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COMPUTER SIMULATION OF THE FEED REQUIREMENTS OF SHORN SHEEP

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INTRODUCTION

RESEARCH in animal production is undertaken to provide information which will allow the prediction of animal performance for a given set of conditions. Thus the energy and protein requirements of domestic ruminants have traditionally been determined from feeding trials in which the performance of a particular class of animal is related to variations in dietary components under defined conditions. However, it is virtually impossible to cover in this way all the situations likely to be encountered in the field. This problem may be overcome by using dynamic computer models which allow for the effects of variation in conditions by expressing the complex of interactions between the animal, its diet, its physiological state, and the environment as a series of equations which represent either the actual metabolic processes involved or the input/output relationships determined experimentally. Such models can provide, in addition to predictions of performance under any particular conditions, a means of assessing the determinants of the system.

In this paper, a deterministic computer model, based on well-known empirical relationships (Graham *et al.*, 1976), is described briefly and is used to explore the effects of shearing on the feed requirements of sheep.

THE MODEL

To operate the model, the computer requires information to define the environmental conditions, the diet and the state of the animal at the beginning of the simulation. If specific relationships are available for the particular diet or conditions to be used in the simulation, these should be substituted for the general equations used in the model. The computer then calculates, for one day, the metabolizable energy available from milk and/or dry feed, and energy balance is obtained by deducting the animal's

maintenance requirements, including the cost of feeding, walking and homeothermy in the cold. The extra heat production due to cold stress is calculated from the fraction of each day during which the ambient temperature is below the lower critical temperature (that ambient temperature below which heat production must be increased to maintain body temperature) and the mean temperature for that period; allowance is made for the level of feeding and surface area of the sheep and the insulation of its fleece. The amount of amino acid nitrogen absorbed from the small intestine is estimated and allocated to body tissues and wool, making allowance for body weight, net energy intake and, when necessary, conceptus growth or milk production. The storage of energy in tissue protein is obtained and any energy surplus or deficit is set against fat reserves. Finally, change of empty liveweight is derived as the sum of fleece growth, conceptus growth and gain or loss of fat and protein (plus associated water and ash). Age, body fat, body protein, fleece and empty liveweight are then incremented before repeating the calculations for another day.

EFFECT OF SHEARING ON THE FEED REQUIREMENT OF SHEEP

When sheep are shorn and subjected to inclement weather conditions they must increase their heat production in order to maintain body temperature. To do this they must mobilize body energy reserves and/or increase feed intake. Under some conditions sheep cannot increase heat production sufficiently, or maintain the increase in heat production long enough, so that substantial off-shears losses occur. In order to provide a basis for management practices that will reduce off-shears cold stress to a minimum, the effects of shearing on heat production, endocrine function, feed intake and feed requirement have been studied by many workers both in the laboratory and in the field (*e.g.*, Graham *et al.*, 1959; Coop and Drew, 1963; Wodzicka-Tomaszewska, 1964; Anonymous, 1968; Farrell and Corbett, 1970; Donnelly *et al.*, 1974; Elvidge and Coop, 1974).

The results obtained in these experiments are quite variable because the conditions to which the sheep were exposed differed between experiments. However, the computer model outlined above integrates what is known of the reactions of sheep to cold stress so that it can be used to explore the effects of shearing sheep differing in liveweight, age or physiological state, and subject to any given set of temperature and wind conditions. It cannot take into account the effects of rain or of solar radiation on

the heat exchanges of the exposed sheep because the appropriate equations have not yet been derived. Two simulations will be described, one for a non-pregnant, non-lactating sheep under two different temperature regimes, and the second for ewes in mid-pregnancy.

