A Statistical Application in Biological Phenomena: The Use of Mixed Models in the Analysis of the Growth Curve of Beef Cattle and Feed Intake of Lactating Sows

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A Statistical Application in Biological Phenomena : The Use of Mixed Models in the Analysis of the Growth Curve of Beef Cattle and Feed Intake of Lactating Sows.

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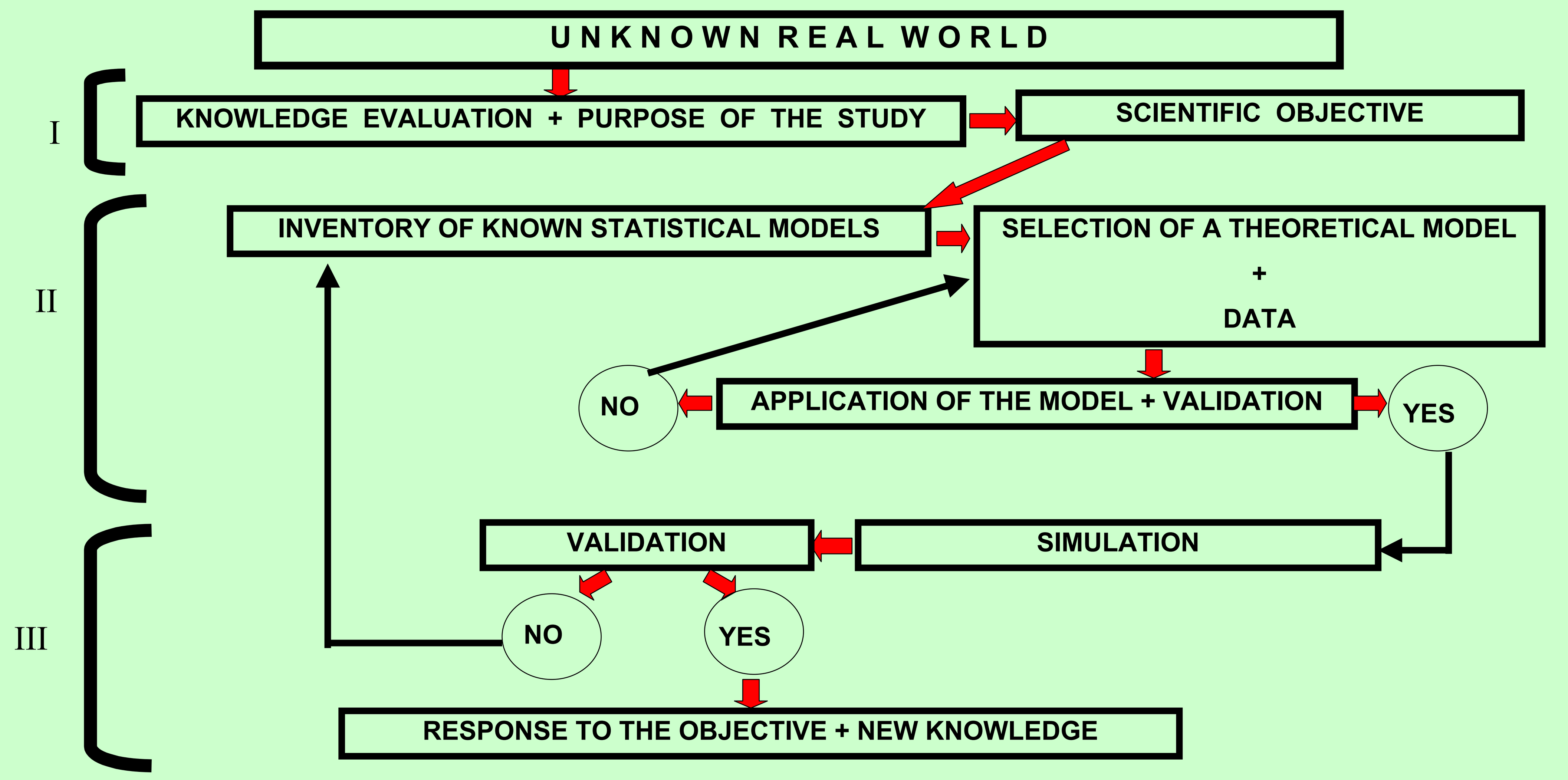
A biostastistical process



An introduction to Linear Mixed Model

Let y_i be the vector of n measurements on the same i^{th} of m individuals.

The linear mixed model is written as

$Y =$ fixed regressions ($X\beta$) + random part ($\varepsilon = Zu + W(t) + e$))

With $\varepsilon \sim N_{nm}(0, V(t,u))$ and $V(t,u) = ZGZ' + R$ where $R = \sigma^2 H + \tau^2 I$

where :

- X is the design matrix of fixed effects
- β is the unknown vector of fixed effects
- Z is the known design matrix of random effects
- u is the vector of unknown random-effects parameters
- W(t) is the unknow vector of serial correlation
- and e is measurement error.

