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# PROBLEMS ASSOCIATED WITH MODELLING BROILER CHICKEN GROWTH USING STATISTICA

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## Summary

In the present work it was attempted to model broiler chicken growth using Statistica 9.1. Chicken body weight was measured at 7 day intervals, from 7 to 49 days of age. The calculations included 21 production cycles of a selected commercial line of broiler chickens. Parameters of selected growth curves and polynomial functions were estimated for each production cycle and for all the cycles. It was possible to estimate. It was possible to estimate the parameters of growth curves was possible for only some of the cases studied. It was difficult to select both the function and an adequate method of estimating its parameters. Each time the selection was made on a trial basis. From this perspective, the polynomial function was the most suitable as it was possible to estimate its parameters, including standard errors, Student t-values and t-test p values for each of the 21 production cycles and for all the cycles.

**Keywords and phrases:** growth function, broiler chicken, polynomial function

**Classification AMS 2010:** 62J02, 90C30, 91B62, 40E10

## 1. Introduction

The growth of living organisms – one of the most important biological processes (Hammond 1932; McMeekan 1940 and 1941; Brody 1945; Ricklefs 1968 and Fl'ak 1998) – has attracted the attention of researchers for a long time.

Mathematical modelling of growth has a long tradition and can be attempted for individual organisms and the whole populations. Moreover, growth can be described using various functions, for example polynomials or a family of Richards curves which includes the following special functions: a modified exponental function, logistic function and Gompertz function (Wesołowska-Janczarek, 1993). It is possible to model the growth of both animals (Szypuła 1977; Pabis 1978b; Jamroz and Preś 1978; Jamroz et al. 1986; Jaros 1986, Jaros and Pabis 1986; Menchaca et al. 1996; Portolano and Todaro 1997; Sorensen et al. 2003; Novak et al. 2004; Bilgin et al. 2004; Pala et al. 2005; Berry et al. 2005) and plants (Pabis and Dec 1983; Dec 1987a,b,c; Wesołowska-Janczarek 1996; Wesołowska-Janczarek and Fus 1996).

The key problem is to select an adequate mathematical model which would reflect the phenomenon as closely as possible. In her studies of Frisian cattle growth, Ptak (1992) estimated the parameters (separately for each animal) of Gompertz, Brody, Richards and von Bertalanffy functions. These growth functions are most frequently used to model growth of various animal species.

Many studies have focused on bird growth: Hyánková et al. (2001) and Goliomytis et al. (2003) have used the Richards function whereas Mignon-Grasteau et al. (1999) and Maruyama et al. (1999) have applied the Gompertz function. Moreover, Maruyama et al. have applied the logistic model (the work in 1999) and the Weibull function (the work in 2001) to model the growth of ducks. In turn, the allometric model was useful to model the growth of broiler ducks taking into account their somatic size (Baumgartner et al. 1982).

The development of information technology has made it easier to use more complicated mathematical and statistical methods. As a result, new problems have arisen which can be encountered by a researcher interested in practical applications of some solutions available in statistical packages such as SAS and Statistica. Technical ease of an application of computer programs is, however, accompanied by some difficulties as the researcher using modules of non-linear estimation has to choose an adequate algorithm and loss function. Unfortunately, the estimation may yield a function which insufficiently describes empirical data or the results can be incomplete without estimation errors of the function parameters.

The objective of the present work was to test the practical applicability of selected nonlinear estimation methods available in Statistica 9.1 to estimate parameters of selected functions describing broiler chicken growth.

## 2. Materials and methods

Body weight records of broiler chickens raised on a commodity farm located near Siedlce were used in the study. The measurements were taken every 7 days on a random sample of 100 birds during 21 production cycles. Growth was modelled using the Brody, Gompertz and logistic functions as well as a fourth-order polynomial function. In the statistical package Statistica, the following sequence was selected: the module ***Advanced Linear/Nonlinear models: Nonlinear Estimation*** and then the option ***User-specified regression, custom loss function)*** (Fig. 1).

