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Mathematical modeling of the native Mexican turkey's growth

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ABSTRACT

Little is known about the productive performance of Mexican turkey, so the objective of the present study was to characterize growth performance curves of backyard turkey under a confined system. Forty fertile eggs were artificially incubated and turkey weight was recorded at hatch. During growth performance weekly weight was measured until 385 days of age. Turkey commercial feed and water were offered *ad libitum*. To characterize growth curves, a fourth degree polynomial model regression and a Richards biological model were used, which were compared by determination coefficient (r^2), to reach the best fit model. The best fit model was the fourth degree polynomial regression model from a mathematical standpoint of view. It was found that maximum tom growth was reached at 15.7 weeks with a weight gain of 259.3 g/week and in hens at 12.4 weeks with a weight gain of 112.0 g/week. Body weight reached by toms at 40 weeks was 6 kg and hens at 35 weeks with 3.6 kg.

Keywords: Age to Slaughter; Growth Curves; Guajolotes; Maximum Weight; Slow Growth Turkeys

1. INTRODUCTION

Growth curves models can describe and summarize quantitative changes that birds experiment through their lives, they are useful to select Creole birds according to the producer request and to program feeding phases, focusing a large amount of nutrients on the fast growth phases, to know the optimal age to slaughter, effects of gene selection on curve components, and weight gain on a certain age [1-3].

In addition, growth curve parameters can be used individually or as a whole to predict growth rates, and other animal husbandry traits [4]. To Knízetová *et al*. [5], the forms that obtain the growth curves are the result of a growth index and changes during ontogenesis.

Animal growth is defined as an increase of cell enlargement or hypertrophy and also includes the increase in number of cell hyperplasia [6,7]. Postnatal growth of domestic animals, which parameters are described as biological constant interpreted under the form of a mathematical equation that generally can be plotted as a sigmoid curve [8], starts with a fixed point (weight at birth) and with a slow initial growth, where the inferior asymptotic is the start of growth [9], the higher asymptotic is the mature size and the point of inflection is the maximum growth point [10].

The sigmoid growth curve extends from conception to maturity. After hatch and for some time there is fast growing phase during which, growth rhythm is almost constant, during the last periods of muscle, bones and vital organs growing, start to gradually decay, and the inflection point appears. The last period is characterized for fat accumulation; and possible maximum weight is achieved, growth stops (maturity phase), finally with the old age corporal volume decreases (declination phase) and muscular mass is lost.

The use of growth sigmoid curve is useful to study the animal development, make comparisons between species, within animals of the same breed [11]. Considering the animal husbandry and economic importance of some characteristics like body weight, weight gain, mature age and highest weight, several models that express growth have been proposed: polynomials, nonlinear and linear mix.

For the case of birds, the absolute growth ratio measures the development of each unit time and represents an index of how much does the bird grow by a selected unit time. Relative growth ratio represents the increase by presenting weight unit, and it's an index of the effort realized by the bird to increase its biomass [1].

Knízetová *et al*. [5] reported that the most appropriated function to estimate growth curves in poultry is the Richards sigmoid model. This biological model has had such a great importance in the poultry growth paradigm, that three growth biological aspects have been described: 1) size, higher limit or asymptotic; 2) the index, a measure to specify the time requested of the growth increase; and 3) shape, a quantitative measure that describe the path of the growth process [12].

Slow growth Mexican bronze turkeys raised in the backyard have characteristics that make them favorable for organic meat production which has a high demand on Europe, USA and Asia [13]; however, information about these turkeys is scarce [14]. This situation turns out to be difficult to establish the right market time. It has not been established the optimal age where maximum growth is achieved, therefore, the objective of the present study was to characterize, through mathematical models, the growth curve and to estimate optimal weight and age to market slow growth bronze turkeys reared on intensive conditions.

2. MATERIALS AND METHODS

Forty fertile eggs were collected from slow growth bronze turkeys in two rural communities from Tututepec and San Pedro Mixtepec from the region of Oaxaca coast, México.

