A Data Envelope Analysis to Assess Broiler Responses to Reduced Protein and Energy Diets Supplemented with Essential Amino Acids

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Abstract: The objective of this paper was to assess broiler responses to reduced protein and energy diets supplemented with Lysine, Methionine and Threonine. A data envelope analysis was used to estimate technical and economic efficiency of diets. The results showed that treatment two (T2) with control energy level, lower crude protein and high Lysine, Methionine and Threonine contents are technically and economically efficient compare to standard feed components in treatment one (T1), and to other treatments (T3 and T4) with variable crude protein and Lysine, Methionine and Threonine and energy contents. Also the results proved that age of 33 days is optimum period for broiler to gain optimum body weight that provide desirable technical and economic efficiency.
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1. Introduction

In animal production industry, there is a need for robust methodologies to optimize efficiency of bio-economic systems due to the use and cost of resources (i.e., feed ingredients and land). Existing methodologies to study efficiency of firms can potentially be used for this application. Production economists define technical efficiency as the level at which a production unit approaches a technology production frontier and allocative efficiency as the adequacy of input utilization in response to price signals (Farrell, 1957).

Modern studies of economic efficiency use stochastic estimations of production function frontiers (Aigner et al., 1977) or data envelope analysis (DEA) (Charnels et al., 1978). The DEA is a deterministic method that uses linear programming to calculate efficiency. Compared with parametric methods, DEA has the advantage that assumptions regarding functional forms are not required. Recently, DEA has been used to assess the effect of managerial practices on technical efficiency at the farm (Romero et al., 2010, Khalid et al 2013) and at individual production unit level (Wang et al., 2006).

Economic analyses in animal science have traditionally used deterministic financial equations to relate animal performance and profitability (Harris and Newman, 1994; Groen et al., 1998). However, these methodologies are sensitive to price assumptions and fail to separate technical and allocative factors. Production economic methodologies have been designed to address these issues; therefore, they may allow a better understanding of bio-economic relationships as biological, technological, and market constraints on efficiency can be independently measured. In addition, stronger, unbiased economic inferences can be made from experimental data. Modern broiler breeder production is a relevant example of bio-economic optimization as hen feed intake is controlled by managers. These decisions affect bird reproductive performance (Hocking, 2004) and energy expenditure (Spratt et al., 1990). If production rate decreases, capital cost per chick increases. If feed allocation exceeds requirements for optimal reproduction, feed cost per chick increases.

The DEA has potential to be used by the poultry industry for efficiency analyses and benchmarking exercises at different levels because it does not require assumptions regarding functional forms and can provide unbiased efficiency scores even with small data sets and multiple inputs or outputs. Technical and economic efficiency scores may constitute stronger measurements of animal performance compared with traditional productivity measures like egg production rates or feed conversion ratios because a greater correlation with profitability of animal production operations is expected (Romero et al, 2010).

This paper used DEA to assess broiler responses to reduced protein and energy diets supplemented with Lysine, Methionine and Threonine. The specific objectives of the paper were to compare technical efficiency of different dietary treatments, and to study potential effects of feed allocation decisions on economic efficiency of broilers.

2. Material and Methods

2.1 Diets and Treatments

Chicks were fed a standard corn-SBM grower mash from 12 to 33 d of age. Since the trial period lies between the starter and the grower periods according to the NRC, the requirements were calculated based on average values between the two periods. Four dietary treatments were utilized in this experiment: T1 was the control diet and was formulated to meet a minimum of 100% of NRC (1994) requirements; it contained 21% CP, 3150 kcal of ME/kg and 100% of Lys, Met, and the requirements; T2, T3 and T4 contained 19.5% CP, 115% of Lys and Met and 108% of the requirements; T2, T3 and T4 contained 3150, 3100 and 3050 kcal of ME/kg, respectively (Table 1).

2.2 Data Envelope Analysis

DEA, a non-parametric method based on a linear convex hull approach to frontier estimation (see Farrell, 1957; Charnes et al., 1978), was used to calculate different efficiency scores for broiler responses to reduced protein and energy diets supplemented with Lysine, Methionine and Threonine. Data envelope analysis involved the use of linear programming to construct a nonparametric piecewise surface over the data representing a production function frontier (Coelli et al., 2005).

In the current study, group of chicks in each dietary treatment (T1, T2, T3, and T4) was used as experimental unit, which used a certain feed intake for different period of time (26, 33 and 37 days) to produce a certain output. For the purpose of the current analysis, input-oriented DEA model was first estimated under the assumption of constant returns to scale (CRS) of activities, this produce what is called CCR model, and secondly was estimated under the assumption of variable returns to scale (VRS) of activities to produce BCC model (see Charnes et al., 1978; Banker et al., 1984).

