Random regression models, a novel approach to growth curves.

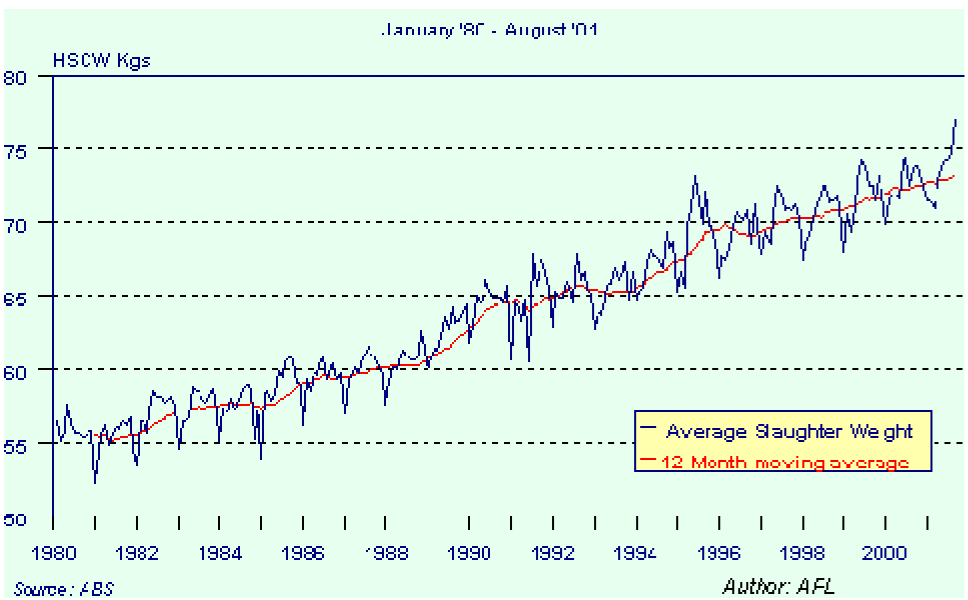
Abe Huisman

Animal Breeding and Genetics Group, Wageningen Institute of Animal Sciences, Wageningen University, P.O. Box 338, 6700 AH Wageningen, The Netherlands.

Why use a random regression model?

A pig changes over time: it puts on weight and eats more, as it becomes larger. Different pigs grow in a different manner. There is evidence that these differences in growth patterns between pigs are caused by genetic factors. This gives the opportunity to select for these different growth patterns, to better meet the demands of markets that differ in desired slaughter weight, eg Bacon, fresh pork, and Italian Parma ham. In Australia, slaughter weights have increased over the past two decades (Figure 1), and the trend is that slaughter weights will keep increasing. This development requires more knowledge on the latter part of the growth curve.

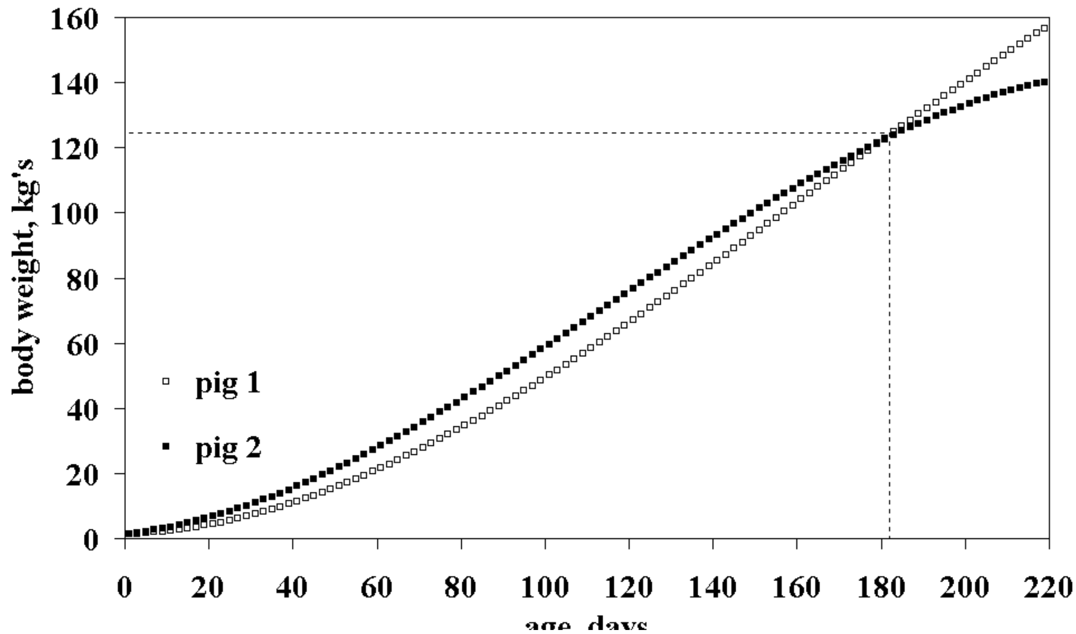
Figure 1. Average slaughter weight in Australia over the past 20 years