Eggs were weighed with a balance Ohaus PA 3102, eggs were marked and set into an automatic incubator Brinsea Octagon 40, and were incubated for 28 days at 37.7˚C. Previous to incubation, the incubator was disinfected with 5% sodium hypochlorite solution.

At hatch, each poult was weighed and marked with color plastic tags attached in the head, each tag had a number to identify each turkey [15]. Each poult was raised individually and was considered as an experimental unit. Raising period was realized in the Universidad del Mar (UMAR) facilities in the Campus Puerto Escondido, Oaxaca, Mexico, with artificial temperature and lasted four weeks, moreover heat source was removed and poults were allocated to the UMAR experimental field on individual cement cages.

During raising period, poults were vaccinated and dewormed following the sanitary program of the region [16]. Hatching time was considerate as week zero, variables were recorded for 55 weeks.

A commercial feed program for turkeys was used in two phases: for growth crumble presentation, and for finalization period pellet. Feed and water were offered ad libitum.

Right after poults hatch, the following productive variables were recorded on a weekly basis: feed intake, weight gain and feed conversion ratio. When turkeys reached two kg body weight, and electronic scale Torrey, model EQB 1007/200, with 50 kg capacity was used for the rest of the experiment.

A dispersion diagram was plotted with weight gain means of males and females, and the mathematical models proposed by Richards were used to estimate constant values of variables; in addition a fourth order polynomial regression model was applied

$$\left(y = \beta 0 + \beta ix + \cdots + \beta nxn\right)[17].$$

Then, a correlation coefficient was calculated which is the confidence mathematical model index [10] and growth was estimated per each sex.

Agudelo-Gómez *et al*. [18] described Richards's equation as:

$$W = \beta_0\left(1 - \beta_{1e}{}^{-\beta 2t}\right)^{\mu}$$

where:

W: Is the weight at any moment

β_0: Is the higher asymptotic that correspond to maximum stable weight

β_1: Fit parameter established for the initial values of w and β_2: mature ratio

μ: Mature grade referred as the point of inflection

To find the best fit determination coefficients were calculated. Comparison of such coefficients a best fit model for the studied phenomenon can be established.

The determination coefficient of a nonlinear model is obtained as:

$$\mathrm{r}^2 = \sum\left(w_i - \bar{w}_m\right)^2 - \sum\left(w_i - w_e\right)^2 \Big/ \sum\left(w_i - \bar{w}_m\right)^2$$

where:

r^2: Determination coefficient

w_i: Weight real value at certain moment

w_e: Estimated weight with the model at certain moment

$\bar{w}_m$: Average weight

Average growth rate it's defined by the change of weight at a certain interval of time:

$$\bar{D}W_m = \Delta W/\Delta t\left(\text{grams/week}\right)$$

If it is wanted to find the velocity of weight increase of an animal respect to the time at any moment, then it would be instant growth rate:

$$DW = \lim_{\Delta t \to 0} \Delta W/\Delta t\left(\text{grams/week}\right)$$

In other words:

$$DW = dW/dt\left(\text{grams/week}\right)$$

Means and analysis of variance were performed by SAS statistical software [19]. Growth curve graphics were elaborated by Graph software package [20].

3. RESULTS AND DISCUSSION

Table 1 shows body weight means for males and females respectively from hatch to 55 weeks old. Estimated equations and determination coefficients are shown in **Table 2**.

Table 1. Means and standard deviation of egg weight before incubation and bronze turkeys slow-growing Mexican males and females after hatching and during 55 weeks.

Production stage/age	Males	Females
	(g)	
Egg to hatching	69.2 (±3.2)	69.0 (±2.4)
Hatching	46.7 (±6.5)	43.0 (±4.3)
5 weeks	318.0 (±31.2)	309.5 (±43.5)
10 weeks	1 212.0 (±65.2)	1 090.7 (±81.7)
15 weeks	2 346.0 (±88.5)	1 801.0 (±82.0)
20 weeks	2 563.5 (±82.0)	2 563.5 (±56.0)
25 weeks	5 082.0 (±155.0)	3 112.4 (±140.1)
30 weeks	5 565.0 (±193.1)	3 512.5 (±93.6)
35 weeks	5 827.5 (±177.1)	3 487.5 (±93.6)
40 weeks	5 825.0 (±108.0)	3 247.5 (±93.6)
45 weeks	5 592.1 (±124.9)	3 015.0 (±124.9)
50 weeks	5 667.5 (±99.6)	3 052.5 (±99.6)
55 weeks	5 422.4 (±201.6)	2 446.4 (±58.0)

Table 2. Estimated equations, coefficients of determination (r^2) obtained in the models studied.