(a) *First Simulation*

The first simulation was for a 3-year-old sheep of 50 kg empty liveweight, exposed to a wind of 2 m/s and each of two temperature ranges, 16.6° C max./8.3° C min. (mean annual temperatures at Palmerston North (Anon., 1975)) and 8.3° C max./0° C min., and given a diet of white clover with a crude protein content of 26% and dry matter (DM) digestibility of 74.6%. It was assumed that feeding and ruminating times were, respectively, 5.3 and 4.2 h/kg DM intake (Black *et al.*, 1976) and that the sheep walked 1 km per day. For the calculation of non-ammonia nitrogen absorption from the small intestine, equation 4 in Graham *et al.* (1976) was replaced by the equation of MacRae and Ulyatt (1974). The model predicted that 650 g DM/day of this white clover was sufficient to maintain empty liveweight in the absence of cold stress. The predicted effects on lower critical temperature

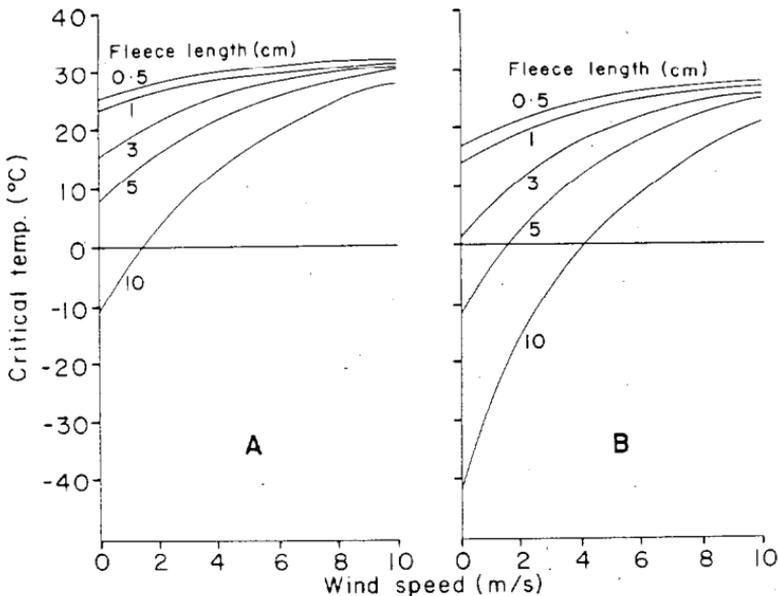


FIG. 1: Predicted lower critical temperature for a 3-year-old sheep of 50 kg empty liveweight given a diet of white clover sufficient to maintain liveweight (A) and at twice that level (B).

of wind speed and fleece length at maintenance and twice maintenance levels of feeding are shown in Fig. 1. The marked effect of wind in reducing the insulation afforded by the fleece is clear and it can be seen that temperatures below $\sim 25^{\circ}\text{C}$ and $\sim 17^{\circ}\text{C}$ in still air would be sub-critical for a shorn sheep (fleece length ~ 0.4 cm) fed at maintenance and twice maintenance levels, respectively. In a light wind (2 m/s), the lower critical temperatures were predicted to rise to, respectively, 28 and 22°C .

When simulating the effects of shearing, it was assumed that residual fleece weight was 150 g (equivalent to a fleece length of 0.45 cm). Then, for the hypothetical sheep described above and given white clover at 650 g DM/day, it was predicted that empty liveweight would fall by 5.7 kg in 8 weeks when wind speed was 2 m/s and the temperature ranged from 16.6 to 8.3°C each day, and by 9.6 kg when the temperature range was 8.3 to 0°C (Fig. 2). The additional energy expenditure due to cold stress is shown in Fig. 3. The metabolizable energy requirement for maintenance on the day of shearing was 98% higher than on the day before shearing in the milder conditions and 150% higher in the colder conditions.