Selection of pigs' aims at improving economic efficiency of pig production per kg pork through improving leanness and feed efficiency of growing pigs. Selection of fattening pigs is usually based on performance measured until animals have reached the desired slaughter weight. Selection for higher leanness or improved feed efficiency during that period is expected to result in a correlated response in mature animals. Mature weight, and the ratio between mature body lipid and protein mass has decreased over the last decades, while growth rate increased over the same period of time (Knap, 2000). Altering the shape of the growth curve through selection might offer a solution for this.

In Figure 2 the growth curves of two pigs are plotted. Both pigs reach slaughter weight at the same age, but the pigs have different growth patterns. If future selection will be on

Figure 2. Different individual growth patterns of 2 pigs.



higher slaughter weights, Pig 1 will be the pig of interest, while Pig 2 already is starting to reach a plateau in growth rate after 180 days of age, Pig 1 still shows linear growth. Pig 1 is more likely to show more lean meat growth at a higher weight. If pigs enter the performance test at a certain weight instead of a certain age, Pig 2 will enter the test at an earlier age, but will only reach the desired slaughter weight at the same age as Pig 1.

Kirkpatrick et al. (1990) showed that changes with age could be represented as a function of time. Traditionally traits that are measured in time are analysed as separate traits, eg birth weight, weaning weight, slaughter weight. Correlations and covariances between these separate traits are than estimated with a multi-trait model. A random regression model can estimate the different weights (birth -, weaning -, slaughter -, and whatever weight we want to measure as well) as a function of time. Using a random regression model it is possible to calculate (co)-variances between the animals weight at every age or point in time. In comparison, to a multi-trait model a random regression model needs fewer parameters to describe the same data. Random regression models provide a method for analysing independent components of variation that reveal specific patterns of change over time.

In current breeding programs selection is based on growth and feed intake measured during a fixed weight or age interval. Differences between animals in performance patterns over time are not taken into account. The use of electronic feeder stations enables large scale collection of data on feed intake and growth curves and provides the necessary information for selection on growth or feed intake patterns.

What is the effect of measuring strategy on selection response?

The objective is to investigate the impact of different measurement strategies on response to selection in growing pigs. Live weights of animals were simulated over a 100-day test period. Genetic and environmental correlations are as plotted in Figure 3. The genetic correlation decreases linearly with an increase in time between measurements. For example, the genetic correlation is 0.995 for two days adjacent to each other. Two measurements taken 50 days apart have a genetic correlation of 0.75. Finally, weight measurements at the beginning of test (day 1) and at the end of test (day 100) have a genetic correlation of 0.50. Environmental correlation decreases exponentially with an increase in time between measurements. The environmental correlation is 0.97 between two adjacent days. Measurements taken 50 days from each other have an environmental correlation of 0.22. Weight measurements at beginning and end of test have an

Figure 3. Genetic and environmental correlation plotted against distance between days on test.

