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Modeling Growth Response of Broiler Chicken to Feed Consumption Using Linear Data Based Model Structure

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Abstract: Data on body weight and feed intake were obtained from broiler chickens raised at the University of Benin Farm Project to model growth response of broilers to feed consumption using a linear data based model structure. The birds were given four treatments based on the frequency of change of four commercial feed brands (A, B, C and D). In treatment 1, only feed A was given. Treatment 2 consist of changing all feed brands weekly, changing at interval of every 4 days (treatment 3) and at an interval of every 2 days (treatment 4). Highest growth response was observed in week 7 for combined feeds and week 8 for sole feeding. Peak feed efficiency was also observed a week lower than this ages resulting to predicted body weight of 1874.46g, 1984.54g 2148.55g and 2502.05g for treatments 1, 2, 3 and 4 respectively. Estimated mean relative prediction error (MRPE) were 4.90%, 8.05%, 5.42% and 6.99% were obtained for treatments 1, 2, 3 and 4 respectively. Feed efficiency and cumulative feed consumption showed similar trend over time with peak feed efficiency at week 7 and drastic change in feed consumption starting at week 3. The results of this study indicated similar trend in response thus implying that the growth trajectories for the treatments are nearly the same.

Key words: Broiler chickens, feed consumption, growth, linear, modeling

Introduction

The level and efficiency of production of any animal depends on the provision of adequate protein, energy, vitamins and minerals in the right proportions in their diets. In broiler nutrition, energy and protein levels are of great significance. Presently, poultry occupies a unique position in the livestock sector of Nigeria (Obioha, 1992). Expansion of the industry depends to a large extent on the availability of good quality feed at affordable price. An overview of the poultry industry shows that majority of the producers are small-scale holder farmers that rely on commercial feed millers for the supply of feed.

The dietary excess or deficiency of useful energy can reduce broilers growth hence knowledge of their growth response will provide an insight into the efficient use of feed. Controlling the growth trajectory of broilers had been shown to be beneficial to the animal, producer and consumer (Plavnik and Hurwitz, 1991; Zabair and Leeson, 1996; Lippens *et al.*, 2000). However, one of the most important inputs that can be used to control broiler growth is the feed intake.

In the literature, mechanistic models have been used to describe the growth response of animals in general (Von Bertalanffi, 1938; Brody, 1945) and for broilers (Timmons and Gates, 1988; Fattori *et al.*, 1991; Cooper and Washburn, 1998; Aerts *et al.*, 2003). Such models have helped in gaining in-sight, transfer of scientific knowledge and for simulation of processes. Beside these mechanistic models, many empirical models that

are mainly the results of non-linear regression analysis applied to growth data (Von Bertalanffi, 1938; Brody, 1945; Fitzhugh, 1976). Such regression models have the advantage that they are accurate and do not have complex structure. Applying linear data based model structures to describe non-linear phenomena have greater advantage of adaptiveness and can take into account the feed intake as a process input.

The objective of this study was to explore the dynamic growth response of broiler chickens fed combinations of commercial feed brand to the process input (feed intake) using a compact linear time varying model structure.

Material and Methods

Site of study: The data used in this study were obtained from the research conducted at the poultry unit of the Teaching and Research Farm of the University of Benin, Benin City, Nigeria. Benin City is located between latitudes 6° and 6°30'N of the equator and longitudes 5° 40' and 6°E of the Green wish Meridian. It has an annual rainfall of 2162mm, mean temperature of 27.6°C and mean relative humidity of 72.5%.

Experimental animals and management: A total of 120 day-old Anak broiler chicks were purchased from Otta Hatchery, Ogun State, Nigeria. The birds were reared in deep litter in a standard tropical open sided poultry building divided into 12 pens. The experiment lasted 10 weeks from June to August 2005.

The chicks were brooded during the first 4 weeks during which each pen was provided with electric bulbs and the open sides of the pen covered with polythene sheet to provide warmth. The birds were vaccinated according to schedule against New castle and Gumboro diseases. Other medications applied included antibiotics, coccidiostats and vitamins. Feed and water were provided *ad libitum*.

