# The Concept of Adjusting Energy Level in Maintenance Rations for Cold Weather

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Nutrient requirements for domestic animals (NRC) published by the National Research Council are the best estimates available. For beef cattle, specific tables are listed for animals of different weights and for various stages of the production cycle. Although these values are useful for many situations, there are instances when they should be adjusted. One needed adjustment is energy requirement for maintenance when cattle are exposed to cold and rate of heat production must increase to compensate for increased heat loss. The two factors that determine the rate of heat loss are: (1) the difference between body temperature and environmental temperature, and (2) the amount of insulation provided by fat, hide, and hair.

The temperature gradient between environmental and body temperature (factor 1) combined with the animal's insulation (factor 2) can be used to predict energy loss per unit of time, i.e. maintenance energy requirement. The relationship of these variables is:

$$\text{Equation 1:} \quad \text{Insulation} = \frac{\text{Temperature gradient}}{\text{Rate of sensible heat loss}}$$

The slower the rate heat is lost, the lower the cost of energy for maintenance; however, there is a minimum rate of metabolic heat production which must be lost or body temperature would rise because heat production must equal heat loss. For cattle consuming a maintenance level of feed this minimum heat production is 131 Kcal/$w^{3/4}$ (Lofgreen and Garrett, 1968). Rate of sensible heat loss in equation 1 equals heat production minus evaporative heat loss. Blaxter (1967) has estimated a relatively constant rate of evaporative heat loss during cold to be 300 Kcal/$m^2$/da for cattle. Blaxter also estimates that 80 Kcal/$m^2$/da is used to warm feed and water. While heat of warming is sensible heat exchange it is not included in equation 1 because this particular avenue of heat flow is not a function of animal insulation, nor is it affected by environmental temperature.

Equation 1 indicates that different combinations of insulation and thermal gradient may result in the same rate of heat loss. In other words, when insulation values are high, animals can tolerate larger thermal gradients (magnitude of cold) without increasing rate of sensible heat loss. But, if insulation value is low, smaller gradients (higher environmental temperature) could result in large rates of heat loss.

The relationship of insulation, temperature gradient, and sensible heat flow establishes an animal's critical temperature. Critical temperature is the environmental temperature below which the animal must increase heat production to maintain constant body temperature, and by definition is the lower limit of the thermal neutral zone. In effect, the critical temperature and thermal neutral zone are much the same, but one may be more appropriate than the other in some situations. When adjusting energy levels in maintenance rations, the critical temperature is most appropriate because it is the temperature below which increased energy is necessary. The major animal variable that determines critical temperature is insulation, which is obvious from equation 1. Using typical insulation values one can calculate critical temperature as follows:

Example:

| | |
|---|---|
| Insulation | $.015/Kcal/m^2/da$ |
| Body temperature | 39 C |
| Heat flow | $2390\ Kcal/m^2/da$ |

$$.015C/Kcal/m^2/da = \frac{39 - x}{2390\ Kcal/m^2/da}$$

then x = 3 C

This example suggests that the critical temperature is 3 C so when the environment is colder than 3 C, more energy will be needed for maintenance.

When adjusting rations for thermal environment an "effective temperature" should be used as environmental temperature. Effect temperature is defined as the heating or cooling power of the environment in terms of dry-bulb temperature. A wind-chill temperature is a good example of an effective temperature and should be used for cattle exposed to cold (see 60th Annual Cattlemen's Day Report, p. 84).

Critical temperature cannot be calculated without some error. First, the insulation value of hair and fat is not uniform over the entire surface of the animal; second, the animal's ability to shunt blood to and from specific areas of the body reduces the accuracy of estimates of insulation. Third, calculations assume that the animal is a sphere with no facing surfaces. Other methods of determining critical temperature are possible and involve measuring heat production of animals exposed to various temperatures to determine effective temperature when heat production is lowest or performance is highest. Using both calculations and deductive interpretation, table 25.1 lists the estimated critical temperature of beef cows presently being used in our research. The more insulation the lower the critical temperature (see heavy winter coat, Table 25.1). This would be expected from equation 1. The effect of wetting the haircoat by rain or high humidity results in reduced insulation. Fat is not considered here and more research is needed on its influence. Recent work has refined observed changes in haircoat insulation (Table 25.2).

Values in Table 25.1are generally higher than calculated values primarily because previous calculations assumed constant insulation over the entire body surface. A second reason for higher values is that many body surfaces face each other so heat lost is regained by the animal. This is enhanced by behavioral thermoregulation.