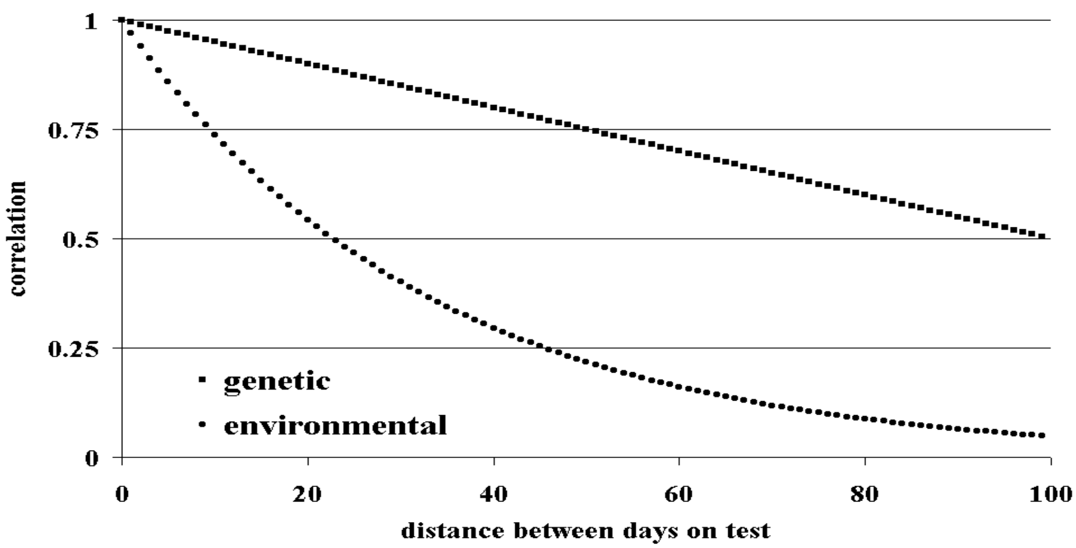
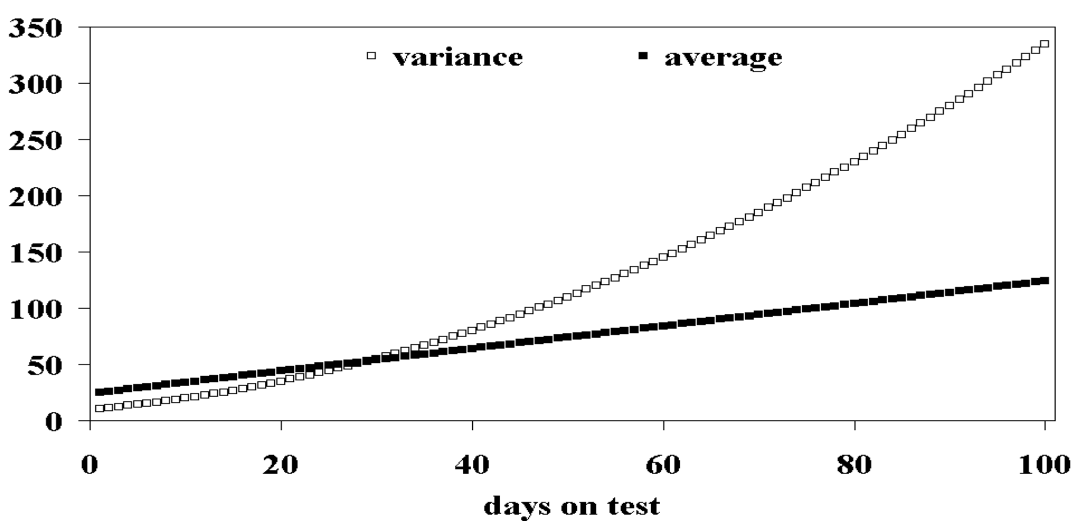


Figure 4. Variances of live weight and average live weight at days on test.



environmental correlation of 0.05. Total variances of live weight and average live weight at each day on test are plotted in Figure 4. The average live weight increases from 25 kg at first test day, through 125 kg at last test day. These correlations, and variances are based on the results of Huisman et al. (2001). Heritability was constant over the 100-days test period (0.33). Animals entered the testing period at day one, and were tested over a 100-day period.

Selection was based on the estimated breeding value for growth during the later part of the test period; that is growth from day 61 through day 100 on test. In each generation the best pigs were selected based on this estimated breeding value for growth to produce the next generation. This was done for 3 generations of selection, with 8 sires and 16 dams per generation; each sire-dam combination had 4 offspring available for selection to produce the next generation. After a new generation was created a random regression model was used to estimate breeding values. Fitting the random regression model resulted in 5 breeding values for each pig. The 5 breeding values were used to calculate a breeding value pattern for each pig over the 100-day test period. Where the first breeding value represents the mean, the second breeding value the slope, and the other 3 breeding values are used to bring some curvature in the breeding value pattern of each individual pig. These breeding values are not comparable with breeding values usually obtained; these breeding values are used as input for a function that describes the breeding value pattern over the 100-day test period. The breeding values for late growth were derived from the individual pig breeding value patterns.

Five different measurement strategies were applied:

→ Strategy 1: pigs were measured in 7-day intervals, starting day 1, ending day 100 on test, resulting in 14 measurements per pig. This strategy is consistent with information received from electronic scaling devices.

