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A computational model to predict lamb growth

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ABSTRACT

The algorithm for a Fortran program which simulates growth of a lamb is presented. The basis of the algorithm is the theory of growth and feed intake by Emmans. The advantages of the current algorithm are its simplicity, the few generalised equations and its easy use at any stage of the growth curve.

Keywords Model, lamb, growth, feed, energy, body composition, intake composition, gompertz function.

INTRODUCTION

A theory increases its usefulness when it can be expressed mathematically. This offers the chance to investigate the implications of the theory through simulation modelling and to test the theory through experimentation. Emmans (1984, 1985) has described a numerical method for predicting the energy requirements of ruminants and the energy content of feeds. The purpose of this project was to incorporate the ideas of Emmans into a fortran program for simulating the growth of lambs given feeds which are first limiting in energy.

METHODS

Emmans (1984) has described an available energy scale, (AVE), for feeds based on Armsby (1903). To derive the AVE content of a feed the heat lost in the production of faecal organic matter (FOM) and methane energy (MTHE) are deducted from the metabolisable energy (ME) content of the feed as follows:

$$AVE = ME - 3.9FOM - 0.66MTHE \quad \text{(Emmans,1984)} \quad (1)$$

Equation 1 has been demonstrated to be general for warm-blooded animals across diets.

The AVE requirements (AVER) of a growing animal are:

$$AVER = M + 51PR + 55LR \quad \text{(Emmans,1985)} \quad (2)$$

where M is the maintenance AVER (MJ/day), PR is the potential rate of protein growth (g/day) and LR is the potential rate of lipid gain (g/day) under non-limiting nutritional conditions (Cropper, 1989).

Emmans (1985) has explained that a maintenance unit is a $P(t)/P_m^{0.73}$ day, where P(t) is an immature protein weight and P_m is mature protein weight (kg); the potential rate of protein growth is described by a Gompertz function and the lipid weight is a log-log linear function of protein weight. Consequently, the predictions of AVER require the knowledge of four animal characteristics: mature protein weight (P_m,kg), a protein growth rate parameter (B, per day), a mature lipid:protein ratio (LPR_m, kg/kg) and an allometric rate fattening parameter (B,*). The equations are general and have been used to predict the feed intake of pigs (Emmans, 1986) and sheep (Emmans, 1987).

A Fortran program was written to predict the potential growth and voluntary feed intake of a lamb given non-limiting nutrition. A component to predict wool protein growth was added, on the basis that wool growth is allometric to body protein in the first year of life, (Cropper, 1987).

The program was later adapted to predict the response of lambs to limitations in energy supply. This assumed that protein supply was adequate and unaffected by energy intake which though an oversimplification of the situation, was more workable and held the possibility of yielding some unusual predictions.

To simulate the response of the lamb to restricted energy supply, the lamb was presumed to partition energy differentially with an order of priority to maintenance, body/wool protein growth and lipid gain. Mobilisation of lipid reserves to supply energy for maintenance and protein growth was incorporated and, when lipid reserves were exhausted mobilisation of body protein was allowed for a limited period.

The equations used were:

Potential protein weight

$$P(t) = P_m \exp\{-\exp[G_{po}-B(t+1)]\} \qquad (3)$$

Potential rate of protein growth (PR)

$$dP/dt = B.\log[P_m/P(t)].P(t) \qquad (4)$$

where:

$$B = B^*/(P_m^{0.27}) \text{ and } B^* = 0.0224 \qquad (5)$$

Similar equations were used to describe the weight and growth of lipid and wool. These were derived from the allometric relationships between protein, lipid and wool. The total available energy requirement (AVER) for this growth can be calculated as shown by Emmans (1985)

$$AVER = M + 51PR + 55LR\ (+51WR) \qquad (6)$$

Where +51WR is a wool protein extension component not included in Emmans work.

Assuming a diet limiting in energy the model limits the actual protein growth according to the energy available, the independent variable time is transformed

$t \rightarrow t_p$, then $P(t_p)$ is used to describe protein weight under limited intake conditions.

Energy for body/wool protein growth is partitioned according to the ratio for potential growth.

$$\text{Partitioning ratio } r = \frac{d_{Wl}/dt_{Wl}}{(d_{Wl}/dt_{Wl} + dP(t_p)/dt_p)} \qquad (7)$$

then

$$\text{body protein } [dP/dt_p] = (1-r).\text{total protein growth}$$

and

$$\text{wool protein } [d_{Wl}/dt_{wl}] = r.\text{total protein growth}$$

The full program written in Fortran is available on request from the authors.

