Ann. Zootech., 1980, **29**, n° h. s., 123-126.

Appendix 1

A possible approach to the prediction of the composition and energy content of empty body gains in growing cattle

G. ALDERMAN

Ministry of Agriculture, London (UK).

The composition of empty weight gains in growing cattle is known to be affected by many factors including breed, sex, liveweight, maturity, rate of gain ; and less certainly, nature of the diet, particularly with regard to type and level of protein supplementation. Nevertheless, when predicting the rate of liveweight gain from a particular diet consumed by a defined animal, some type of function is required to describe the observed changes in body composition in relation to plane of nutrition.

Table 6.22 of the ARC Technical Review No. 2 Ruminants, 1965 contains a family of equations relating energy retention (Eg) to energy value (EVg) of liveweight gains. After conversion to empty body gains the equations can be represented accurately by one equation :

$$EVg\ (MJ/kg) = 6.9 + 0.3\ Eg + 0.019\ EBW \qquad (1)$$

where EBW is empty body weight, kg.

Another approach is given by the NRC (1976) which gives:

$$NEg\ (Mcal) = (0.05272\ G + 0.00684\ G^2)\ W^{0.75} \text{ for steers}$$

$$\text{and } NEg\ (Mcal) = (0.05603\ G + 0.01265\ G^2)\ W^{0.75} \text{ for heifers.}$$

where W is liveweight, kg.

Dividing through by gain (G) to obtain the energy value of gains and converting to joules, these become :

$$\text{for steers } EVg\ (MJ/kg) = (0.221 + 0.029\ G)\ W^{0.75} \qquad (2)$$

$$\text{for heifers } EVg\ (MJ/kg) = (0.234 + 0.053\ G)\ W^{0.75} \qquad (3)$$

Both these approaches only consider the energy retained as the factor determining the energy value of gains with a different relationship for heifers and steers in the NRC proposals and ignore the effect of amounts of protein available for gain upon the composition of the gain laid down. It seems evident that protein is the first limiting factor and that excess retained energy will be stored as fat.

If the assumption is made that the amount of protein laid down as gain can be predicted from dietary protein intake, by some such procedure as already exists for energy intake and energy stored, then the following statements are self evident :

Let P_g be protein gain, kg/*d*
and E_g be total energy stored, MJ/*d*
Then the net energy of protein gain $= 23.6 \times P_g$ (MJ/*d*)
therefore energy available for fat deposition $= E_g - 23.6\ P_g$ (MJ/*d*)
and the amount of fat formed (F_g) will be $\frac{(E_g - 23.6\ P_g)}{39.3}$ kg/*d*

TABLE 1

ENERGY VALUE OF STEER EMPTY BODY GAINS, MJ/kg

Energy stored MJ/day	Protein deposition g/day											
	25	50	75	100	125	150	175	200	225	250	275	300
2	14.1	7.3	-	-	-	-	-	-	-	-	-	-
4	26.1	14.1	9.6	-	-	-	-	-	-	-	-	-
6	-	20.3	14.1	10.8	8.7	-	-	-	-	-	-	-
8	-	-	18.3	14.1	11.4	9.6	-	-	-	-	-	-
10	-	-	22.3	17.2	14.1	11.9	10.3	8.9	-	-	-	-
12	-	-	26.1	20.3	16.6	14.1	12.2	10.6	9.5	-	-	-
14	-	-	-	23.3	19.1	16.2	14.1	12.4	10.9	9.9	-	-
16	-	-	-	26.1	21.5	18.3	15.9	14.1	12.4	11.2	10.3	-
18	-	-	-	-	23.8	20.3	17.7	15.7	13.8	12.5	11.5	9.6
20	-	-	-	-	26.1	22.3	19.4	17.2	15.5	13.8	12.6	11.9
25	-	-	-	-	-	27.0	23.7	21.1	19.0	17.2	15.5	14.6
30	-	-	-	-	-	31.3	27.7	24.7	22.5	20.3	18.3	17.2
35	-	-	-	-	-	35.4	31.5	28.2	25.5	23.3	21.0	19.8
40	-	-	-	-	-	-	34.9	31.5	28.6	26.1	23.7	22.3

$$\text{calculated from } EV_g = \frac{E_g}{(0.00525\ P_q + 0.0055\ E_g)} \quad \text{(MJ/kg)} \qquad (6)$$