→ Strategy 2: pigs were measured on day 25, day 50, day 75, and day 100 on test, resulting in 4 measurements per pig.

→ Strategy 3: pigs were measured on day 25, day 50 and day 75 on test, resulting in 3 measurements per pig. This strategy represents the current measurement strategy of a Dutch pig breeding company.

→ Strategy 4: pigs were measured on day 25 and day 75 on test, resulting in 2 measurements per pig. This strategy represents the current measurement strategy of another Dutch pig breeding company.

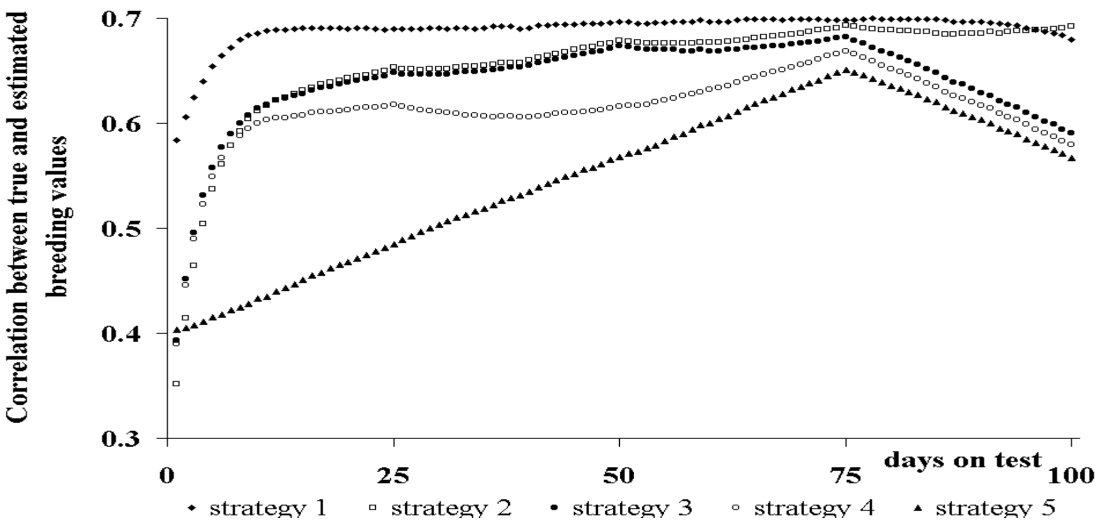
→ Strategy 5: pigs were measured only at day 75 on test, resulting in 1 measurement per pig. This strategy represents the most simple and straightforward measurement strategy.

The different measurement strategies are compared based on achieved genetic gain after 3 generations of selection, and how well estimated breeding values resemble true breeding values. True breeding values are the simulated breeding values, whereas estimated breeding values are the breeding values estimated with the data from the different measurement strategies applying a random regression model.

Effect of measurement strategy on selection response.

In a simulation study it is necessary to have a number of replicates to make results somewhat more reliable. Here the results are averaged over 200 replicates. In Figure 5 the

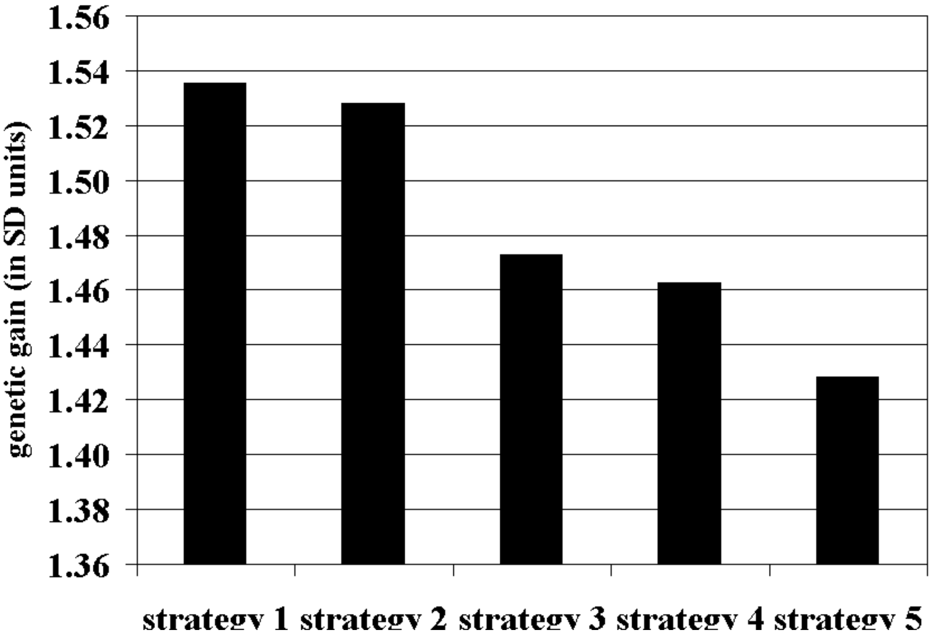
Figure 5. Correlation between simulated and estimated breeding values on each test day for the 5 measurement strategies.



