably since this allowed feed intake to be an output of the model as opposed to an input. This author suggested that broilers will attempt to grow as rapidly as possible and in such a manner as to reproduce as early and as efficiently as possible.

Curnow (1986) showed that many relationships exist between the variables involved in dietary amino acid effects and that many of these can be described by both linear and non-linear regression models, or by the response surface regression equations resulting from amino acid interactions as a whole. An important determination of the optimum economic decision from a response surface regression equation involves the shape of the curve around the point at which the requirement of the average individual in the flock is met (Gous, 1986; Pesti *et al.*, 1986).

Unfortunately, current models are unable to predict effects such as disease challenge as a constraint or the effect of vaccinations and whilst average daily temperatures and humidity are included in the EFG Model, the effect of wind chill during shed ventilation is yet to be added to the model. Due to these inaccuracies, the astute nutritionist is required to interpolate the missing data and adjust constraints accordingly. In addition, the EFG model takes no account of amino acid imbalances and if a response to nutrients is influenced differentially by changing the amino acid balance of a feed, the coefficients of response will be lower than they should be, resulting in an overestimation of the efficiency of utilisation of the limiting nutrient (Gous, 2007).

All too often, simulation modelling is unable to mimic exactly what is happening commercially and rather than adjust constraints, the nutritionist simply declares that the model does not work and cannot therefore be used or relied upon. However, with a careful

and logical approach to setting constraints, the EFG is remarkably accurate in predicting broiler performance responses and by using the optimiser, one is then able to effectively move towards better profit and/or improved performance in the target broiler. This paper compares two breeds of broilers in two very different climates over three integrated broiler companies and whilst the individual recommendations are all very different, in every instance, enormous progress has been made towards improved performance and profitability. It is extremely important that sound inputs are used prior to running the model and where data is missing, that good estimates are made of other constraints that affect broiler performance. The strength of the model is in the optimiser but one requires accurate modelling prior to optimisation and where accurate data is available, one needs to use this data as best as possible.

MATERIALS AND METHODS

In this exercise, an Integrator in a tropical climate with Ross 308 broilers (Papua New Guinea) is compared to an integrator in a similar climate (Fiji) with Cobb 500 broilers and New Zealand (temperate climate) with Ross 308 broilers. In Fiji and New Zealand, 4 phases of feeds are supplied to the broiler whilst Papua New Guinea feed 3 phases. Therefore, for the purposes of this exercise, comparison is made to 35 days of age, where applicable, and to 2.0 kg's liveweight. All data is presented on an as hatched basis.

Initially, data loggers (Escort Junior[®], EJ-HS-B-8, Tech Innovators Ltd) for temperature and humidity were placed in individual sheds to record actual temperature and humidity over the full growth cycle. Once accurate temperature and humidity data had been recorded and captured in the model constraints were added based on the disease situation (and in some instances management constraints) within each environment. As can be expected, the recorded temperature profiles were substantially different between different climates and both tropical regions were unable to reduce temperatures low enough beyond 14 days of age to allow unrestricted growth in the broilers. Daily variability existed in all data-logged scenarios and, based on the model outputs for recommended “ideal” temperature profile, new “suggested, achievable” profiles were submitted for each integrator (Figure 1).

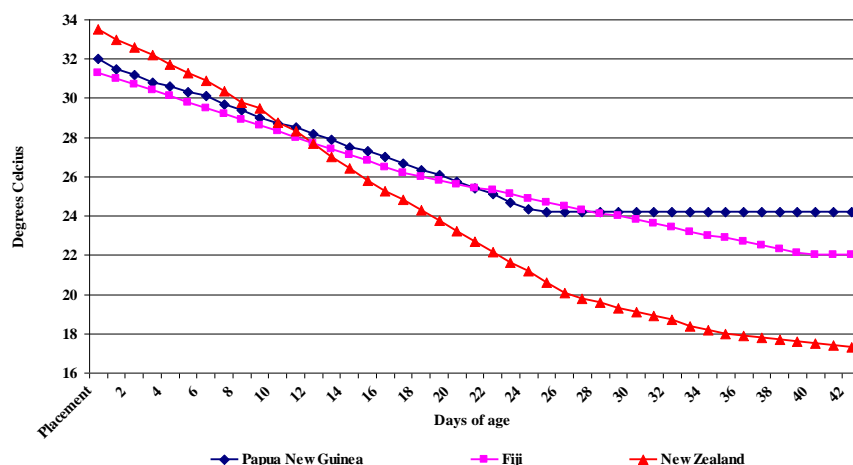


Figure 1. Suggested “achievable” temperature profiles for 3 broiler integrators.