TABLE 2

PREDICTED EMPTY BODY GAINS OF STEERS, kg/d

Energy stored MJ/day	Protein deposition g/day (P_g)											
	25	50	75	100	125	150	175	200	225	250	275	300
2	0.14	0.27	-	-	-	-	-	-	-	-	-	-
4	0.15	0.28	0.42	-	-	-	-	-	-	-	-	-
6	-	0.30	0.43	0.56	0.69	-	-	-	-	-	-	-
8	-	-	0.44	0.57	0.70	0.83	-	-	-	-	-	-
10	-	-	0.45	0.58	0.71	0.84	0.97	1.11	-	-	-	-
12	-	-	0.46	0.59	0.72	0.85	0.98	1.12	1.25	-	-	-
14	-	-	-	0.60	0.73	0.86	1.00	1.13	1.26	1.39	-	-
16	-	-	-	0.61	0.74	0.87	1.00	1.14	1.27	1.40	1.53	1.66
18	-	-	-	-	0.76	0.89	1.02	1.15	1.28	1.41	1.54	1.67
20	-	-	-	-	0.77	0.90	1.03	1.16	1.29	1.42	1.55	1.69
25	-	-	-	-	-	0.93	1.06	1.19	1.32	1.45	1.58	1.71
30	-	-	-	-	-	0.96	1.08	1.22	1.35	1.48	1.61	1.74
35	-	-	-	-	-	0.99	1.10	1.24	1.37	1.51	1.64	1.77
40	-	-	-	-	-	-	1.15	1.27	1.40	1.53	1.66	1.80

calculated from $EBG = 0.00525\ P_g + 0.0055\ E_g$ (kg/day) (5)

In order to predict liveweight gain, information is needed on how much water will be associated with the amounts of protein and fat formed. From a consideration of the tabulated ranges of empty body composition (ARC, 1980) it was evident that fat and water are inversely and highly correlated, contrary to the usual argument that protein and water are in nearly constant ratio :

$$\text{Water (g/kg)} = 814 - 0.96 \text{ Fat (g/kg)} \quad (r = 0.993) \tag{4}$$

This relationship can be expanded to cover any rate of empty body gain (EBG) if the amount of fat formed per day is known (F_g) as follows:

$$\text{Water (kg/}d\text{)} = 0.814 \text{ EBG} - 0.96 \text{ } F_g$$

Substituting for F_g in terms of energy and protein stored per day we have

$$\text{Water (kg/}d\text{)} = 0.814 \text{ EBG} - \frac{0.96 \text{ } (E_g - 23.6 \text{ } P_g)}{39.3}$$

Now predicted empty body gain, $\text{EBG} = P_g + F_g + W_g$ (kg/d)

$$\text{Substituting, EBG} = P_g + \frac{(E_g - 23.6 \text{ } P_g)}{39.3} + 0.814 \text{ EBG} - \frac{0.96 \text{ } (E_g - 23.6 \text{ } P_g)}{39.3}$$

$$\text{Rearranging EBG } (1 - 0.814) = P_g + \frac{0.04 \text{ } (E_g - 23.6 \text{ } P_g)}{39.3}$$

$$\text{Dividing out EBG} = 5.25 \text{ } P_g + 0.0055 \text{ } E_g \text{ (kg/day)} \tag{5}$$

This equation is subject to the constraint that $E_g > 23.6 \text{ } P_g$ but also to the fact that minimum amounts of fat are laid down with protein depending upon breed age, sex etc.

It follows that the energy value of EB gains will be given by:

$$EV_g = \frac{E_g}{\text{EBG}} \text{ MJ/kg} = \frac{E_g}{5.25 \text{ } P_g + 0.0055 \text{ } E_g} \text{ MJ/kg}$$

$$\text{or if protein gains are as g/day } EV_g = \frac{E_g}{0.00525 \text{ } P_g + 0.0055 \text{ } E_g} \text{ MJ/kg} \tag{6}$$

Values for EV_g from equation (6) are given in Table 1, and predicted empty body gains, EBG, from equation (5) in Table 2. Values in Table 1 are limited to those known to have been recorded, but the sensitivity of energy value of gains to changes in amounts of protein deposited per day is notable.

The effect of sex or hormone treatment has been estimated to be $\pm$ 15 per cent of the values for steers i.e. heifers energy values will be + 15 per cent and bulls — 15 per cent of the values in Table 1. By inspection it can be seen that this effect only requires a change in protein deposition of $\pm$ 30 g/d for the change steer to bull or steer to heifer at weight gains of the order of 1 kg/d. This underlines the sensitivity of weight gains and feed conversion efficiency of the amount of protein deposited per day in the growing animal.

In addition, inspection of Table 2 shows the insensitivity of weight gains to change in energy retention *if protein gain remains constant,* or changes relatively little as appears to be the case with some continental breeds with a high capacity for protein deposition. It follows logically from the relationship derived as equation (4) above, suggesting almost equal weight for weight replacement of fat by water.

Whilst this approach does not solve the problem of predicting energy value of empty body gain, it does suggest that attention must be focused on the amounts of protein deposited per day and the need to quantify breed, age and dietary effects. The effects of sex and energy retention are secondary to these main determinants.

References

ARC, 1975. *The Nutrient Requirement of Farm Animals,* Technical Review No. 2, Ruminants, Agricultural Research Council, London.

NRC, 1976. *Nutrient Requirements of Domestic Animals* No. 4, Nutrient Requirements of Beef Animals, 5th revised edition, National Academy or Sciences, Washington DC.

ARC, 1980. *The Nutrient Requirement of Farm Animals,* Technical Review by the Agricultural Research Council, Working Party, 1980. Commonwealth Agricultural Bureau, UK.