Models	Equations	r^2
	Males	
Polynomial	$W = 0.0057t^4 - 0.7023t^3 + 24.62.37t^2 - 83.0818t + 148.6012$	0.995
Richards (β_2 variable)	$W = 5990\left(1 + 34.95e^{(0.0031t - 0.2991)t}\right)^{-1.3551}$	0.981
Richards (β_2 constant)	$W = 5990\left(1 + 34.95e^{-0.2122t}\right)^{-1.3551}$	0.978
	Females	
Polynomial	$W = 0.0038t^4 - 0.4195t^3 + 12.1218t^2 + 24.1287t - 16.6680$	0.991
Richards (β_2 variable)	$W = 3750\left(1 + 57.84e^{(0.005166t - 0.3663)t}\right)^{-1.096}$	0.959
Richards (β_2 constant)	$W = 3750\left(1 + 57.84e^{-0.2216t}\right)^{-1.096}$	0.793

It was observed that polynomial regression equation that included the fourth degree, showed a good fit, in females with values of r^2 = 0.991 and in males 0.995, while the Richards (β_2 variable) nonlinear model showed a lower fit with 0.959 for females and 0.981 for males.

The Richards (β_2 constant) model showed a lower fit to the original data, with a determination constant of 0.978 for males, and 0.793 for males which are not acceptable for the application of the present study. The fourth degree polynomial model curves for male and female are shown in **Figures 1** and **2**, respectively.

Figures 3 and **4** are showing the Richards (constant) biological model curves for bronze male and female turkeys; and the **Figures 5** and **6** are the Richards models (variable).

Brisbin *et al.* [22] mentioned that Richards model or any other biological model trends to change because in the equation a large number of biological parameters are evaluated; or can be affected by environment factors as changes in the temperature or diet.

Other limitations found in the use of polynomial models

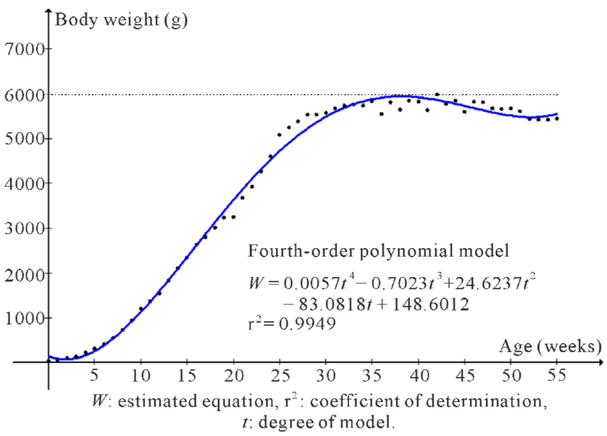

Figure 1. Fourth-order polynomial model for growth of native male turkey slow growth phenotype bronze.

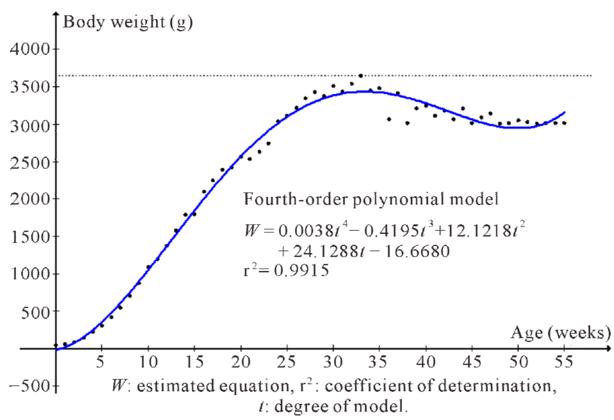

Figure 2. Fourth-order polynomial model for growth of native female turkey slow growth phenotype bronze.