In all 3 regions that were the subject of the current study, high humidity was an issue and in Fiji (Nadi) this climbs from approximately 55 % at day-old to 75 % by 35 days in tunnel ventilated sheds with the option of cooling pads. In Papua New Guinea, sheds are open-sided

and humidity tends to be at 70 % from day-old climbing to between 80 % and 90 % by 4 weeks of age. New Zealand has a combination of cross-flow and tunnel ventilated sheds without cooling pads and these require heating prior to placement of day-old broilers and this reduces shed humidity to approximately 40 % at placement and, depending on the time of year, this climbs either rapidly or slowly to reach 75 % by between 18 and 28 days of age. The suggested temperature profiles shown in Figure 1 are designed to fit with the actual shed humidity's recorded.

In the temperate, disease free New Zealand environment, no constraints on growth were set whilst both tropical environments required constraints based on the presence of mild to severe Infectious Bursal Disease (IBD). The Fiji integrator, who import eggs for hatching from New Zealand produce day-old broilers that are passive, immunologically incompetent against IBD and develop Inclusion Body Hepatitis (IBH) at between 18 and 21 days of age and a subjective constraint, was included in the model to account for this.

Substantial dietary differences existed in each of the regions modelled and the initial diets (Table 1.) were evaluated with the "composition" section of the EFG Model and these were then used in the initial simulation modelling.

In all 3 regions, feed ingredients are costly due to net importation of both proteinaceous raw materials and a large proportion of grains. The exceptions to this are relatively cheap meat and bone meal (MBM) in New Zealand due to the large dairy and beef industries whilst in Papua New Guinea, very cheap wheaten middlings are available due to large flour mills and very small pig and ruminant populations that would normally use this milling by-product. In Fiji and Papua New Guinea the cost of energy is also high and although it is relatively cheaper in New Zealand, trials have not demonstrated significant responses to additional energy and it is hypothesised that this is due to the unique disease-free status of New Zealand.

Once each situation had been modelled and the results compared to actual commercial values, changes to each set of feed specifications were carried out using the EFG broiler optimiser with the objective function set at maximising profit over feed cost. Within the set constraints and suggested temperature profiles for each region, the model is able to solve for optimum amino acid and dietary energy concentration through repeated iterations that are schematically represented in Figure 2. The optimiser is also able to adjust the amount of each phase of feed offered to the broiler but this was not done for this assessment.

The optimiser has a choice of "ideal protein" amino acid ratios that can be user defined and adjustments were made based on ileal digestible lysine and Degussa (Pack *et al.*, 2002) "ideal protein" ratios for all three modelling scenarios.

The price of tallow had climbed dramatically at the time the exercise was done for Papua New Guinea so modelling used more sorghum grain and suggested a lower protein (amino acid) profile for the lowest cost scenario.

In Fiji, offering synthetic threonine resulted in significantly cheaper feeds whilst also allowing dietary energy to increase.

Table 1. Diets, amounts fed per phase and costs prior to EFG modelling.

