A comparative evaluation of functions for the analysis of growth in turkeys

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Three mathematical functions, used previously to describe the relationship between body weight (BW) gain and metabolizable energy (ME) intake in broilers, were used in this survey with growing turkeys to investigate the relationships between BW and cumulative ME intake (cMEI), and between BW gain and crude protein (CP) intake in two different studies. All statistical analyses were performed using the mixed non-linear procedure of SAS (SAS 2000). In the first analysis, two functions (monomolecular and Richards equations) were assessed as candidates for describing the relationship between BW and cMEI. When the Richards equation was fitted, the additional parameter *n* tended to the value -1, resulting in the monomolecular equation as a special case of this generalised function. Therefore, it was concluded that the monomolecular equation was adequate to describe the relationship between BW and cMEI. In the second analysis, the scope of a specifically re-parameterized monomolecular equation was extended to growing turkeys to provide an estimate of their CP requirements for maintenance and growth. The estimated maintenance requirement (3.95 g/kg of BW/d) and the calculated values of efficiency of utilization of protein for growth (0.64) were in good agreement with values reported previously by other researchers.

Keywords: mathematical functions; turkeys: energy and protein requirements

Introduction

An alternative independent variable that can be used in growth studies is cumulative nutrient consumption (Fitzhugh, 1976), allowing for assessing efficiency of feed utilization. Although growth curves are useful tools in analyzing the growth response to genetic selection and to environmental changes, this modelling is applied at the whole animal level, considering only the final output of the system. Since animal production systems are an example of input-output systems, such data give no information on the mechanisms involved in animal growth. The usefulness of non-linear models (France *et al*., 1989) to predict daily energy dietary requirements for maintenance and growth in broilers and turkeys has recently been demonstrated (Darmani-Kuhi et al. 2003a, 2003b, 2004). The present study aims to apply these models in order to provide an estimate of cumulative ME and CP requirements in growing turkeys.

Materials and methods

The function forms, $f(x)$, listed in Table 1 and 2, were used to investigate the relationships between BW and cumulative ME intake (cMEI), and between BW gain (BWG) and CP intake (CPI) in two different analyses (analysis I and II, respectively). All statistical analyses were performed using the mixed non-linear procedure of SAS (SAS 2000). Mixed model analysis was chosen for analyses because the data were gathered from various published reports and therefore need to consider the report (data source) factor as a random effect. Performance of the models was evaluated using the significance level of the parameters estimated, variance of error estimate and its standard error.

Table 1 The functional forms used in Analysis I to describe the relationship between body weight, Y(X), and cumulative MEI, X

Function [†]	$f(x)$ [‡]	$df(x)/dx$ [§]	x at inflexion (x^*) [§]	$f(x)$ at inflexion (f^*) [§]
Monomolecular	$a-(a-b)\ e^{-cx}$	$c[a-f(x)]$	None	None
Richards	$\dfrac{ab}{\left[b^n+(a^n-b^n)\ e^{-cx}\right]^{1/n}}$	$cf(x)\left[\dfrac{a^n-[f(x)]^n}{na^n}\right]$	$\dfrac{1}{c}\ln\left[\dfrac{a^n-b^n}{nb^n}\right]$	$\dfrac{a}{(n+1)^{1/n}}$

[†] Thornley and France (2007).
[‡] The parameters a and b are the final and initial values, respectively, of Y; c is positive and $n \geq -1$.
[§] $df(x)/dx$ is at its maximum at the inflexion point (x^*, f^*).

Table 2 The monomolecular model used in Analysis II to describe the relationship between body weight gain, *f*(*x*), and CP intake, *x*.

Function[†]	$f(x)$	x_m
Monomolecular	$a-(a+b)\ e^{-cx}$	$c^{-1}\ln[(a+b)/a]$

[†] The parameters a, b and c are positive entities, with $f_{max} = a$ and $f_{min} = -b$. The expressions for x_m were obtained as the x value when $f(x) = 0$.

Results

Fitting the Richards equation (Analysis I) to the pooled cMEI data set showed that n was not significantly different from −1. Therefore, the sigmoidal trend was discarded and diminishing returns behaviour was assumed (*Figure 1a*). To evaluate the monomolecular model performance, a case study was conducted with data used for the calculation of cumulative ME requirements for male turkeys proposed by NRC (1994). BW profiles were simulated from the model using the relevant parameter estimates and compared with data from NRC (1994) (*Figure 1b*). There was close agreement between the values of BW proposed by NRC (1994) and those obtained using our model.