Estimation :

- Likelihood-based methods provide estimation of G, R, β and u
- Estimation of β and u are the empirical best linear unbiased estimator (EBLUE) and best linear unbiased predictor (EBLUP)

Application : two zootechnical examples

Effect of breed (Creole vs. Large White) on lactating sow feed intake

Knowledge evaluation :

Genotype difference :

Prolificity : + LW sow (12 vs. 9 piglets/farrowing); **Adaptation to heat stress:** + CR sows (assumed).

Factors influencing feed intake (FI) during lactation :

Animal : breed, litter size, etc …; **Environmental :** temperature, humidity, etc..; **Dietary :** energy and protein contents, etc …

Purpose of the study :

Is sow feed intake pattern a good criteria to study heat stress tolerance in lactating sows?

Scientific objective : a descriptive purpose

Quantify the effect of genotype on feed intake during lactation

Model and data

Data : Daily feed intake (FI) performance from farrowing to 21 d post-partum in 35 Creole (CR) and 44 Large White (LW) lactating sows (225 lactations).

Model : Let y_{ijkl} be the observed value of FI of the sow j(i) of genotype i of the contemporary group l, taken in day k of lactation. Feed intake was expressed per metabolic weight and per one weaned piglet to take into account different maintenance and production requirements between CR and LW sows.

The mixed model is written as : $Y_{ijkl} =$ Fixed part $(\Sigma_m [(\beta_m + \delta_m)t_k^m]_{m=0,\dots,3})$ + Random part $(g_{j(i)} + r_i(t_k) + e_{ijkl})$

β is the fixed regression coefficients to fit mean FI pattern

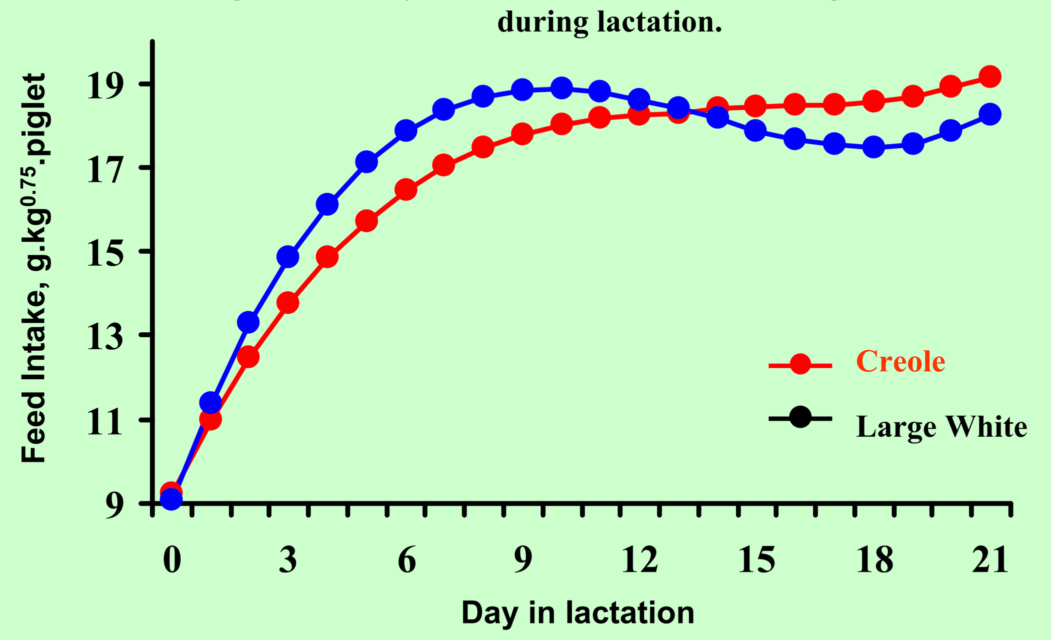
δ is the fixed parameters to fit the effect of breed on the mean curve

g is the random-effect associated with the animal (because a sow has several lactations); r is the random-effect associated with time t_k (because of correlation between measurements on the same sow at different times); e is the measurement error

Results and discussion

Genotype effect	Pvalue
δ_{0_i} deviation from the intercept	0.42
δ_{1_i} deviation from the linear parameter	< 0.001
δ_{2_i} deviation from the quadratic parameter	< 0.001
δ_{3_i} deviation from the cubic parameter	< 0.01

Figure 1a. Daily feed intake of Creole and Large White sows during lactation.



The intercept was the same in both breeds. Nevertheless, the differences were significant when the linear, quadratic and cubic coefficients were considered; so LW and CR sows have different feed intake pattern (Figure 1a). FI of LW sow was greater during the first two weeks post-partum, but it was lower at week 3 of lactation.

CR sows were able to increase their FI (and their heat production) as their requirements for milk production increased. At the opposite, it seems that LW sows needs more time for adaptation because their consumption decreased during the third week and increased after.

Estimation of genetic variability of Creole cow growth curve

Knowledge evaluation :

Factors influencing body growth of Creole cows :

•**genetic :** pedigree, **non genetic effect :** Management, environment, etc …

Selection criteria : Liveweight at 18 months of age (LW18).