Raw Material %	Papua New Guinea			Fiji			New Zealand		
	Starter	Grower	Finisher	Starter	Grower	Finisher	Starter	Grower	Finisher
Yellow Maize	-	-	-	-	-	-	15.0	15.0	15.0
Sorghum	49.1	57.0	56.6	-	-	-	28.9	31.1	35.5
Wheat	-	-	-	48.0	57.4	63.8	15.0	15.0	15.0
Soya Oil Cake Meal	25.3	18.4	16.3	27.3	19.6	12.0	25.6	24.9	21.6
Meat and Bone Meal	12.0	9.7	8.6	5.8	5.0	5.0	9.1	8.3	7.3
Rice Bran	-	-	-	6.1	6.3	7.5	-	-	-
Blood Meal	-	-	-	-	-	-	2.5	-	-
Poultry By-product Meal	3.0	2.0	3.0	4.5	4.5	4.5	-	-	-
Wheaten Middlings	6.0	8.0	10.0	6.3	5.2	5.3	1.9	2.0	2.0
Tallow	3.2	3.5	4.2	-	-	-	-	1.6	2.0
Vegetable Oil	-	-	-	-	-	-	0.8	0.5	0.2
Limestone Flour	-	-	-	0.7	0.8	0.8	-	0.3	0.1
Salt	0.13	0.09	0.10	0.13	0.15	0.13	0.15	0.17	0.18
Sodium Bicarbonate	0.20	0.26	0.26	0.11	0.04	0.05	-	0.02	0.03
L-Lysine HCl	0.19	0.21	0.15	0.24	0.23	0.23	0.16	0.24	0.24
DL-Methionine	0.30	0.26	0.21	0.30	0.25	0.20	0.24	0.24	0.23
L-Threonine	0.05	0.07	0.05	-	-	-	0.09	0.08	0.09
Vitamins & Minerals	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Suitable Enzymes	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EFG Composition (%)									
AME (MJ/kg)	11.37	11.70	11.85	10.91	11.16	11.33	12.01	12.30	12.45
Crude Protein	26.1	22.1	21.1	26.0	22.8	20.0	25.4	23.0	21.3
Crude Fat	6.6	6.8	7.6	3.4	3.5	3.6	3.0	4.4	4.6
Crude Fibre	3.0	3.1	3.1	3.0	2.9	2.8	3.0	2.6	2.6
Digestible Lysine	1.30	1.08	0.98	1.31	1.10	0.91	1.35	1.20	1.10
Digestible Methionine	0.68	0.59	0.51	0.65	0.55	0.47	0.67	0.61	0.56
Digestible Threonine	0.86	0.75	0.70	0.77	0.66	0.58	0.89	0.79	0.75
Calcium	1.4	1.1	1.0	1.1	1.1	1.0	1.0	1.0	0.9
Total Phosphorus	1.01	0.88	0.83	0.82	0.75	0.73	0.82	0.78	0.72
Available Phosphorus	0.60	0.50	0.48	0.47	0.44	0.45	0.50	0.46	0.42
Sodium	0.22	0.20	0.20	0.18	0.16	0.16	0.15	0.15	0.15
Chloride	0.21	0.18	0.18	0.22	0.22	0.21	0.21	0.22	0.22
Potassium	0.81	0.72	0.70	0.90	0.78	0.66	0.75	0.73	0.68
Cost/ton in United States \$:	\$ 447.28	\$ 431.75	\$ 417.36	\$ 411.15	\$ 393.68	\$ 368.64	\$ 370.90	\$ 349.08	\$ 341.10
Cost/ton in New Zealand \$:	\$ 721.42	\$ 696.37	\$ 673.16	\$ 663.15	\$ 634.97	\$ 594.58	\$ 598.22	\$ 563.04	\$ 550.16
Grammes Fed per Bird:	500	1,000	2,000	600	700	2,000	350	1,150	1,750

New Zealand has been using the EFG Model and Optimiser for the past 8 years and the current diets are the optimum for maximum margin in New Zealand \$/m² of shed per year so recommendations remain virtually unchanged. The only suggested changes for New Zealand were in the temperature profile used as shown in Figure 1.

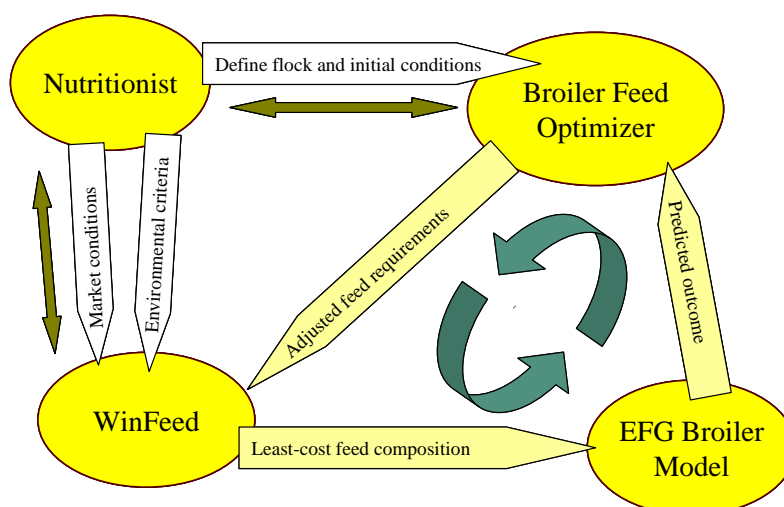


Figure 2 Flow of information in modelling, optimisation and feed formulation of a broiler chicken (after Gous, 2006).

In both tropical climates, theft of broilers is an issue so lighting tends to remain at 24 hours throughout the growth period of the broilers in these countries whilst in New Zealand, intermittent light patterns are standard practice and although these cannot be modelled, they do have an affect on feed wastage and should be included in the constraints.