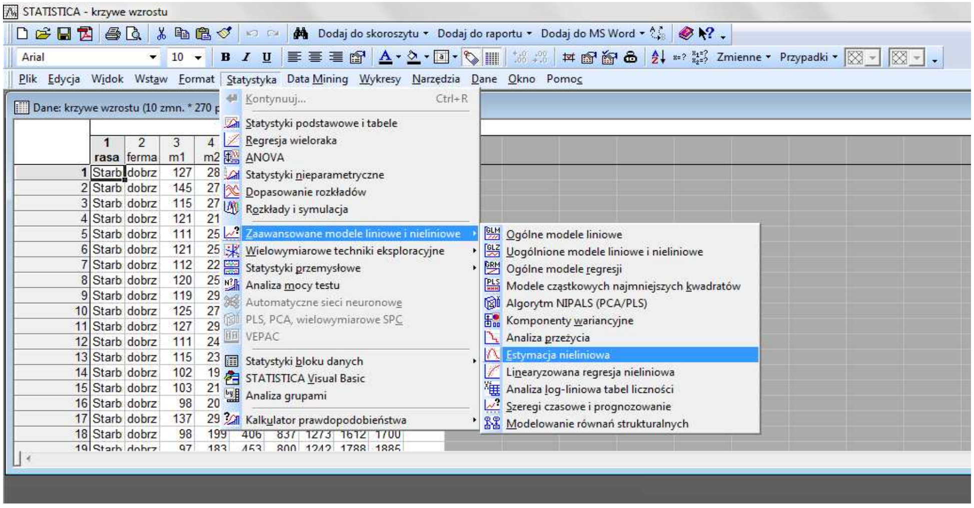


**Fig. 1**. Window of calculation module selection
Source: own calculations in Statistica 9.1

The default model was selected as a loss function (Fig. 2). Its role is to estimate the squares of deviations of estimated and observed values. Minimization of the loss function is a procedure of estimating the parameters of regression function being estimated (describing chicken growth). The formulae of successive user-specified functions were typed using the option of saving as a text file for future use:

Brody function – y =A*(1-B*Euler^(-K*t))
Gompertz function – y =A*Euler^(-B*Euler^(-K*t))
logistic function – y =A*(1+Euler^(-K*t))^(-M)
polynomial function – y =a+b*t+c*t^2+d*t^3+e*t^4, in which:
Euler = the e constant, t – point of body weight measurement (t = 1, …, 7).

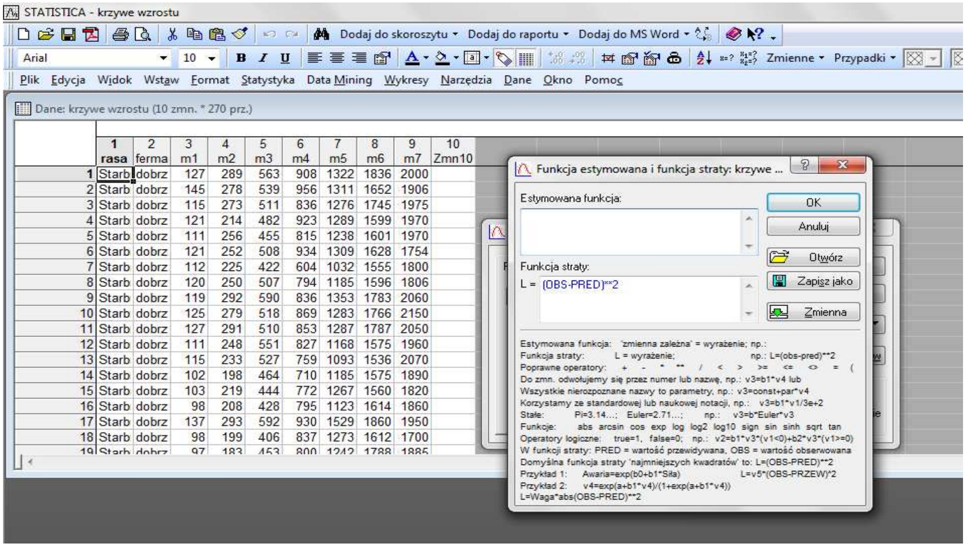


**Fig. 2.** Window of defining the user-specified function and loss function
Source: own calculations in Statistica 9.1

In the next step, the first (default) estimation option, that is the quasi-Newton algorithm, was used to estimate parameters of nonlinear regression function. The function parameter estimates obtained were presented as values of the arithmetic mean, standard deviation, minimum and maximum values and estimate numbers – the number of production cycles, out of 21, for which parameters were estimated during calculations.