Purpose of the study :

Is possible to make the selection at an earlier age than 18 months of age?

What is the level of relationships between selection criteria and liveweight at different ages?

Scientific objective : predictive purpose

Estimate genetic variability of growth parameters

Model and data

Data : Growth performance from birth to 10 years in 227 Creole cows (117 dams).

Model : Let y_{ij} be the j^{th} liveweight record for cow i taken at age t_{ij}.

The mixed model is written as : $Y_{ijkl} =$ Fixed part $(F_i + \Sigma_m (\beta_m t_{ij}^m)_{m=0,\dots,3})$ + Random part $(g(t_{ij}) + r(t_{ij}) + e_{ij})$

β is the fixed regression coefficients to fit mean growth curve

F_i is the fixed effect of mother calving number on growth on body weight at birth

g is the random-effect associated with the genetic additive effect

r is the random-effect associated with the permanent environment effect (non genetic variation due to the cow)

e is the measurement error

Results and discussion

Figure 1b. Heritability of liveweight of Creole cow.

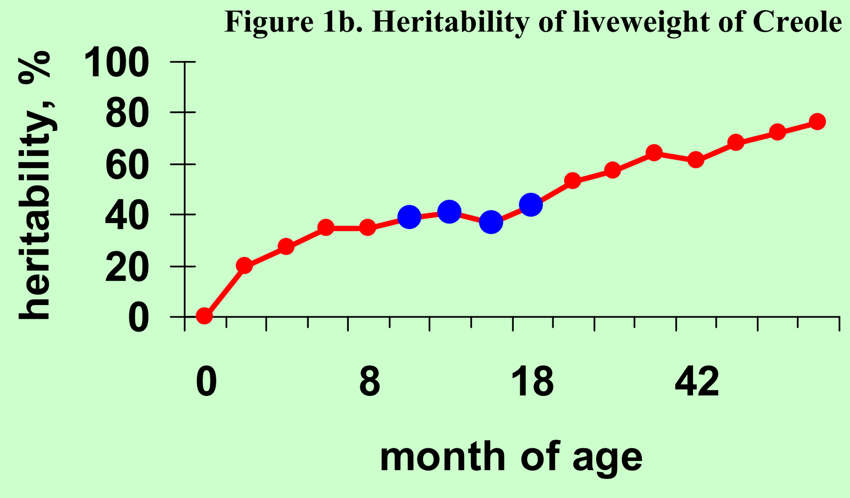
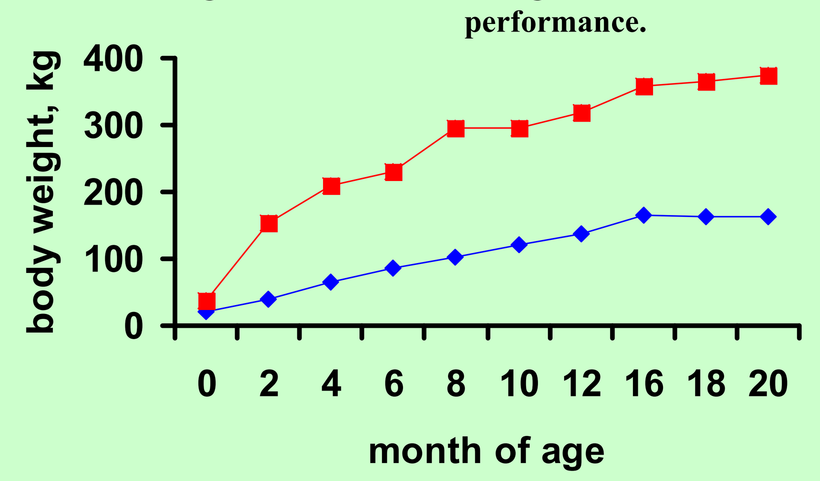


Figure 2b. Best and worst genetic Creole cow for growth performance.



Genetic correlation between liveweight at 10, 12 and 16 months of age and the selection criteria at LW18 are high (>0.84). We can estimate heritability h² (figure 1b) from the estimation of the additive genetic covariance function g. h² is the part of variance due to additive genetic component related to the total phenotypic variance. h² at 10, 12, 16 months of age (• in figure 1b) are to the same extent as heritability at 18 months of age (> 30%).**That means, selection for growth performance at 10 months of age is approximatively equivalent as selection at LW18.** This is illustrated in Figure 2b which presented the best genetic animal (in red) of the studied population and the worst cow (in blue) for growth performance criteria. The deviation at LW10 and at LW18 is 180 and 200 kg, respectively, and genetic part both represent 40 % in the deviation.

Conclusion

The use of linear mixed models, with random regression, is an answer to the difficulty in the choice of many statistical models in zootechnic area:

- Mixed models take into account random and fixed parts to provide good estimations (Best linear unbiased)
- They tend to be generally used in zootechnical research because characters of economical interest are often longitudinal data, that means repeated measurements on the same animal.