Experimental design: 120 day-old Anak broiler chicks of both sexes were randomly assigned to 4 treatments over the experimental period. Each treatment had 3 replicates of 10 experimental units each assigned into a completely randomized design (CRD).

Experimental diets: Four commercial brands of broiler feed namely: Guinea feed (A), Pfizer feed (B), Jachem feed © and Top feed (D) were used. These feed were combined to give 4 treatments based on the frequency of change from one feed to the other. In treatment 1, only feed A was given. Treatment 2 consist of changing all feed brands weekly, changing at interval of every 4 days (treatment 3) and at an interval of every 2 days (treatment 4). The starter and finisher commercial feed brands of the feeds were used. The day old chicks were placed on feed A for one week to stabilize them. Three replicates were assigned to each of the treatments with treatment 1 acting as the control.

Data collection and statistical analysis: Data were obtained on body weight (BWT) and feed intake (FDIN) of the birds using a weighing scale. Average body weight was obtained by dividing total weight at a given time with the number of birds in each replicate. Feed intake was taken at the end of each week for all the treatments by subtracting the amount of feed left from the known amount that was given and by dividing with the number of birds in each replicate to obtained average feed intake/bird.

Mathematical modeling: The growth response of broiler chickens (system output) was model to the process input (feed intake) using a linear time varying model structure. It was assumed that the nonlinear relationship between cumulative feed intake and weight can be described by the following linear relation

$$W_k = \theta_{1k} + \theta_{2k}.CF_k \text{ (Aerts *et al.*, 2003)}$$

Where W_k is the measured average weight (kg) of the birds at time k; CF_k is the measured cumulative feed intake in kg at time k; θ_{1k} and θ_{2k} (kg/kg) are the time variant model parameters estimated at time k (wks). The parameter θ_{2k} , more specifically, is the feed efficiency at the time k (defined as change of bird weight per change of feed intake). The parameter θ_{1k} at the start of the

experiment equal the weight of day old chick. In matrix notation, the equation above can be written as

$$W_k = a_k x_k$$

Where a_k is $[\theta_{1k} \ \theta_{2k}]$; x_k is $[1.CF_k]^t$, the superscript t meaning the transpose of a matrix.

It can be demonstrated that, on each time instant k, the estimate of the parameter vector a_k is equal to the previous estimate a_{k-1} plus a correction term, which is the product of a gain factor and the difference between the new observation of the process output w_k and the process output w_{k-1} estimated by using the parameter vector a_{k-1} of the previous time instant (ie $w_k = a_{k-1}.a_k$). The gain factor is a function of the inverse of the data covariance matrix, p_{k1} and x_k . The standard errors on the parameter estimates can be computed as the square root of the diagonal elements of the covariance matrix of the estimation errors $p_k.p_k$ which is defined as the product of p_k and the variance of the model prediction errors (Young, 1984).

The parameter θ_{1k}, θ_{2k} were estimated based on all data of weight and cumulative feed consumption of the production period using linear least squares approach. The goodness of fit of the modeling techniques was quantified by the mean relative prediction error (MRPE) as was similarly used by Oltjen and Owens (1987); Talpaz *et al.* (1991) and Aerts *et al.* (2003) represented as

$$MRPE = 1/N \sum \sqrt{(W_k - W_k^p / W_k)^2} \cdot 100$$

Where MRPE is a percentage; N is the number of samples; W_k is the weight measured at time k (kg); W_k^p is the predicted weight at time k (kg).