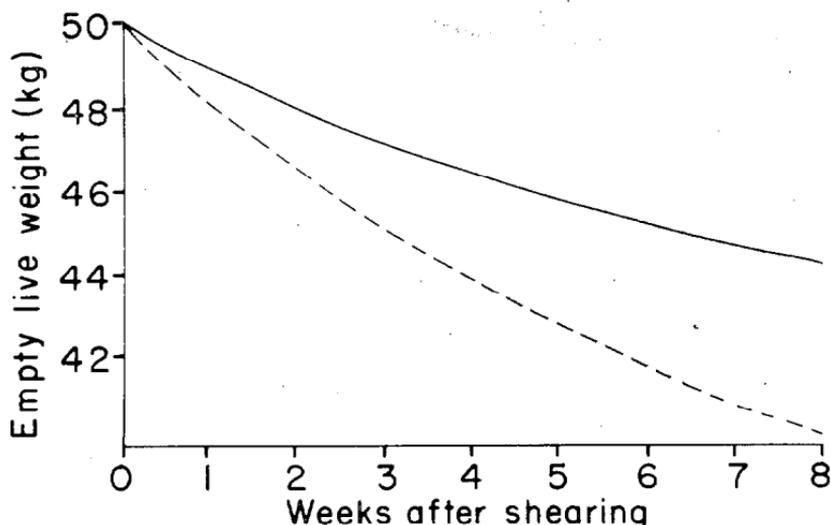


FIG. 2: The predicted effect of shearing on the empty liveweight of a 3-year-old sheep, given white clover at 650 g DM/day containing 26% crude protein and with DM digestibility 74.6%. It was assumed that the times spent eating and ruminating were, respectively, 5.3 and 4.2 h/kg DM and that the sheep walked 1 km/day. Wind speed was 2 m/s and daily max./min. temperatures were 16.6/8.3°C (—) and 8.3/0°C (---).

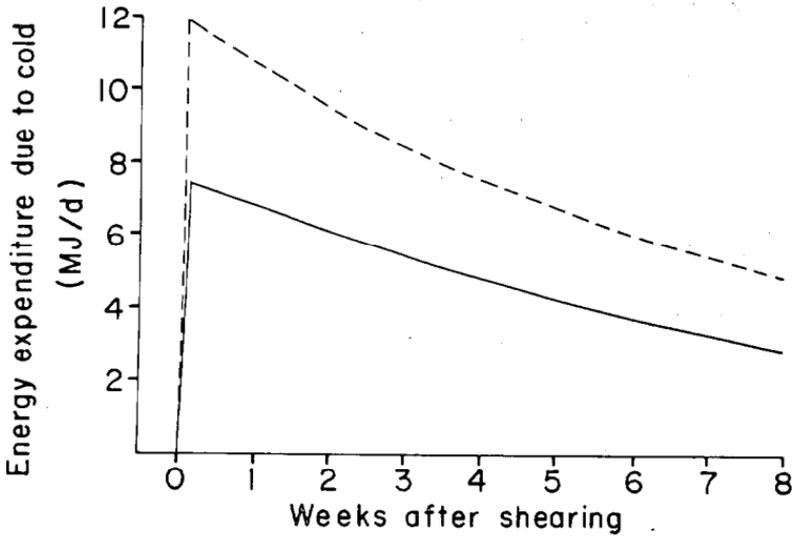


FIG. 3: Additional energy expenditure due to cold stress after shearing (for details of sheep, diet and climate, see Fig. 2).