The next algorithms (Simplex procedure, quasi-Newton simplex procedure, Hooke-Jeeves algorithm, Hooke-Jeeves and quasi-Newton method, Rosenbrock pattern search method, Rosenbrock and quasi-Newton method) were applied to analyse results of one, randomly selected production cycle in order to check their efficiency based on the same numerical data (Fig. 3). Only the results for which the determination coefficient exceeded 90% were taken into account. The description of the above-mentioned algorithms can be found in the work by Stanisz (2000).

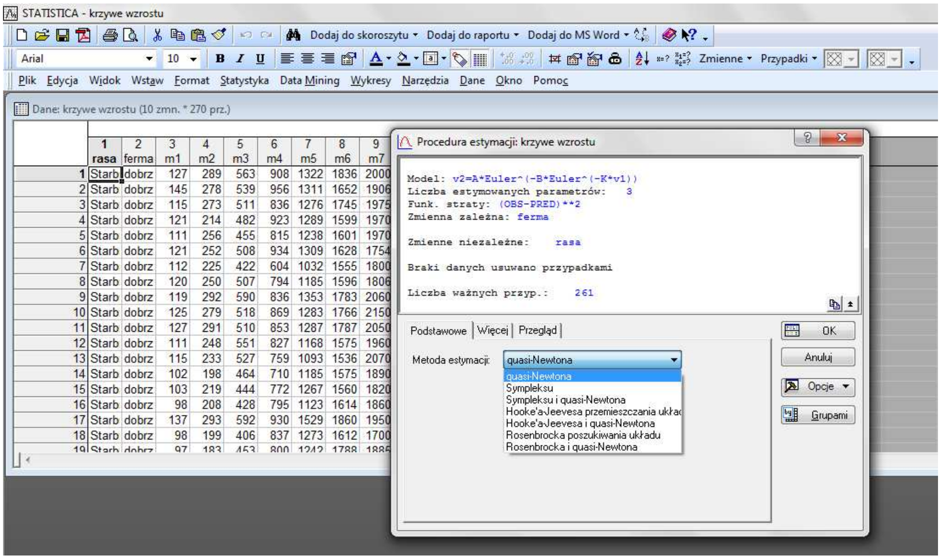

**Fig. 3.** Window of selecting a function parameter estimation method
Source: own calculations in Statistica 9.1

## 3. Results and discussion

An application of the quasi-Newton algorithm, which is a default algorithm in Statistica, produced estimates of growth curve parameters for a small number of production cycles (Table 1). When growth was described using the Brody and Gompertz functions, parameter estimates were obtained for 9 out of 21 production cycles only and the production cycles were different for both the functions. However, it should be stressed that the results of calculations were not complete. Function parameter estimates were accompanied by standard errors, t-Student test values and t-test p values for one production cycle (logistic function) only.

Mean values of chicken body weight over 49 days of fattening and for all 21 production cycles were well described by only the Gompertz function. No parameters were estimated for the Brody and logistic functions.

Lack of complete results (lack of values of standard errors, t-Student test values, and t-test p values) was the most frequent problem signalled by the notification window: ***Estimation failed; change estimation method/start values*** or ***Exceeded maximum number of iterations; 30 more iterations?*** (Fig. 4). The latter situation is better. Additional iterations can produce a complete set of results (parameter estimates with standard errors, t-Student test values and t-test p values).