RESULTS AND DISCUSSION

The model was proposed as a simple energy partitioning model which could examine growth and composition of animals under non-limiting or restricted energy supply.

The results of 3 simulations are presented in Figures 1-3:

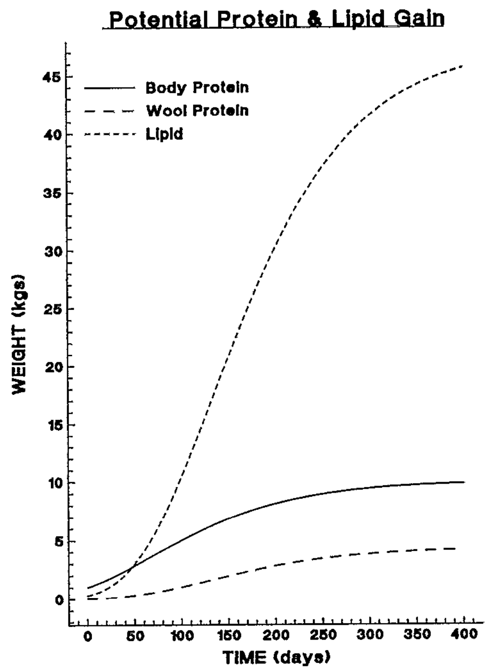

FIG 1 Changes in body composition of lambs during unrestricted growth.

Figure 1 depicts unrestricted growth. Expected body composition changes result (Cropper, 1989).

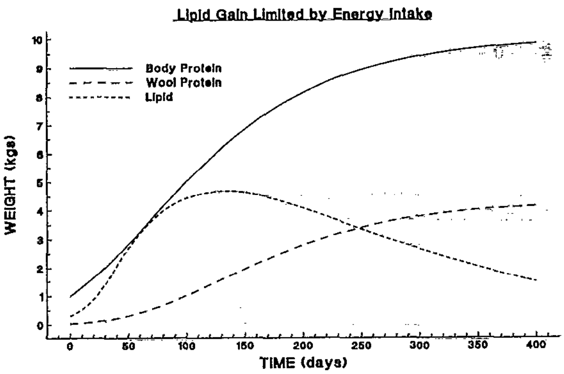

FIG 2 Changes in body compostion of lambs when growth is limited by a maximum feeding level of 12 MJ of ME.

In Figure 2, a maximum feeding level of approximately 12 MJME was set. Lambs under these conditions grew normally for a period but, as weight of the animal increased, energy intake was insufficient to meet maintenance, protein and lipid growth. In this situation lipid reserves were mobilized to meet the priority functions of maintenance and protein growth. The energy supply was however, sufficient to meet the animals requirement to reach a mature protein weight. The result was leaner than 'normal' carcases in the latter stages of this growth curve. Lipid growth declines and is mobilized at more extreme levels of undernutrition.

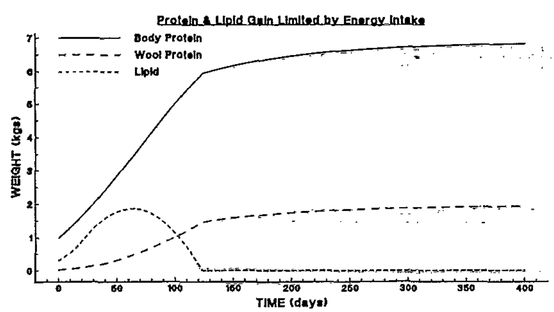

FIG 3 Changes in body compostion of lambs when growth is limited by a feeding level of 7 MJ of ME.

In Figure 3, a maximum feeding level of approximately 7 MJME was set. This was clearly insufficient for the animal to meet lipid or mature protein weight. As in the previous situation, lipid reserves are mobilized and marked changes from 'normal' body composition result.

More severe restriction or imposition of restricted energy supply at any stage of the growth curve can be simulated. These indicate situations where body protein and lipid reserves can be mobilized. Knowledge gained from the simulations can be applied to design experiments to test the theories of Emmans (1985, 1986) and to identify practical strategies to produce lean lamb of high carcase weight.

The model presented here has the advantage that it is simple to use and requires minimum data inputs. It is versatile and can readily incorporate new genotypes, a feature not available in current feeding tables in use in NZ. It can also predict potential growth rates of animals at any stage of growth for comparison with field or experimental growth rates.

The limitations of the model are that it does not take into account protein supply from various diets and that the mobilization of lipid is poorly represented. At present all lipid is mobilized before protein begins to be mobilized to meet maintenance requirement, a feature unlikely to occur. These features could be altered, but for the purpose of designing experiments to alter body composition through nutrition, the model has proved extremely useful.

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