Results and Discussion

The modeling technique was used to model the broiler chicken growth response for the 4 treatments used in this study. The observed and predicted growth responses of the birds to treatments 1 to 4 together with their respective MRPE are depicted in Fig. 1 to 4 respectively. Results of the feed efficiency and cumulative feed consumption of the birds at different times for the treatments are depicted in Fig. 5 and 6 respectively. Highest growth response was observed at week 8 in treatment 1 and week 7 in other treatments. Peak feed efficiency were also observed at this corresponding ages that resulted to predicted body weight of 1874.46g, 1984.54g, 2148.55g and 2502.05g for treatments 1, 2, 3 and 4 respectively. In treatment 3 and 4, a drop in predicted weight occurred at week 6 which was however compensated for at week 7. The drop was also noticed in week 6 in treatment 2 but the magnitude was not as high as it was in treatments 3 and 4. In the case of treatment 1 the actual and predicted

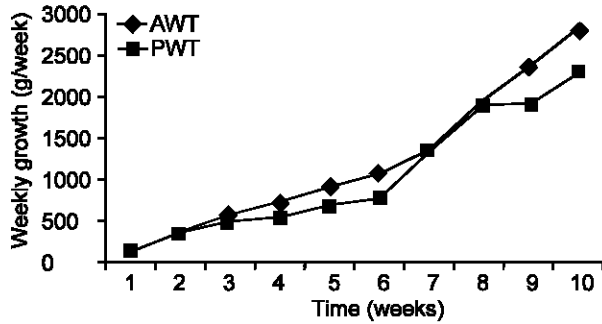


Fig. 1: Actual and predicted average weekly growth of broiler chickens fed one commercial feed brand (MRPE = 4.90%)

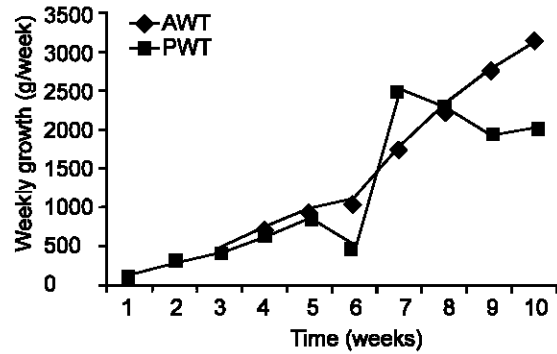


Fig. 4: Actual and predicted average weekly growth of broiler chickens fed four commercial diets at an interval of two days (MRPE = 6.99%)

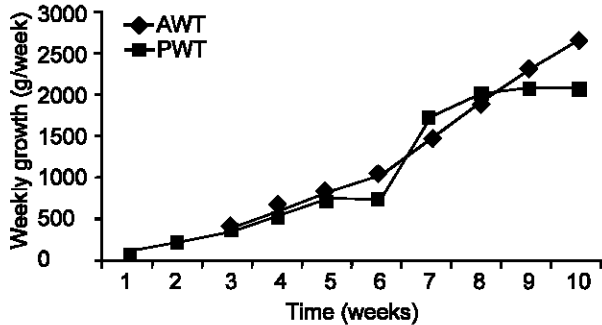


Fig. 2: Actual and predicted average weekly growth of broiler chickens fed four commercial diets on weekly interval (MRPE = 8.05%)

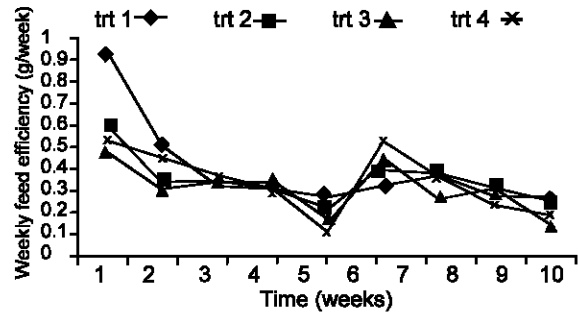


Fig. 5: Estimated weekly feed efficiencies (model parameter O2) for broiler chickens fed four commercial feed brands at different intervals.