Table 2 shows the adjusted, formulated diets for Papua New Guinea and Fiji. These diets, as derived from the optimiser were modelled to estimate the expected improvements in each region and, to date, commercial results have been close to the predicted responses with the exception of Fiji since this integrator was unable to reduce the temperatures to the suggested new profile.

Table 2. *Suggested diets, amounts fed per phase and costs as recommended by EFG modelling for Papua New Guinea and Fiji.*

Raw Material %	Papua New Guinea			Fiji		
	Starter	Grower	Finisher	Starter	Grower	Finisher
Yellow Maize	-	-	-	-	-	-
Sorghum	53.8	58.8	61.2	-	-	-
Wheat	-	-	-	49.4	62.0	65.4
Soya Oil Cake Meal	20.8	17.2	15.4	25.7	14.1	13.7
Meat and Bone Meal	12.0	8.8	7.4	6.0	7.4	5.7
Rice Bran	-	-	-	6.1	6.3	7.5
Blood Meal	-	-	-	-	-	-
Poultry By-product Meal	3.0	2.5	3.0	4.5	4.5	4.5
Wheaten Middlings	8.0	10.0	10.3	6.3	4.3	1.0
Tallow	1.0	1.2	1.3	-	-	-
Limestone Flour	-	-	-	0.6	-	0.8
Salt	0.13	0.11	0.10	0.14	0.13	0.03
Sodium Bicarbonate	0.20	0.24	0.20	0.11	0.06	0.19
L-Lysine HCl	0.19	0.26	0.29	0.27	0.36	0.36
DL-Methionine	0.30	0.25	0.24	0.20	0.18	0.16
L-Threonine	0.05	0.07	0.08	0.10	0.15	0.15
Vitamins & Minerals	0.50	0.50	0.50	0.50	0.50	0.50
Suitable Enzymes	0.02	0.02	0.02	0.03	0.03	0.03
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0
EFG WinFeed Solution (%)						
AME (MJ/kg)	11.70	12.00	12.10	11.20	11.80	11.33
Crude Protein	25.0	22.0	21.0	25.3	22.0	20.0
Crude Fat	4.5	4.6	4.8	3.6	3.7	3.6
Crude Fibre	3.1	3.2	3.2	3.4	3.0	2.8
Digestible Lysine	1.33	1.10	1.06	1.27	1.10	0.91
Digestible Methionine	0.70	0.60	0.58	0.60	0.56	0.47
Digestible Threonine	0.88	0.75	0.72	0.84	0.75	0.58
Calcium	1.4	1.1	1.0	1.1	1.0	1.0
Total Phosphorus	1.01	0.85	0.79	0.83	0.84	0.73
Avaliable Phosphorus	0.68	0.55	0.50	0.47	0.53	0.45
Sodium	0.20	0.20	0.18	0.18	0.17	0.16
Chloride	0.25	0.20	0.20	0.22	0.22	0.21
Potassium	0.77	0.73	0.70	0.90	0.70	0.66
Cost/ton in United States \$:	\$ 418.43	\$ 398.21	\$ 390.85	\$ 393.16	\$ 372.52	\$ 366.49
Cost/ton in New Zealand \$:	\$ 674.88	\$ 642.27	\$ 630.40	\$ 634.13	\$ 600.84	\$ 591.11
Grammes Fed per Bird:	500	1,000	2,000	600	700	2,000

RESULTS

Table 3 shows the performance prior to modelling and the predicted output using the adjusted feeds and temperature/humidity profiles applicable to each integrator. In addition, the feed costs per kg of liveweight have been added to the table. The feed cost per kg of liveweight is used extensively within the industry and whilst it is a useful comparative measure over a wide range of broiler performance, it is a poor measure of profit since it excludes other costs associated with growing the broiler and does not take carcass yield into account. The revenue per kg of broiler dressed mass over time and per m² of shed area is equally as important as costs and the EFG optimiser is driven by profit parameters. This is evident in the New Zealand scenario to 35 days of age where feed cost per kg is slightly higher in the modelled prediction but lower to 2.0 kg's liveweight. The reason for this discrepancy is weight at 35 days is higher in the predicted output with a slightly worse feed conversion ratio (FCR) to the heavier weight. However, for the purposes of this exercise, and given the vast differences in both costs and revenues between the integrators in this study, feed cost per kg of liveweight has been used.