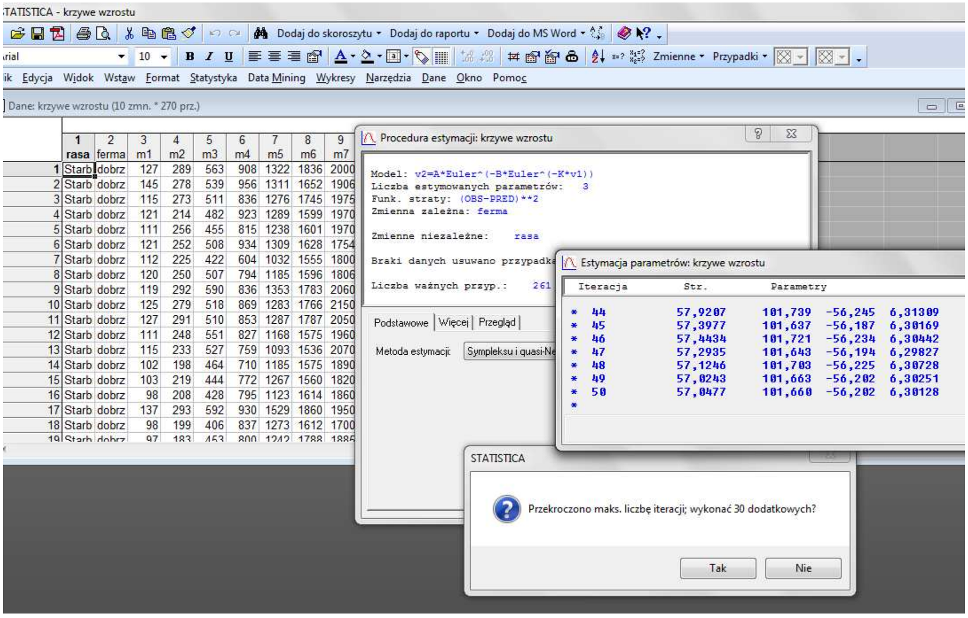


**Fig. 4**. Notification windows appearing during estimation of function parameters
Source: own calculations in Statistica 9.1

If the function parameters have been estimated, the results window opens (Fig. 5). It contains, first and foremost, parameter estimates and some additional information (given below) about their significance.

For the polynomial functions (Table 2), parameter estimates were obtained in addition to standard errors for the results of each production cycle and all the 21 cycles.

The values presented in table 3 indicate that an application of the remaining 5 algorithms of estimating parameters of all the functions examined (based on results of one production cycle) did not substantially change the results. No errors of the parameter estimators of the functions were obtained so the significance of these parameters remained unknown. What is bothering is a considerable disparity between estimates obtained using different methods and lack of the possibility of obtaining parameter estimates by means of some algorithms. Two estimation methods proved to be ineffective and only four were effective for the Brody curve and the Gompertz curve, respectively. Only when the logistic function was the case, all the estimation methods yielded results which were, however, so different (ranging from 9.7 to 2795) that they had to be discarded.