The Data Envelope Analysis Program (DEAP) version 2.1, which was written by Tim Coeli (Centre for Efficiency and Productivity Analysis, Armidale, Australia), was used to construct DEA frontiers for the calculation of technical and cost efficiency scores.

Different forms of efficiency in DEA were estimated: these are overall technical efficiency (TE_{CCR}), pure technical efficiency (TE_{BCC}) and scale efficiency (SE). And by considering the cost of inputs, two additional measurement of efficiency were calculated; allocative and economic efficiency.

Technical efficiency referred to the ability of an experimental unit to produce as large as possible an output from a given set of inputs (Ali et al., 2012). Scale efficiency was defined as the level at which the experimental unit approached the optimal scale, where productivity was maximized. Scale efficiency would equal 1 if the production process exhibited CRS at the observed input-output combination (Weersink et al., 1990).

Allocative efficiency measured the extent to which hen input utilization was appropriate, with a combination of inputs that minimized chick costs. Allocative efficiency was calculated in reference to the iso-cost line tangent to the frontier surface. This iso-cost line was a function of the relationship between input prices. Therefore, increased cost of one input would favor a reduction of utilization of such input. Economic efficiency considered both technical and allocative efficiency and measured the overall efficiency of the experimental unit with respect to the economic objective of cost minimization (Ali et al., 2012).

3. Results and Discussions

3.1 Performance Results

The live weight (BW), feed intake and feed conversion ratio (FCR) of broiler chickens given experimental diets at different ages were shown in table 2.

3.2 Technical Efficiency

The TE score of less than one indicates that broilers using more input than required from the different sources (Chauhan et al., 2006). Therefore, it is desired to suggest optimum levels of input to be used from each source for every inefficient broiler in order to avert wastage of input without reducing the output level. Table 3 summarizes technical efficiency scores under constant returns to scale (CRS) and variable returns to scale (VRS), and scale efficiency scores for the considered treatments under different age. Under the age of 26 days, technical efficiency scores are less than one for T1, T3 and T4 while for T2 technical efficiency is one under both CCS and VRS. This means under feed components of T2, the body weight are minimizing feed consumption and maximizing production. Broiler chickens under the age of 26 days showed an increasing return to scale for the four treatments, which means that it is still technically feasible to increase the feed intake and expanding the time period to gain more body weight. Therefore, it is not technically feasible for the producer to stop feeding the broilers in the age of 26 days although feed intake under T2 is technically efficient.

Table 1. Dietary ingredients (g/kg) and chemical composition of the experimental diets

		Experimental diet			
		T1	T2	T3	T4
Ingredients (g/kg)	*Price (SR/kg)*				
Corn	1.1	553.4	608.2	619.6	639.5
Soybean meal	1.5	344.9	292.0	291.3	285.1
Palm oil	5.0	63.5	55.9	44.9	30.9
Dicalcium phosphate	2.0	23.0	23.0	23.0	23.0
Ground limestone	0.05	5.0	5.0	5.0	5.0
L-Lysine.HCL	13.0	0.0	3.2	3.2	3.3
DL-methionine	23.0	1.4	2.2	2.2	2.2
L-Threoinine	14.0	0.0	1.4	1.4	1.4
Salt	0.03	3.0	3.0	3.0	3.0
Vitamin premix[1]	20.0	2.5	2.5	2.5	2.5
Trace mineral mix[2]	6.0	0.5	0.5	0.5	0.5
Choline Cl 60	4.0	0.5	0.5	0.5	0.5
Na Bicarbonate	1.5	1.5	1.7	1.9	2.0
Potassium sulfate	2.0	0.8	0.9	1.0	1.1
Calculated analysis					
ME, kcal/kg		3150	3150	3100	3050
Crude protein, %		21.0	19.5	19.5	19.5
Lysine, %		1.10	1.26	1.26	1.26
Methionine, %		0.44	0.51	0.51	0.51
Threonine, %		0.77	0.89	0.89	0.89
TSSA, %		0.81	0.82	0.82	0.82
ME/CP ratio		150	161	159	156
Lys/ME ratio, g/Mcal		3.49	4.00	4.06	4.13
Determined analysis					
Crude protein, %		21.2	19.6	19.5	19.6
Lysine, %		1.08	1.30	1.26	1.28
Methionine, %		0.40	0.47	0.48	0.46
Threonine, %		0.74	0.85	0.86	0.90
Alanine, %		1.23	0.99	1.16	1.03
Argenine, %		1.21	1.15	1.21	1.10
Glutamic acid, %		4.72	3.78	4.36	3.85
Glycine, %		1.10	0.87	1.00	0.87
Histadine, %		0.69	0.56	0.63	0.57
Isoleucine, %		1.11	0.91	1.05	0.97
Leucine, %		2.49	1.96	2.27	2.09
Phenylalanine, %		2.97	2.19	2.43	2.57
Serine, %		1.14	1.00	1.12	0.99
Tyrosine, %		2.13	1.50	1.88	1.78
Valine, %		1.30	1.02	1.23	1.06