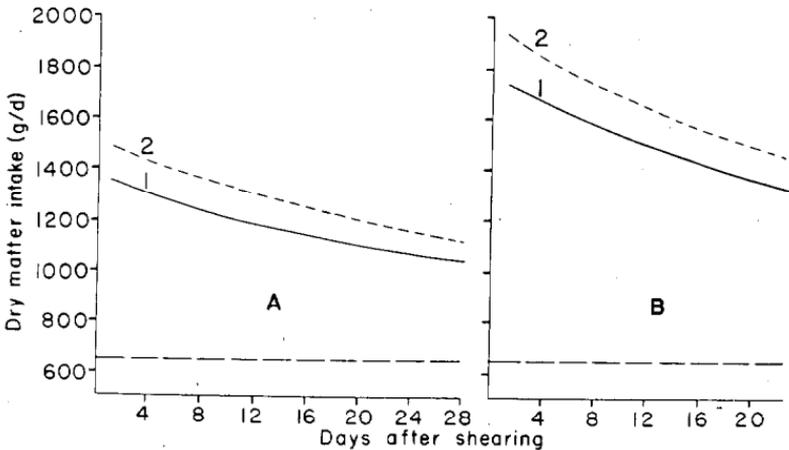


FIG. 4: The feed requirement (g white clover DM/day) for maintenance of empty body weight before shearing (---) and of empty body weight (1) and body energy (2) of the sheep described in Fig. 2. Daily max./min. temperatures were 16.6/8.3°C (A) and 8.3/0°C (B) and wind speed was 2 m/s.

The model was then used to calculate the intake of white clover that would be required for maintenance for the first 4 weeks after shearing (Fig. 4). Compared with the day before shearing, the sheep required 2.08 times as much dry matter on the day of shearing in the milder conditions, and 2.68 times as much in the colder conditions, to maintain empty liveweight. It can be seen from Fig. 4 that more feed was required to maintain tissue energy reserves than was needed to maintain empty liveweight. This is a consequence of the assumption in the model that nitrogen metabolism is not affected by cold stress (Graham *et al.*, 1959; Thompson *et al.*, 1975) and implies that, when empty liveweight is being maintained, loss of body fat is balanced by gains in body lean — *i.e.*, body composition is changing.

(b) *Second Simulation*

For the second simulation, an attempt was made to simulate the third experiment reported by Elvidge and Coop (1974) in which Romney ewes about 5 years old were penned, both outdoors and in a sheep shed on gratings 2 m above ground level, for eight weeks from the 52nd day of pregnancy. Some animals were shorn at the beginning of the experiment and again after 4 weeks and others were left unshorn. The data describing the initial conditions for the sheep, the composition of the diet and the environmental conditions are listed in the footnotes to Table 1 and were obtained from the original publication and Elvidge (*pers. comm.*). For this simulation, the original equation for

TABLE 1: THE EFFECT OF SHEARING ON LIVWEIGHT CHANGES (kg/d) IN PREGNANT EWES¹

Site	Unshorn		Shorn	
	Observed ¹	Predicted	Observed ²	Predicted
Indoors ²	0.02	0.06	— 0.07	— 0.08
Outdoors ³	0.02	0.02	— 0.15	— 0.15

¹ 5-year-old (Romney) ewes, initially 53 kg empty liveweight, 52 days pregnant, carrying 1.8 kg wool and given 680 g dry matter per day (digestibility 72%) containing 13.8% crude protein; eating and ruminating times, respectively, 5.3 and 4.2 h/kg dry matter.

² Sheep shed with grating floor 2 m above ground; diurnal temperature range 12.0 to 4.0° C; assumed still air (0.1 m/s).

³ Diurnal temperature range 13.2 to 1.9° C; daily wind run 200 km (2.31 m/s).

⁴ Elvidge and Coop (1974), experiment 3.

absorbed non-ammonia nitrogen was retained (equation 4, Graham *et al.*, 1976).

In Table 1, the liveweight changes observed by Elvidge and Coop (1974) are compared with the predicted values. The predicted values for the sheep penned outdoors were the same as the observed values but there were small differences in the values for the sheep held indoors. Given the accuracy of the prediction for the outdoors sheep, it seems likely that there was considerable air movement indoors rather than still air as assumed in the simulation. The calculated lower critical temperatures for the unshorn sheep were lower indoors than outdoors (Table 2),

TABLE 2: PREDICTED LOWER CRITICAL TEMPERATURES FOR SHORN AND UNSHORN PREGNANT EWES¹

Site	Day after Shearing	Lower Critical Temperature (°C)	
		Unshorn	Shorn
Indoors	1	8	27
	7	8	26
	28	6	23
Outdoors	1	18	29
	7	18	29
	28	16	27

¹ See Table 1 for details.

and the predicted liveweight changes reflect this. By contrast, their observed liveweight changes were the same both indoors and outdoors which is consistent with the indoor environment being more stressful than was assumed.