Table 3. *Performance and costs prior to modelling and predicted improvements.*

Performance and Feed Costs	Papua New Guinea		Fiji		New Zealand	
	Prior to EFG	EFG Predicted	Prior to EFG	EFG Predicted	Prior to EFG	EFG Predicted
Liveweight at 35 Days (g)	1,695	1,754	1,660	1,940	2,087	2,155
FCR at 35 Days (g feed/g liveweight)	1.658	1.550	1.739	1.634	1.499	1.500
Cost in US \$ (cents/kg Liveweight)	70.50	61.42	65.97	60.04	51.93	51.94
Cost in NZ \$ (cents/kg Liveweight)	113.71	99.06	106.40	96.84	83.76	83.77
Days to 2.0 kg's Liveweight	42.5	39.7	41.2	35.6	34.0	33.5
FCR to 2.0 kg's (g feed/ g liveweight)	1.813	1.624	1.894	1.653	1.476	1.466
Cost in US \$ (cents/kg Liveweight)	73.25	67.10	69.87	61.92	51.22	49.74
Cost in NZ \$ (cents/kg Liveweight)	118.15	108.23	112.69	99.87	82.61	80.23

In New Zealand, small changes are constantly undertaken to optimise the business and poultry meat revenue remains reasonably acceptable relative to feed prices due to a stable market that is protected from imports due to freedom from IBD and Newcastle disease.

The feed savings and projected improvements in Papua New Guinea are due to substantial improvements in dietary energy and improved digestible amino acids with the greatest affects occurring from 30 days of age to depletion and whilst weight differences at day 35 are not large, there is a considerable improvement in FCR to this age. The biggest overall saving is in diet cost and savings realised in US \$ per tonne were \$ 28.85 in the starter, \$ 33.54 in the grower and \$ 26.51 in the finisher feed. Part of the problem with this integrator is lead-times on importation of raw materials and the delays this causes with feed changes. In addition, nutritional advice is outsourced and diet updates do not take place quite as often as they should, particularly when large changes in raw material prices occur. The market in Papua New Guinea is primarily a whole bird frozen market and birds are grown to a set weight. The improvement in days to 2.0 kg's is not as important as the reduced costs and the improvement realised of US \$ 6.15 cents represents a substantial feed cost improvement per kg of liveweight of 8.4 %.

The potential improvement in Fiji was due largely to the ability to cool sheds and improvements to the ventilation systems were required to allow temperature to go below 25 °C from 24 days of broiler age onwards. This integrator usually kept sheds closed up to 14 days of broiler age and working to the suggested achievable profile, sheds were ventilated earlier and diets could therefore be formulated to a lower cost with a saving of US \$ 17.99 in

the starter, \$ 21.16 in the grower and only a small \$ 2.15 in the finisher. Most of the feed savings were realised in lower dietary energy. Unfortunately, this integrator implemented all the new diets with the cost savings and although they were able to get good ventilation to 3 weeks of broiler age, the shed ventilation systems were unable to bring the temperatures down to the required profile. Therefore, the predicted improvement in performance was not fully realised but they did get liveweights to approximately 1,800 g by 35 days and instead of getting an 11.3 % feed cost improvement were still able to achieve a feed cost improvement per kg liveweight of 5.3 % (US \$ 66.17 cents per kg liveweight to 2.0 kg's). Even though the added improvement has an excellent payback, due to capital constraints, any shed improvements were put on hold at the time the recommendations were implemented.

If improvements to broiler performance or reduced feed costs per kg of liveweight gain can be achieved through using the EFG Model, then it becomes a useful tool for both managers and nutritionists even if the full extent of improvement is not realised in practice.

DISCUSSION

Gous (2006) suggested that the EFG Model is a tool which broiler nutritionists and managers can use to make informed decisions on feeds and feeding programmes to maximise profitability under most circumstances. Furthermore, this case study demonstrates the usefulness of a model in optimising performance and increasing profitability by implementing the most appropriate feeding strategies.

However models, such as the EFG Model, are not as widely used under commercial conditions as one would expect, given the potential benefits of such technologies. Gous (2007) suggested that broiler operations did not appear to be as enthusiastic about the models as are the modellers themselves. He further suggested that this scepticism was partially as a result of bad experiences with inaccurate models. The EFG Model cannot be expected to predict every individual situation or absolute trial result since the data that drives the modelled responses is an average of many trials. In addition, the modelled output relies on good data input and, where necessary, an interpolation of data is required to set constraints for factors such as disease challenges. With practice and persistence, accurate modelled outputs can be simulated and within similar constraints, using the optimiser as a nutritional tool, substantial improvements can be made to profitability of a given broiler operation.

It is the view of the author that the EFG model is an indispensable tool in adding maximum value to any broiler operation and that cost and time inputs are a small price to pay for the rewards generated.

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