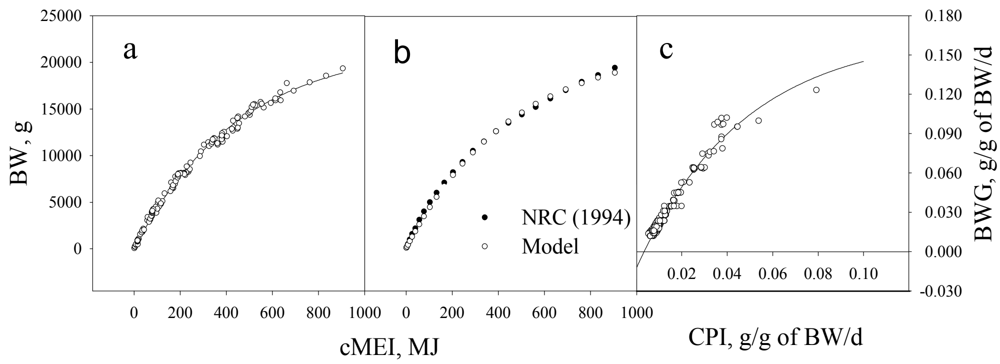

Figure 1 Plots of A) body weight (BW, g) against cumulative metabolizable energy intake (cMEI, MJ) showing the fit of the monomolecular equation (Analysis I), B) comparison between BW proposed by NRC (1994) and BW values estimated from cMEI using the monomolecular equation (Analysis I), C) rate of BW gain (BWG, g/g BW/d) against crude protein intake (CPI, g/g BW/d) showing the fit of the monomolecular equation (Analysis II).

Figure 1c shows the fit of the monomolecular equation to BW gain data *versus* CP intake in Analysis II. The fitted curve and general goodness of fit, based on variation accounted for ($\bar{r}^2$) and standard error (SE) estimated for the growth parameters, indicated that fit of the model to the data sets was acceptable (Table 3).

Table 3 Parameter estimates obtained and growth indicators calculated using the monomolecular model (Analysis II) Standard errors are given in parentheses*.

Parameter estimates					
a	*b*	*c*	σ^2_{error}	$\bar{r}^2$	-
0.1589 (0.0074)	0.0151 (0.0013)	22.95 (1.62)	0.000014 (0.000002)	96.45	-
Calculated growth indicators†					
x_m g/kg of BW/d	$20\times\bar{k}_{pg}(1-4)$ ‡§ %	$\bar{k}_g$ (1-4)§	$\bar{k}_g$ (1-2)§	$\bar{k}_g$ (2-3)§	$\bar{k}_g$ (3-4)§
3.95	64	3.21	3.49	3.19	2.91

* Number of observations = 199.
† Indicators calculated based on parameter estimates for *a*, *b* and *c*.
‡ The average net protein utilisation for growth between 1-4 times maintenance calculated based on the assumption that the carcass of turkeys contains approximately 20% crude protein.
§ The average efficiency of CP utilization for growth (g BWG/g CP) between 1-4, 1-2, 2-3 and 3-4 times maintenance.

Discussion

The suitability of models specifically re-parameterized for analyzing energy balance data relating growth rate to ME intake has been investigated in broilers (Darmani-Kuhi *et al*. 2003a, b) and turkeys (Darmani-Kuhi *et al*. 2004). In this study, the scope of the models was extended to growing turkeys to provide an estimate of their energy and protein needs for maintenance and growth. Based on statistical performance and the biological interpretability of the parameter estimates, it was found that the data could be accurately described by the monomolecular (diminishing returns) model (Table 3 and *Figure 1*). The estimated CP requirement for maintenance (3.95 g/kg of BW/d) and the average net protein utilisation for growth between 1-4 times maintenance (64%), calculated based on parameter estimates for the monomolecular model, agreed well with previous studies. Results of this study along with those previously reported for broilers (Darmani-Kuhi *et al*. 2003a, b) and turkeys (Darmani-Kuhi *et al*. 2004) can be considered as a base for accepting the general validity of these models.

References

DARMANI KUHI, H., KEBREAB, E., LOPEZ, S. and FRANCE, J. (2003a). An evaluation of different growth functions for describing the profile of live weight with time (age) in meat and egg strains of chicken. *Poultry Science* **82**, 1536-1543.

DARMANI KUHI, H., KEBREAB, E., LOPEZ, S. and FRANCE, J. (2003b). A comparative evaluation of functions for the analysis of growth in male broilers. *Journal of Agricultural Science, Cambridge* **140**, 451-459.

DARMANI KUHI, H., KEBREAB, E., LÓPEZ, S. and FRANCE, J. (2004). A comparative evaluation of functions for describing the relationship between live-weight gain and metabolizable energy intake in turkeys. *Journal of Agricultural Science, Cambridge* **142,** 691-695.

FITZHUGH, H. A. Jr. (1976). Analysis of growth curves and strategies for altering their shape. *Journal of Animal Science* **42**, 1036-1051.

FRANCE, J., DHANOA, M. S., CAMMELL, S. B., GILL, M., BEEVER, D. E. and THORNLEY, J. H. M. (1989). On the use of response functions in energy balance analysis. *Journal of Theoretical Biology* **140**, 83-99.

THORNLEY, J. H. M. and FRANCE, J. (2007). *Mathematical Models in Agriculture: Quantitative Methods for the Plant, Animal and Ecological Sciences*. . CABI Publication, Wallingford, UK.