Estimation and Identifiability for a Dynamic Model of Maternal Nutrition and Fetal Growth in Sheep

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Abstract

The optimal maternal nutrition intake is extremely important in the second half of pregnancy for fetal development in mammals. It affects the health and wellbeing of the offspring. The purpose of this study was to determine the optimal daily nutrition intake for sheep during the second half of their pregnancy, to achieve a pre-determined desirable birth weight for lambs. By achieving the optimal birth weight, the postnatal development of the animals is likely to be improved.

In this study, pregnant sheep carrying singletons or twins were considered. There were two levels of nutrition, low and high. Various dynamic mathematical models were proposed to obtain the optimal daily nutrition intake. The model parameters were estimated by weighted least-squares. Bootstrap simulations were used to check the reliability of each estimated parameter. Finally, the optimal daily nutrition intake was obtained by solving the boundary value problems, with pre-determined parameter values.

The results suggested that the optimal daily nutrition intake for sheep in the second half of their pregnancy was a constant. For the particular breed of sheep, with target weight 6.5 kg for singletons, the optimal nutrition intake was 1.36 kg of dry matter per day. For twins, with a target weight of 12 kg, the optimal nutrition intake was 1.93 kg of dry matter per day. In addition, a comprehensive and generic 'black-box' algorithm was produced using the software MATLAB. It could return the optimal daily nutrition intake for any type of mammals given a time series of fetal weight and maternal nutrition.

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Glossary

BLUE	Best linear unbiased estimate
BVP	Boundary value problems
GLS	Generalised least squares
ODE	Ordinary differential equation
PCA	Principal component analysis
QQ Plot	Quantile-Quantile plot
SSE	Sum of squares of errors
WLS	Weighted least squares

a	A factor which influencing the 'carrying capacity' on historical intake	kg
b	The discount factor, which indicates that the cumulative intake is influenced by the past	day^{-1}
k_0	The basic component of the 'carrying capacity'	kg
L	The value of nutrition intake at which the per unit mass growth rate is half of the maximum	kg/day
L_0	The value of cumulative intake at which the influencing factor is half of its maximum	kg
r	The maximum per unit mass growth rate	day^{-1}
t	Time	day
u	The daily maternal nutrition intake	kg/day
x_0	The initial fetal weight at the start of the second half of pregnancy	kg
y	A cumulative nutrition intake	kg