correlations between the true breeding values and the estimated breeding values are plotted for each test-day. Correlations between true and estimated breeding values are highest for measurement strategy 1, when pigs are measured every 7 days. There is only a small difference between measurement strategy 1 and 2, which is at the beginning of the test when the correlation between true and estimated breeding values is somewhat lower for measurement strategy 2. This is because there are fewer measurements done for strategy 2. The correlations between true and estimated breeding values for strategies 2, 3, and 4 resemble each other. The difference between measurement strategies 2 and 3 is the decline in correlation after day 75 on test for measurement strategy 3, after which no measuring is done. Measurement designs 3 and 4 both show the decline in correlation between true and estimated breeding value after day 75 on test, for the same reason. In addition, strategy 3 has lower correlations between true and estimated breeding values between day 25 and day 75 on test, since it does not have information available at day 50 on test. For measurement strategy 5 the highest correlation between true and estimated breeding value occurs at day 75 on test, the day at which measurements are done. The decline in correlation between simulated and estimated breeding values with an increase in time away from day 75 on test represents the genetic correlation assumed (see Figure 3).

Achieved genetic gain after 3 generations of selection for late growth is highest for measurement strategy 1. Response to selection decreases with fewer measurements being taken (Figure 6). The difference between strategy 1 and 2 is very small -about 0.5%- because both measurement strategies have measurements over the whole test period, and the genetic correlation between days on test was very high. The response to selection for the other 3 measurement strategies is lower because there are not enough measurements done at the end of the test period.

Figure 6. Achieved genetic gain after 3 generations of selection for the 5 measurement strategies.



Conclusion and Discussion

In the case of selection for late growth, achieved genetic gain is lowest when only one measurement is done, and genetic gain is higher when measurements are taken more often. There is not much difference in achieved genetic gain when measuring on a 7-day interval or a 25-day interval, although estimating breeding values based on a 7-day interval will lead to more accurate breeding values. When selection is focussed on growth at the latter part of the growth curve, highest genetic gain is achieved when measurements are taken in that part of the growth curve. For the selection of pigs with a higher slaughter weight, highest genetic gain will be achieved when measurements are taken in that weight range.

Future research

Bunge Meat Industries (BMI) collects feed intake and weight data using electronic recording devices. For every pig each feeding event and at the same time its weight is recorded over an 8-week test period. The collected data shows that weight is increasing from 70 kg at beginning of test through 110 kg at end of test (Figure 7). Number of pigs is equal to 1586, number of weight recordings per day are in Figure 8. Number of weight recordings drops at the end of the test period. The previous results were all based on simulated data, but with the BMI-data the effect of measurement interval can also be studied using real data.

Figure 7. Average live weight and standard deviation of live weight for the 8-week test period of BMI collected data.