Table 25.2 data show that total insulation and haircoat insulation are closely related (r = .98), suggesting that insulatory value of the haircoat could be used to indicate total insulation. The best measurement of haircoat to predict insulation value uses hair depth and weight per unit area in this equation:

Equation 2: Total Insulation ($C/Mcal/m^2/da$) = 7.18 + 3.08 (hair depth, cm) + .017 (weight in $gms/m^2$)

After total insulation is estimated, increased energy loss per degree increase in temperature gradient is determined by modifying equation 1 as follows:

$$\text{Insulation} = \frac{1\ C}{\text{rate of sensible heat loss}}$$

For example, if insulation value is .015 $C/Kcal/m^2/day$ then for each 1 C of thermal gradient the increased rate of heat loss is 66.6 $Kcal/m^2/da$ as shown below:

$$.015\ C/Kcal/m^2/da = \frac{1\ C}{X}$$

$$x = 66.6\ Kcal/m^2/da$$

One remaining conversion that must be dealt with in determining rate of heat loss is converting heat production during feeding, which is described per unit of metabolic size, ($131\ Kcal/w^{3/4}/da$), to rate of heat loss per unit of surface area ($2770/Kcal/m^2/da$). Both values are a function of body weight but at slightly different powers ($w^{.75}$ vs. $w^{.66}$). Thus, body weight has a relatively small effect when converting rate of heat loss per unit of metabolic size to heat loss per unit of surface area.

Table 25.3 shows the percentage increases in NRC maintenance energy requirement at four different insulation values for animals of five different weights.

Values in table 25.3 can help cattlemen properly adjust energy in rations.

Example 1: If a 500 kg. (1100 lb.) cow has a winter coat (critical temperature 0 C) with an estimated insulation value of .020 $C/Kcal/m^2/da$, how much energy does she require if the wind-chill is -25 C?

Answer: The cow is experiencing 25 C of cold (difference between critical and effective temperatures) and according to table 25.3 needs 1.8% additional energy per degree of cold or 45% more than the NRC maintenance energy requirement.

Thus,

| | |
|---|---|
| NRC Requirement | 13,850 Kcal |
| Adjustment (45%) | 6,232 Kcal |
| Adj. Requirement | 20,082 Kcal |

Example 2: Suppose a 400 kg. cow is wet, the dry-bulb temperature is 2 C (35 F) with a wind-chill of -5 C (23 F). What is her adjusted maintenance requirement for energy?

Answer: In this case the cow experiences 20 C cold (difference between critical temperature -15 C and effective temperature -5 C). Table 25.3 indicates a 3.7% increase per degree cold, therefore, 74% adjustment.

| | | |
|---|---|---|
| NRC Requirement | 11,700 | Kcal |
| Adjustment (74%) | 8,660 | Kcal |
| Adj. Requirement | 20,360 | Kcal |

The value of the described system is to more accurately feed energy during periods of cold stress. The system is based on an assumed accuracy of existing NRC requirements at thermal neutral temperature. The system does have some shortcomings in its present form, however, the adjustments attempt to correct NRC requirement for effect cold.

Table 25.1. Estimated critical temperature - beef cows.

| Coat description | Critical temperature | Expected insulation ($C/Kcal/m^2/da$) |
|---|---|---|
| Summer coat or wet | 15 C (59 F) | .010 |
| Fall coat | 7 C (45 F) | .015 |
| Winter coat | 0 C (32 F) | .020 |
| Heavy winter coat | -7 C (18 F) | .030 |

Table 25.2. Haircoat, external, and total insulation of cattle by month in Kansas.[1]

| Month | Insulation ($C/Kcal/m^2/da$) Haircoat | External[2] | Total[3] |
|---|---|---|---|
| Jan. | .019 | .029 | .032 |
| Feb. | .015 | .023 | .027 |
| Mar. | .011 | .018 | .022 |
| April | .008 | .014 | .018 |
| May | .005 | .011 | .015 |
| June | .003 | .008 | .013 |
| July | .002 | .007 | .012 |
| Aug. | .002 | .006 | .012 |
| Sept. | .002 | .007 | .012 |
| Oct. | .003 | .009 | .013 |
| Nov. | .004 | .010 | .015 |
| Dec. | .006 | .013 | .018 |

[1]Calculated on fifteenth of each month.

[2]External insulation included haircoat and air interface.

[3]Total insulation includes hide, haircoat, and air interface.

Table 25.3. Increased maintenance energy costs for cattle per degree (C) cold.

| Insulation ($C/Kcal/m^2/da$) | Cow weight (kg) 200 | 300 | 400 | 500 | 600 |
|---|---|---|---|---|---|
| | Percentages | | | | |
| .010 | 4.1 | 3.9 | 3.7 | 3.6 | 3.5 |
| .015 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 |
| .020 | 2.1 | 1.9 | 1.9 | 1.8 | 1.8 |
| .025 | 1.7 | 1.6 | 1.5 | 1.4 | 1.4 |
| .030 | 1.3 | 1.2 | 1.2 | 1.2 | 1.1 |