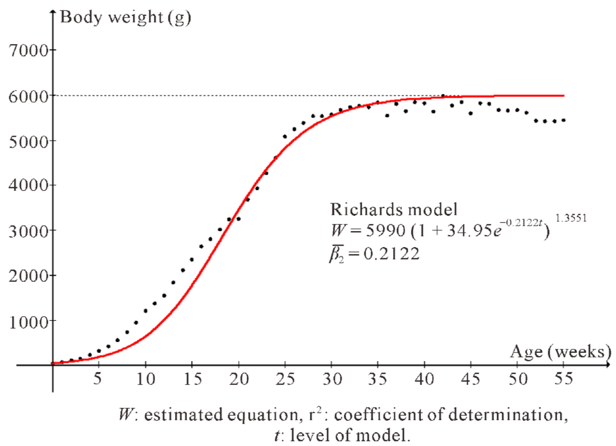

Figure 3. Growth curve with Richards model (constant) native male turkey slow growth phenotype bronze.

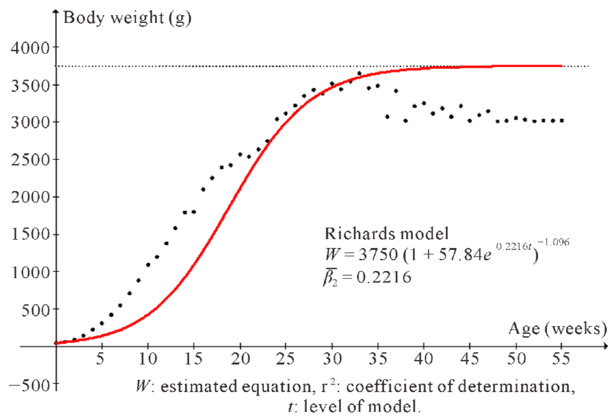

Figure 4. Growth curve with Richards model (constant) native female turkey slow growth phenotype bronze.

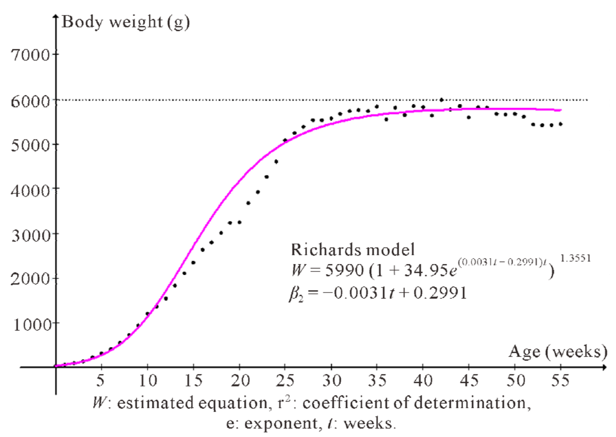

Figure 5. Growth curve with Richards model (variable) native male turkey slow growth phenotype bronze.

in comparison with biological models like the Richards, are that they exhibit multicollinearity along the curve and dependence of the function of high concentration point areas [18].

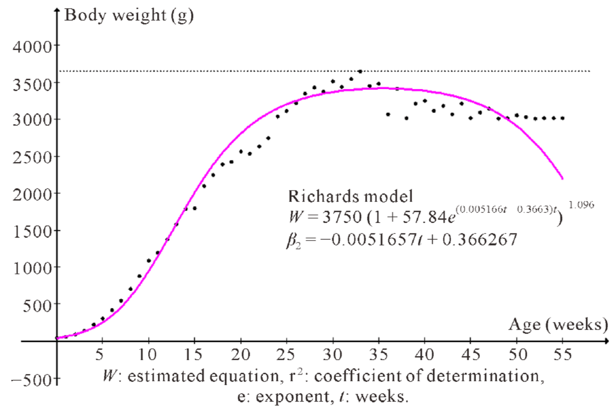

Figure 6. Growth curve model with variable Richards native female turkey slow growth phenotype bronze.