Source: Experiment

Table 2. Live weight (BW), feed intake and feed conversion ratio (FCR) of broiler chickens given experimental diets at different ages from 12 to 33 d of age.

Parameters	Treatment			
	T1	T2	T3	T4
Performance at 19 d				
BW(g)	342.8	342.8	319.2	335.9
Feed (g)	440.4	441.9	418.9	437.7
FCR (g: g)	1.291	1.287	1.313	1.303
Performance at 26 d				
BW(g)	534.3	520.4	528.2	517.4
Feed (g)	735.4	714.2	726.6	718.9
FCR (g: g)	1.381	1.374	1.376	1.390
Performance at 33 d				
BW(g)	618.7	619.2	585.4	599.8
Feed (g)	906.3	833.1	871.0	914.1
FCR (g: g)	1.467	1.398	1.494	1.524
Cumulative Performance				
BW(g)	1495.7	1482.8	1437.0	1453.1
Feed (g)	2082.2	1989.3	2016.5	2070.7
FCR (g: g)	1.395	1.344	1.404	1.425

Source: experiment results
BW: body weight
FCR: feed conversion ratio

Table 3. Technical efficiency scores under constant and variable returns to scale and scale efficiency scores.

	TE_{CCR}	TE_{BCC}	SE	RTS
26 days				
T1	0.93	0.94	0.98	irs
T2	1	1	1	
T3	0.93	0.93	0.99	irs
T4	0.93	0.96	0.97	irs
Average	0.94	0.96	0.98	
33 days				
T1	0.94	1	0.94	drs
T2	1	1	1	
T3	0.94	0.98	0.95	irs
T4	0.91	0.93	0.97	irs
Average	0.95	0.98	0.96	
37 days				
T1	0.92	0.94	0.98	irs
T2	1	1	1	
T3	0.98	1	0.98	irs
T4	0.93	0.95	0.97	irs
Average	0.96	0.97	0.98	

Source: DEA analysis
TE_{CCR}: technical efficiency at constant return to scale
TE_{BBC}: technical efficiency at variable return to scale
SE: Scale efficiency
RTS: return to scale
irs: increasing return to scale
drs: decreasing return to scale

Technical efficiency scores for broilers under the age 33 days are slightly better compare to 26 days and again feed components of T2 provide higher technically efficiency compare to the other feed components (T1, T3 and T4) under both CCR and BCC model. Under this age, T1 showing decreasing return to scale, which means under control diet or standard treatment which provide minimum requirement of feed components, the 33 days is better age for broilers that provide optimum body weight gain and technical efficiency. This is consistent with the results presented in Table 2 above, where feed conversion factor is high under 33 days age , while for T3 and T4 the scale efficiency refers to increasing return to scale. Under the age of 37 days, T2 is still technically efficient under both models, while T3 is technically efficient under BCC model.

3.3 Allocative and Economic Efficiency

Table 4 summarizes Economic and allocative efficiency scores for the four treatments. All treatments for broilers under age of 33 days are allocatively efficient, which means hens input utilization was appropriate and minimized cost of input use. Instead, broilers under age of 26 and 37 days showing a lower allocative efficiency comparing to 33 age, this suggests that 33 days is optimum age for broilers to gain maximum body weight.