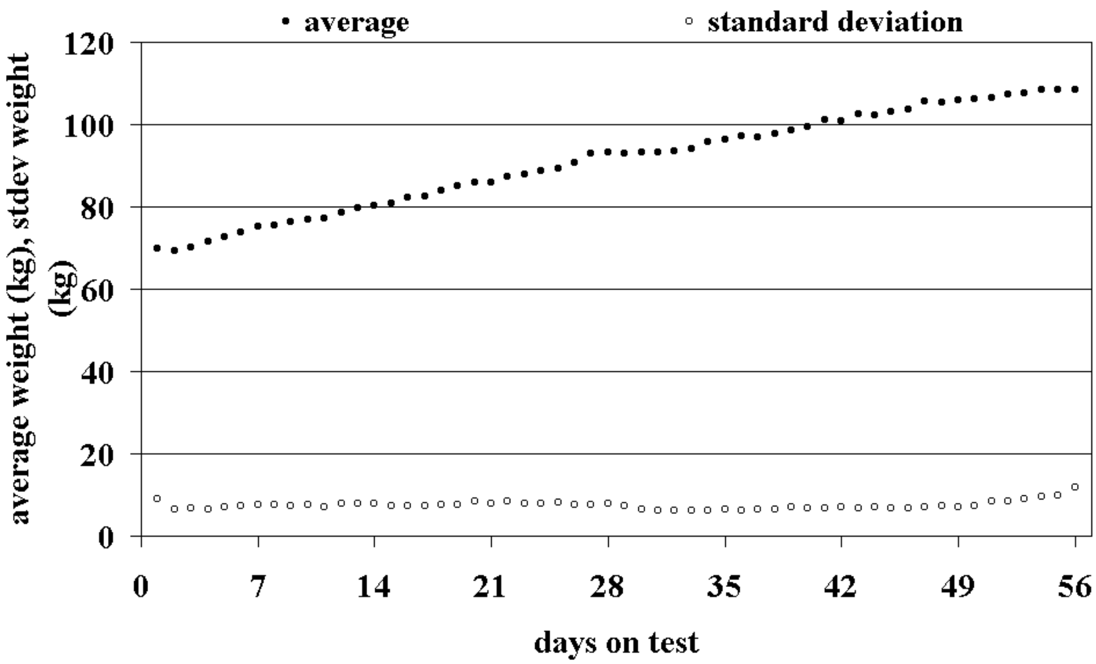
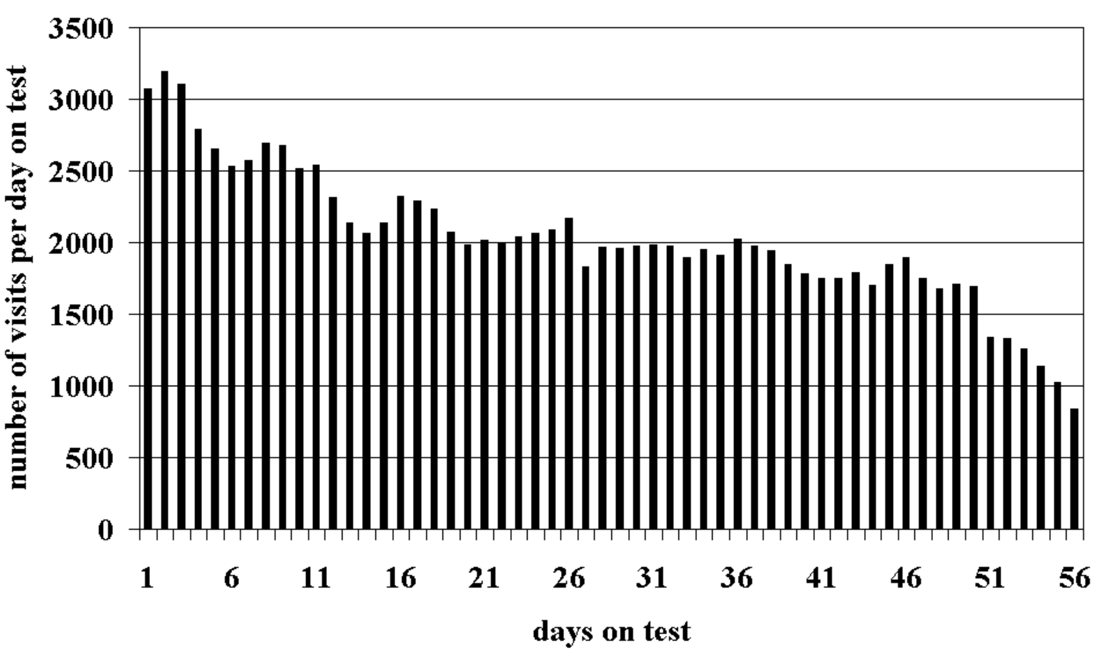


Figure 8. Distribution of weight recordings over days on test.



References

Huisman, A. E., R. F. Veerkamp, and J. A. M. van Arendonk. 2001. *Genetic parameters for different random regression models to describe weight data of pigs.* Journal of Animal Science 79(In press).

Kirkpatrick, M., D. Lofsvold and M. Bulmer. 1990. *Analysis of the inheritance, selection and evolution of growth trajectories.* Genetics 124: 979-993.

Knap, P. 2000. *Time trends of Gompertz growth parameters in 'meat-type' pigs.* Animal Science 70:39-49.