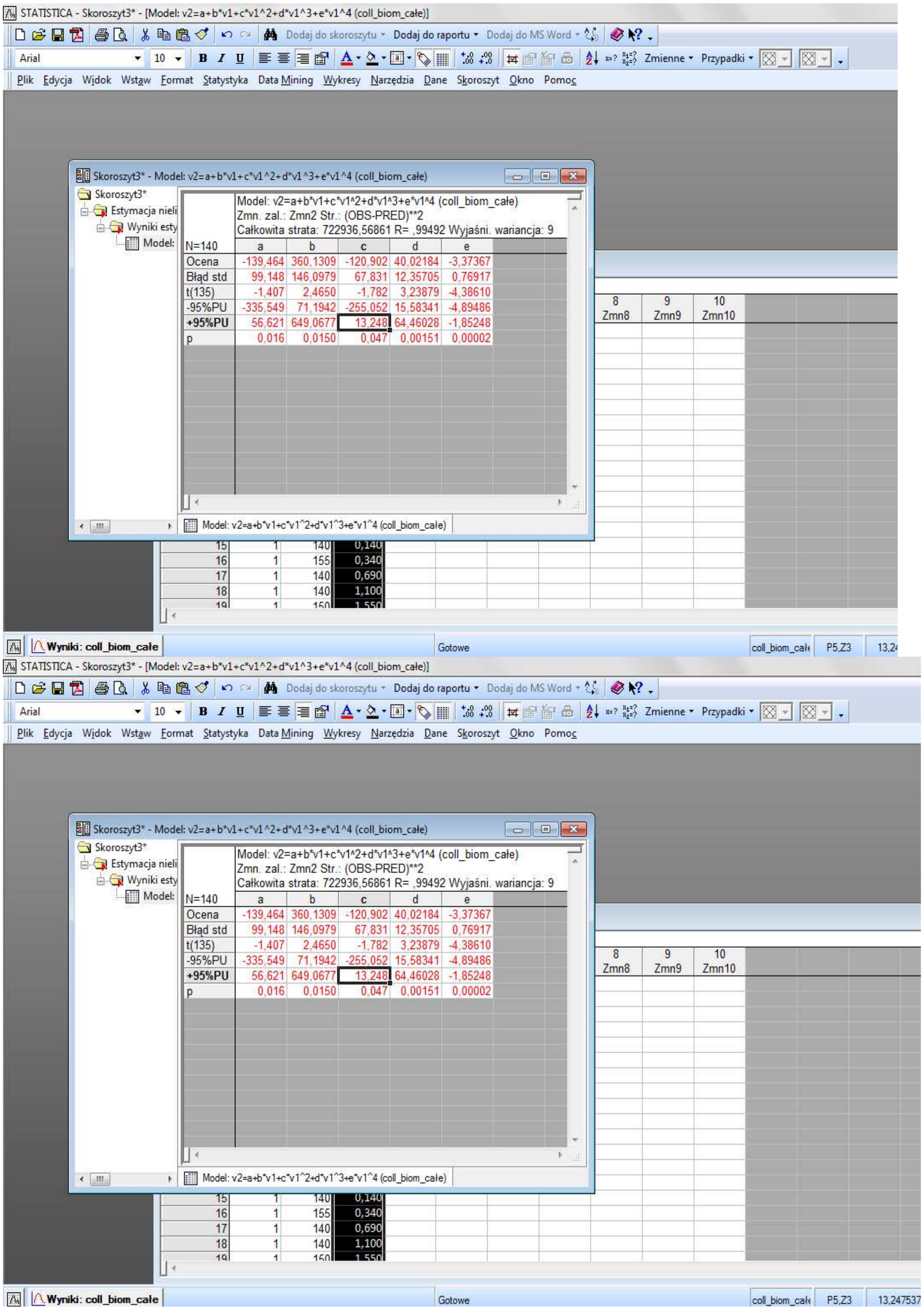


**Fig. 5.** Results spreadsheet for the polynomial function
Source: own calculations in Statistica 9.1

**Table 1.** Means ( $\bar{x}$ ), standard deviations (Sd), min., max., and numbers of estimations (n) for estimates of growth curve parameters using the quasi-Newton method

| Growth curve | Statistics of parameter estimates | Parameter estimate | | |
|---|---|---|---|---|
| | | **A** | **B** | **K** |
| Brody | $\bar{x}$ | 26436 | 1.017 | 0.019 |
| | Sd | 16093 | 0.008 | 0.008 |
| | min | 11862 | 1.01 | 0.01 |
| | max | 54689 | 1.03 | 0.03 |
| | number of estimations (n) | 9 | | |
| | for all 21 cycles | no result | no result | no result |
| Gompertz | $\bar{x}$ | 2922 | 4.928 | 0.412 |
| | Sd | 847 | 0.375 | 0.063 |
| | min | 2313 | 4.17 | 0.27 |
| | max | 5076 | 5.36 | 0.47 |
| | number of estimations (n) | 9 | | |
| | for all 21 cycles | **2781** | **4.87** | **0.42** |
| | | **A** | **K** | **M** |
| logistic | $\bar{x}$ | 4176 | 0.350 | 6.253 |
| | Sd | 807 | 0.044 | 0.159 |
| | min | 3260 | 0.29 | 6,11 |
| | max | 5386 | 0.41 | 6.55 |
| | number of estimations (n) | 7 | | |
| | for all 21 cycles | no result | no result | no result |

Source: own calculations.

**Table 2.** Means ( $\bar{x}$ ), standard deviations (Sd), min., max., and numbers of estimations (n) for estimates of coefficients of polynomial growth curves using the quasi-Newton method

| Specification | Free term | Coefficient preceding x | Coefficient preceding $x^2$ | Coefficient preceding $x^3$ | Coefficient preceding $x^4$ |
|---|---|---|---|---|---|
| $\bar{x}$ | -146.16 | 371.57 | -127.311 | 41.294 | -3.453 |
| Sd | 127.59 | 219.96 | 121.333 | 25.000 | 1.675 |
| min. | -342.86 | -37.28 | -310.42 | -0.61 | -6.17 |
| max. | 96.43 | 669.11 | 93.54 | 80.73 | -0.38 |
| Number of estimations | 21 | | | | |
| For all the 21 cycles | -139.46 | 360.13 | -120.90 | 40.02 | -3.37 |

Source: own calculations.