The feed requirements of the sheep penned outdoors are shown in Table 3. Empty liveweight gain includes growth of the foetus and of wool so that maintenance of empty liveweight involves the loss of body tissue by the ewe. Thus the feed requirement for maintenance of empty liveweight is considerably less than that for maintenance of the ewe's body (a parameter that cannot be observed in the field) both before and after shearing. The model predicted that the feed requirement for maintenance of empty liveweight increased by a factor of 2.22 for the first 4 weeks after shearing which compares well with the value of 2.12 calculated by Elvidge and Coop (1974) from their liveweight and liveweight change data on the assumption that each kg of liveweight change was equivalent to 2.0 kg digestible organic matter.

TABLE 3: FEED REQUIREMENT CALCULATED FOR PREGNANT EWES PENNED OUTDOORS¹

	Period after Shearing (days)			
	0-7	0-28	28	Unshorn 0-28
Dry matter intake ² (g/day) required to:				
(a) Achieve maintenance of				
Empty liveweight	1540	1355	1146	610
Fleece-free ewe body	1710	1542	1368	890
Ewe tissue energy	1880	1680	1468	915
(b) Equal unshorn performance for				
Empty liveweight	1595	1408	1200	680
Fleece-free ewe body	1552	1380	1205	680
Ewe tissue energy	1692	1495	1290	680

¹ See Table 1 for details.

² Digestibility 72%, crude protein content 13.8%.

DISCUSSION

The computer model described by Graham *et al.* (1976) provides a means of exploring the effects of shearing on the feed requirements of sheep in more detail than is possible by direct experimentation. Validation of the model (Table 1) allows some confidence to be placed in the estimates of feed requirements. It is then a simple matter to provide estimates for sheep of any age, liveweight and physiological state exposed to any desired combination of temperatures and wind speed. By contrast the results of experiments such as that of Elvidge and Coop (1974) cannot be applied to other conditions. It should be borne in mind that the predictions made by the model represent acute cold stress under dry conditions and it is not yet possible to account quantitatively for acclimatization to cold. However, to the extent that acclimatization involves an increase in basal metabolic rate (Webster *et al.*, 1969) and in the ability to maintain high rates of heat production for extended periods (J. W. Bennett, pers. comm.) it should not affect the estimates of feed requirement for maintenance in the first week or so after shearing when the temperature was sub-critical all day (Tables 1 and 2).

Although the feed requirement for maintenance increases as soon as the sheep is shorn, studies of voluntary feed intake after shearing indicate that it does not increase immediately but increases steadily, reaching a peak in about 3 to 4 weeks and then declining (Wodzicka-Tomaszewska, 1964; Weston, 1970; Donnelly *et al.*, 1974). It is clear that sheep cannot increase their

voluntary intake rapidly enough to meet the increase in energy requirement immediately after shearing in cold conditions. Therefore, if such conditions are likely at shearing time, the plane of nutrition of sheep due to be shorn should be increased as much as possible for a week or two prior to shearing.

Although empirical models, such as the one used here, are useful for assessing such things as the effects of increased energy expenditure on growth and body composition and the reasons why pastures of white clover support higher growth rates in weaned lambs than do perennial ryegrass pastures (Black *et al.*, 1976), they are valid only for the conditions under which the original relationships were obtained. Mechanistic models are needed which integrate the metabolic and physiological processes that occur within the animal so that not only the magnitude but also the mechanism of responses to manipulations of the animal and its environment can be evaluated.

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