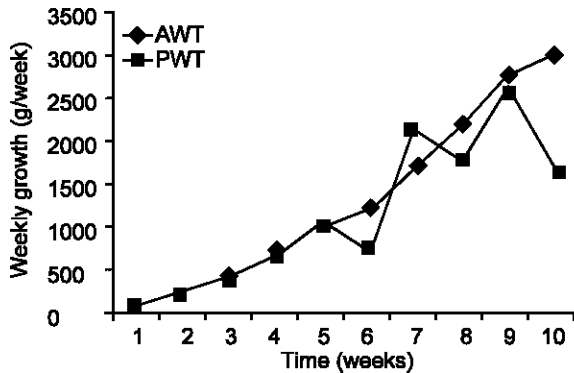


Fig. 3: Actual and predicted average weekly growth of broiler chickens fed four commercial diets at an interval of four days (MRPE = 5.42%)

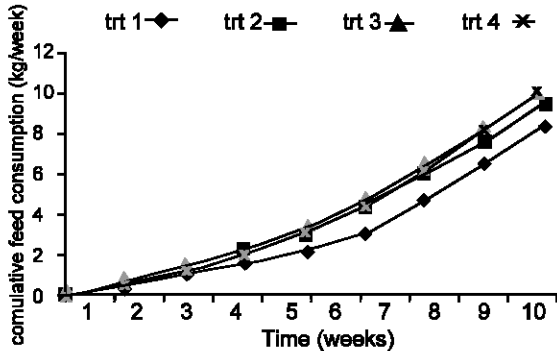


Fig. 6: Estimated cumulative feed consumption for broiler chickens fed four commercial feed brands at different intervals.

growth response were similar until week 8 when a drop was noticed in the predicted value. The very low magnitude of growth response of the birds was compensated from the 6th week. According to Talpaz *et al.* (1991) who constructed a model that described normal growth by a Gompertz equation, described compensatory growth as the product of three terms: a time derivative, a compensatory factor that is the function of the severity of feed restriction and a time – dependent

exponential term. The same principle could be attributed to the result of this study where the adjustment to the more frequent change in the feed brands accounted for the compensatory factor. The more frequent the higher the compensatory growth. Although, Talpaz *et al.* (1991) and Aerts *et al.* (2003) obtained a prediction errors that ranged from 0.1 to 4.7% and 4.4 to 4.7% respectively, in the present study higher prediction error values of 6.32 to 8.96% was obtained. The difference could be due to

differences in prediction horizon and the aim of the experiments. While they were looking at feed restriction, this study was on how birds react to changing feed brands.

A cursory look at the MRPE values shows that the weight trajectory of birds fed treatments 3 and 4 could be predicted with less accuracy than of birds fed treatments 1. This can probably be explained by the fact that the birds fed treatment 3 and 4 showed more pronounced accelerated growth from age 6 weeks resulting in a loss of model accuracy. Evidence for the pronounced growth could also be inferred from the feed efficiency value (Fig. 5).

The time causes of the feed efficiency (Fig. 5) showed a maximum at week 6 except for birds fed treatment 1. All birds showed accelerated growth at this week. The weekly growth and feed efficiency of the birds showed similar trend in their response thus implying that the growth trajectories for the treatments are nearly the same.

The cumulative feed consumption trend showed that up to week 3 birds consumed similar quantity of feed. Thereafter, the trends with the combination of feed brands were also similar. It is only in treatment 1 that birds consumed less and weighed more thus suggesting better feed efficiency.

The model adopted in this study predicted growth of broiler chickens vary well up to the end of the starter phase for treatments 2, 3 and 4, but with less accuracy at the finisher phase for birds fed treatments with shorter time change of feed brands (3 and 4) thus suggesting that changing of feed brands in the absence of one's choice of feed brand at least once a week will not affect the performance of broiler chickens. It is however worth noting that the relationship between cumulative feed intake and weight which is non linear in nature could be approximated by applying a recursive model but not with accuracy. Similar use of recursive modeling approach has been applied in predicting daily milk yield of cows (Van Bebber *et al.*, 1999), feed intake and growth of beef cattle (Oltjen and Owens, 1987), monitoring changes in feed consumption data of commercial laying hen flock (Roush *et al.*, 1992) and prediction of broiler growth response and feed intake (Aerts *et al.*, 2003). This technique will allow detection of early changes in feed consumption by comparing the predicted response on every time instance with the actual observed response.

Conclusion: The results of this study showed that drastic change in feed consumption was noticed at the 3rd week while peak feed efficiency was at week 7 and 8 for different feed brands and single feed respectively thus suggesting that keeping the birds beyond this ages will not be too beneficial.

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