**Table 3**. Values of parameters of growth function curves for a randomly selected production cycle obtained using different estimation algorithms

| Growth curve | Estimation algorithm | Parameter estimate | | |
|---|---|---|---|---|
| | | **A** | **B** | **K** |
| Brody | 1. Simplex | 10.31 | -29.22 | -0.298 |
| | 2. Simplex and quasi-Newton | 10.31 | -29.22 | -0.298 |
| | 3. Hooke-Jeeves | 1.162 | -261.0 | -0.298 |
| | 4. Hooke-Jeeves and quasi-Newton | 1.162 | -261.0 | -0.298 |
| | 5. Rosenbrock | Unsuccessful estimation | | |
| | 6. Rosenbrock and quasi-Newton | Unsuccessful estimation | | |
| Gompertz | 1. Simplex | 1.585 | -5.397 | -0.044 |
| | 2. Simplex and quasi-Newton | 7.877 | -3.854 | -0.057 |
| | 3. Hooke-Jeeves | Unsuccessful estimation | | |
| | 4. Hooke-Jeeves and quasi-Newton | Unsuccessful estimation | | |
| | 5. Rosenbrock | Unsuccessful estimation | | |
| | 6. Rosenbrock and quasi-Newton | Unsuccessful estimation | | |
| logistic | 1. Simplex | 9.662 | -0.094 | -5.151 |
| | 2. Simplex and quasi-Newton | 9.662 | -0.094 | -5.151 |
| | 3. Hooke-Jeeves | 301.1 | -2.106 | -0.142 |
| | 4. Hooke-Jeeves and quasi-Newton | 303.9 | -5.584 | -0.053 |
| | 5. Rosenbrock | 1942 | 1.549 | 179.5 |
| | 6. Rosenbrock and quasi-Newton | 2795 | 0.486 | 6.682 |

Estimation of polynomial function parameters (Table 4) proved to be impossible for the Rosenbrock method as well as Rosenbrock and quasi-Newton method. When the remaining methods were applied, no significant parameter estimates of growth functions were found. What is more, substantial differences between the estimates obtained cast doubt on the reliability of the results.

**Table 4.** Values of polynomial function coefficients obtained by means of different estimation algorithms

| Estimation algorithm | Free term | Coefficient preceding x | Coefficient preceding $x^2$ | Coefficient preceding $x^3$ | Coefficient preceding $x^4$ |
|---|---|---|---|---|---|
| 1. | 86.26 | -8.610 | 48.30 | 11.59 | -1.738 |
| 2. | 92.90 | -8.790 | 51.05 | 10.80 | -1.669 |
| 3. | 370.9 | -462.3 | 275.3 | -32.19 | 1.100 |
| 4. | 406.8 | -502.6 | 286.8 | -33.14 | 1.100 |
| 5. | Unsuccessful estimation | | | | |
| 6. | Unsuccessful estimation | | | | |

An application of the quasi-Newton algorithm resulted in very different values of the parameter estimates A, B and K. Taking into account the fact that chicken rearing results for individual production cycles were similar, it is difficult to account for such results. An application of successive estimation methods yielded similarly different results. Moreover, the usefulness of these methods depended on the function calculated. It should be stressed that all the four coefficients of polynomial function were significant in one case only.

In the study by Ptak (1992), which compared 5 nonlinear models of growth curves reflecting the growth of calves raised in 10 countries, values of estimated parameters were similar but the author applied her own software.

## 4. Conclusions

The package Statistica v. 9.1 is equipped with a module for estimating function parameters defined by the user. This module can be applied to estimate parameters of growth curves and the polynomial function. However, the usefulness of this module for the rearing results of broiler chickens proved to be limited and the results obtained were not satisfactory.

An application of Statistica to estimate parameters of user's function should be considered with caution and taking a very critical approach. Depending on the numerical data, the estimation results obtained have got a completely different scientific and practical applicability. Without further research it is difficult to choose the best estimation method. It is equally difficult to attempt to determine which function best approximates the variation observed in the body weight of broiler chickens.

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