Table 4. Economic and allocative efficiency scores for the treatments

	T1	T2	T3	T4	Average
26 days					
AE	0.90	1	0.97	0.96	0.96
EE	0.83	1	0.90	0.89	0.90
33 days					
AE	1	1	1	1	1
EE	0.94	1	0.94	0.91	0.95
37 days					
AE	0.89	1	0.99	0.96	0.96
EE	0.81	1	0.97	0.92	0.92

Source: DEA analysis
AE: allocative efficiency
EE: economic efficiency

Consistent with the hypothesized trade-off between feed intakes and time to reach a level of broiler optimum weight, the analyzed treatments suggested that T2 with low crude protein and more Lysine, Methionine and Threonine as compared to (T1) would be cost-efficient under three period of age, while standard treatment (T1) and other two experiments (T3 and T4) are cost inefficient as economic efficiency scores are less than one for them. The fact that the economic efficiency of T2 did not change at different age periods, where low and high changed in the opposite direction occurred, suggests that the iso-quant is linear with constant slope i.e constant proportions iso-quant (Chambers, 1988). Therefore, the tangency point of the iso-cost line was always at the standard combination

4. Conclusion

This paper examines technical and economic efficiency of different feed allocation in four treatments for broilers production by applying DEA. The results showed that treatment two (T2) with lower crude protein diet and high Lysine, Methionine and Threonine contents are technically and economically efficient compare to standard feed components (high crude protein and less Lysine, Methionine and Threonine contents) in treatment one (T1), and to other treatments (T3 and T4) with variable crude protein, Lysine, Methionine and Threonine and energy contents. Also, the results proved that age of 33 days is optimum period for broiler to gain optimum body weight that provide desirable technical and economic efficiency. Broiler responses to reduced protein and energy diets supplemented with Lysine, Methionine and Threonine is biologically and economically feasible and may greatly reduce the cost of production

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References

1. A. A. Ali and I. E. E. Abdel Karim Yousif.2012 . Economic efficiency of wheat and faba bean production for small-scale farmers in Northern State – Sudan. The Journal of Animal & Plant Sciences, 22(1): 2012, Page: 215-223. ISSN: 1018-7081
2. Aigner, D., C. A. K. Lovell, and P. Schmid. 1977. Formulation and estimation of stochastic frontier production function models. J. Economics. 6:21–37.
3. Banker, R. D., A. Charnes, and W. W. Cooper. 1984. Some models for estimating technical and scale efficiencies in data envelope analysis. Manage. Sci. 30:1078–1092.
4. Chambers, R. G. 1988. The production function. Pages 6–48 in Applied Production Analysis: A Dual Approach. Cambridge University Press, Cambridge, UK.
5. Charnes, A., W. W. Cooper, and E. Rhodes. 1978. Measuring the efficiency of decision making units. Eur. J. Oper. Res. 2:429–444.
6. Coelli, T. J., D. S. Prasada Rao, C. J. O'Donell, and G. E. Battese. 2005. Pages 162-208 in An Introduction to Efficiency and Productivity Analysis. Springer, New York, NY.
7. Farrell, M. 1957. The measurement of productive efficiency. J. R. Stat. Soc. [Ser. A] 120:253– 290.
8. Groen, A. F., X. Jiang, D. A. Emmerson, and A. Vereijken. 1998. A deterministic model for the economic evaluation of broiler production systems. Poult. Sci. 77:925–933
9. Harris, D. L., and S. Newman. 1994. Breeding for profit: Synergism between genetic improvement and livestock production (A review). J. Anim. Sci.72:2178–2200.
10. Hocking, P. M. 2004. Roles of body weight and feed intake in ovarian follicular dynamics in broiler breeders at the onset of lay and after a forced molt. Poult. Sci. 83:2044–2050.
11. Khalid Mahmood Awan, Abdul Hanan Abdullah, Khalid Hussain. Channel Based Resource Allocation Mechanism (CBRAM) in WiMAX. *Life Sci J* 2013; 10(3): 40-46]. (ISSN: 1097-8135) .http://www.lifescience site.com 7
12. Romero L. zuidhof M., Jeffrey S., Naeima A., Renema R. and Robinson F. 2010. A data envelope analysis to assess factors affecting technical and economic efficiency of individual broiler breeder hens. Poultry Science 89:1769-1777, doi: 10.3382/ps.2009-00391.
13. Spratt, R. S., H. S. Bayley, B. W. McBride, and S. Leeson. 1990. Energy metabolism of broiler breeder hens. 1. The partition of dietary energy intake. Poult. Sci. 69:1339–1347.
14. Wang, C., R. Fare, and C. F. Seavert. 2006. Revenue capacity efficiency of pear trees and its decomposition. J. Am. Soc. Hortic. Sci. 131:32–40.
15. Weersink, A., C. G. Turvey, and A. Godah. 1990. Decomposition measures of technical efficiency for Ontario dairy farms. Can. J. Agric. Econ. 38:439–456.

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