It is acknowledged that the polynomial model importance is given by its application. It's easy to obtain; however, the calculations are slow and demanding from a computational standpoint.

Despite the latest, the linear and quadratic answers are easy to interpret biologically [23]. In the present study, the female body weight at 20 weeks old was 75% for the male body weight at the same age, this is in agreement with Juárez and Fraga [24], due to the sexual dimorphism in turkey that is considerable, where the mature female weight is 50% to 85% less than the one in males.

Fast growth bronze turkey phenotype reaches their complete development at 22 - 26 weeks, with average weight of 9 - 11.5 kg for males and 6.5 - 7.8 kg for females [25]; however, it was observed in the present study that, due to the slow growth of the genetic line used, growth is extended until 35 weeks for females and 40 weeks for males, that's where the maximum weight is reached. The male presented the maximum instant growth three weeks later than the female and with a gain weight capacity over twofold (**Figures 7** and **8**).

This is useful information to determine the feeding programs for this genetic line, and because of the differences in growth, it's recommended to separate by sex the raising changing the feed formula at 12 weeks for females and 15 weeks for males.

The idea is confirmed when observing the maximum estimated weight, where the males can reach 2.4 kg more than the females with five more weeks of fattening. The latest is useful to make productive decisions, because the market optimal age for females is at 35 weeks, while the male is 40 weeks where their maximum body weight is reached.

The weight for Mexican male mature turkeys, without specific line or genotype, is reported variable and ranks from 5.0 - 6.8 kg, and for females 2.0 - 6.0 kg [26-29]. These weights are in agreement with the ones estimated

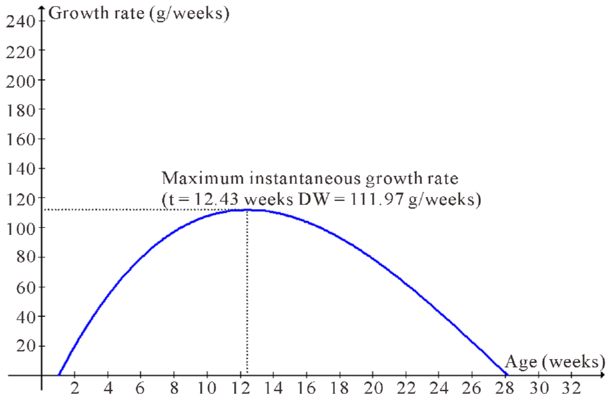

Figure 7. Growth rate in female native turkey slow growth phenotype bronze.

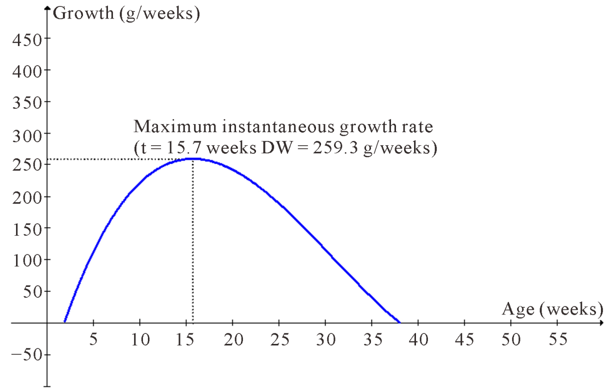

Figure 8. Growth rate in male native turkey slow growth phenotype bronze.

in the present study; however, the maximum weights reported in other studies for males are 8.9 and 20.0 kg and for females 3.0 - 17.0 kg [14,27,30]. This difference in weight can be due to the fact that the maximum weights are considered that the bird can reach along their entire life, when the bird stops growing and starts fat deposits, while the present study estimated the adequate market weight, or they may be heavy fast growth genetic lines different from the bronze turkey.

Based on the present results, it is concluded that the fourth degree polynomial model is the most adequate to estimate the slow growth bronze turkey growth, which has the maximum instant growth rate at 12 - 15 weeks.

The age and weight for slaughter were of 35 weeks and 3.6 kg for females and 40 weeks old and weight of 6.0 kg for males. It is important to characterize other phenotypes, because they are less studied and they represent an important zoo genetic resource adapted to organic production conditions.

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