LIVESTOCK FEEDING SYSTEMS AND THE THERMAL ENVIRONMENT

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SUMMARY

In devising management and feeding systems for ruminants kept in thermally stressful environments the classical temperature-metabolic rate model is insufficient to adjust for thermal effects. For ruminants kept in natural environments the thermally-induced adaptive changes in metabolic and digestive functions have significant influence. Adjustments are suggested for incorporation in practical livestock feeding systems.

INTRODUCTION

The need to establish an Australian national feeding system for livestock was discussed at previous conferences of this society (Pryor 1980). Livestock feeding systems are usually based on measurements from animals in protected environments and, unless means for adjusting for variations in the environment are incorporated, may be somewhat inappropriate in practical farming situations where animals are subjected to the naturally occurring environment. This paper examines the classical temperature-metabolic rate model and suggests possible avenues for incorporating adjustment factors into ruminant feeding systems to account for the influence of the thermal environment.

TEMPERATURE-METABOLIC RATE

(i) Classical model The model often used to describe the effects of the thermal environment on livestock is the relationship between an expression of effective ambient temperature and metabolic heat production. The model relies on the premise of a zone of thermoneutrality (TNZ) wherein, by definition, an animal's metabolic heat production is constant and independent of ambient temperature. Above and below the TNZ the animal's heat production becomes increasingly dependent upon ambient temperature. The lower limit of the TNZ is called the lower critical temperature (LCT) and is defined as the temperature below which the animal must increase its rate of metabolic heat production by cold induced thermogenesis to maintain homeothermy. Similarly, there is an upper critical temperature (UCT) above which the animal expends energy to avoid an unacceptable rise in body temperature. Experimental support for the model has been achieved in research laboratories through short-term calorimetric studies on sheep and cattle, wherein it has been shown that a variety of factors, including animal age, type, weight, hair coat depth and level of feeding, have a marked influence on TNZ, UCT and LCT (see Webster 1976 and Blaxter 1977).

From the considerable research on cold-exposed animals, the LCT expressed in terms of effective still air temperature can be predicted from an animal's liveweight, thermoneutral rate of heat production and thermal insulation (Young 1975a; Webster 1976; Blaxter 1977). Typical estimates of LCT for young lambs and calves are about 10°C and decrease as the animal grows. Values for dry and pregnant cows in temperate winter environments are between -10° and -20°C, while values for high-producing dairy cows and grain-fed animals range from -20° to -40°C. Similarly, estimates for fully-fleeced sheep are also very low (-20° to -30°C) whereas shortly after shearing the estimated LCT may be +20°C or above.

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(ii) Field application Estimates of TNZ and critical temperatures have proved useful in the design of animal housing and in practical husbandry decisions involving the more cold susceptible animals, such as poultry, pigs, young lambs and calves and recently shorn sheep, where a thermal stress could not only markedly influence growth or productivity but could also be a challenge to homeothermy and survival. On the other hand, the extremely low LCT values of most adult ruminants are rarely encountered in practice. However, analysis of the performance of grain-fed cattle in feedlots in North America indicate that SO-70% of the variation in performance over time can be accounted for by climatic variables (Young 1981).

PHYSIOLOGICAL ADAPTATION

Physiological adaptation to the thermal environment is well documented for small mammals (Dill 1964). After several weeks of exposure to a thermal stress an animal's ability to thermoregulate is improved. With adaptation to cold there are increases in thermal insulation, appetite and metabolic intensity, while these components decrease with adaptation to warm or hot conditions. With prolonged cold exposure, the increased metabolic intensity is reflected as an increase in thermoneutral metabolic rate as well as in summit metabolism when the animal is challenged by severe cold. There is increasing research evidence that similar thermally-induced adaptive changes occur in livestock and may have important practical consequences (Young 1981; Young and Degen 1981).

(i) Metabolic intensity The influence of prior cold exposure on metabolic intensity, measured as resting metabolic rate in conditions free from a direct or immediate thermal stress, has been confirmed in both sheep and cattle (Slee 1971; Young 1975b). Reduced metabolic intensity in ruminants with physiological . adaptation to hot conditions has been suggested but, as yet, the confounding influences of the concomitant reduced food intake have not been resolved.

On the basis of studies in Canada, the resting metabolic rates of cattle during winter have been estimated to increase by approximately 2.9 kJ.kg$^{-.75}$ for each 1°C decrease in mean ambient temperature (Young and Degen 1981). Alternatively, this has been expressed as a 0.91% decrease or increase in maintenance energy requirement for each $^{\circ}$C above or below 20°C to which cattle have been exposed (NRC, 1981). The increase in maintenance energy requirement with cold adaptation may be looked upon as an insurance premium paid for protection of the animal against the risk of calamitous cold weather.

(ii) Feeding value Digestibility and metabolisability are biological measures assigned to feeds and used as predictive values in feeding situations. However, such values depend not only on the physical and chemical nature of the feed itself but also on the animal ingesting the feed, its physiological state and the amount of feed ingested. Independent of any influence of the environment on plant growth, there is evidence that the thermal environment directly influences the digestive functions in animals. Although the nature and extent of these thermally-induced physiological changes are not fully resolved, the possible consequences to applied animal nutrition may be important (Young and Degen 1981). While there seems to be some dependence on ration type, the ability of ruminant animals to digest roughage increases with warmer temperatures and decreases with colder temperatures. The change in digestibility of roughage feed is about 0.012 digestibility percent units per $^{\circ}$C (Young and Christopherson 1976). The influence of temperature on digestibility is apparently independent of the level of intake and is most probably associated with increased rumination, gut mobility and rate of passage of digesta through the gastro-intestinal tract (Kennedy et al. 1977; Gonyou et al. 1979). During heat exposure, rumen mobility decreases and there is a concomitant increase in retention time of digesta that should increase roughage digestibility (Attebery and Johnson 1969).

NRC (1981) suggested the following general formula to adjust for the thermal effect on digestibility of diet component values for roughages consumed by cattle exposed for prolonged periods to effective ambient temperatures markedly different from 20°C:-

$$A = B + B\,[C(T-20)]$$

where A and B are, respectively, the adjusted and unadjusted diet component values; C is the correction factor (0.0016 for dry matter digestibility; 0.0010 for diet energy components DE, ME, NE and TDN, and 0.0011 for dietary nitrogen); and T is the effective ambient temperature (°C) of prolonged exposure.

(iii) Food intake. A major effect of the thermal environment on animals is through the influences on food intake. Appetite is usually stimulated by cold exposure but progressively depressed by high temperatures, and has simplistically been assumed to reflect the dietary energy demand for metabolism. However, insufficient research attention has been given to the physiological changes in animals which cause or allow for the observed thermally-induced changes in appetite. The shifts in digestive function mentioned above which alter feeding values of dietary components may also be associated with the thermal effects on appetite. With cold exposure there is a more rapid clearance of material from the rumen, allowing for increased food intake. On the other hand, the decreases in rumen mobility and rate of passage during heat exposure would tend to reduce appetite.

CONCLUSIONS

The influences of the thermal environment on animals are extensive and complex. The simple relationship between ambient temperature and metabolic rate is insufficient to describe adequately the effects of the naturally occurring environment on animals in practical situations. Recognition of physiological adaptation to the thermal environment by ruminants and the resulting changes in metabolic and digestive function is essential in the development of adjustment factors for practical livestock feeding systems.

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