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FEED REQUIREMENTS OF BEEF CATTLE

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SUMMARY

The feed requirements of beef cattle, in terms of metabolizable energy (ME) have been reviewed with particular reference to animals weighing up to 400 kg. Results from grazing experiments in New Zealand, while agreeing in general with the utilization of ME fed above maintenance as laid down in feeding standards, indicate that the total feed requirements are considerably in excess of these standards. Most cattle feeding experiments carried out in New Zealand have not led to any marked advance in defining feed requirements of grazing beef cattle.

IN THIS PAPER the metabolizable energy system (ME system) has been used to express feed requirements. Requirements are probably best expressed in terms of net energy (NE) since they are then direct measures of the energy expended or retained by the animal. Conversely, food values are probably best expressed in terms of ME owing to the difficulties involved in determining NE values. Since any system used should be capable of expressing feed requirements and food values in common terms for convenience, NE requirements have been converted into ME requirements where applicable.

Many in New Zealand consider that the digestible dry matter (DDM) or digestible organic matter (DOM) systems are simpler, more easily understood and sufficiently reliable. However, with the recent trend for an increasing range of feeds for our livestock, then the ME system has considerable advantages over digestible energy systems. If methane and urinary energy represented a constant proportion of apparently digested energy, then possibly the ME system would not be preferable but results of feeding trials with even common feedstuffs (Rattray and Joyce, 1969; Joyce, 1971; J. B. Hutton, unpubl.; A. M. Bryant, unpubl.) have shown that urinary energy as a percentage of gross energy intake can vary from 2.9% to 10% or as a percentage of digested energy from 4.4% to 14.3%.

The feed requirements of beef cattle are dealt with under three main headings:

- (1) Requirements of energy for pregnant and lactating beef cows.
- (2) Requirements of energy and protein by calves from birth to 100 kg liveweight.
- (3) Requirements for energy of cattle between 100 and 400 kg liveweight.

In converting the various published estimates of feed requirements into terms of ME the following factors have been used:

1 kg pasture DM = 2.6 Mcal ME (M/D = diet concentration)

1 kg pasture DOM = 4.0 Mcal ME

1 Mcal DE = 0.81 Mcal ME

1 Mcal NE_m = 1.33 Mcal ME (assumed net availability of ME for maintenance of 75%, A.R.C., 1965; N.R.C., 1970 assume a net availability of 58 to 67% and have calculated their own estimates of ME requirements from NE values).

Conversion of NE_p to ME:

$$K_f = 18.4 \text{ M/D} + 3.0 \text{ (A.R.C., 1965)}$$

$$\text{ME} = \text{NE}_p / K_f$$

or $\text{ME} = \text{NE}_p / K_f + 1.33 \text{ NE}_m$

(N.R.C. (1970) assume net availability of ME for weight gain of 32 to 48% according to level of concentrates in ration.)

1. FEED REQUIREMENTS OF PREGNANT AND LACTATING BEEF COWS

The feed requirements of beef cows during their pregnant and lactating phases, while of importance in practice, have received little attention in the past. Almost our entire knowledge on this subject in New Zealand has been inferred from research work on the dairy cow and even for this class of animal comparatively little is known on the effect that the physiological state of pregnancy has on feed requirements.

PREGNANCY

Hutton (1963) considered that feed intake over the last month prepartum should be increased to allow a true weight gain of 0.23 kg/day for the 520 kg beef cow. This would be equivalent to 3.7 Mcal ME/day additional to maintenance requirements or 110 Mcal ME extra over the last month of pregnancy. Coop (1965), in assessing the ewe equivalence of various classes of livestock, assumed that the beef cow would require an additional 200 Mcal ME over and above maintenance needs to satisfy pregnancy requirements over the year. The N.R.C. (1963) recommendation for wintering pregnant heifers and cows (450 kg LW) was that the ration should be increased from a maintenance level of 10.7 Mcal ME/day to 14.5 Mcal ME/day *i.e.*, an increase of 3.8 Mcal/day or a total of 114 Mcal ME during the last month, a figure comparable to that proposed by Hutton (1963). The latest N.R.C. recommendations (N.R.C., 1970) based on NE instead of DE, however, appear to make no definite recommendation for satisfying the additional requirements of pregnancy. The A.R.C. recommendation for a similar 450 kg cow is that intake be progressively increased over the last 8 weeks prior to parturition — *i.e.*, non-pregnant 10.5 Mcal ME/day, 8-4 weeks from term 12.5, 4-2 weeks 15.9 and 2-0 weeks from calving 17.3 Mcal ME/day or 171 Mcal ME during the last month of pregnancy over and above maintenance requirements.

Therefore, the generally recommended increase for pregnancy over maintenance requirements in terms of ME is 100 to 200 Mcal during the month immediately prior to parturition, although the A.R.C. suggests this period should possibly be lengthened to 2 months.

LACTATION

The only published records of milk production levels from New Zealand beef cows appear to be those of Walker (1963). In that experiment, using a suckling system of measurement, the average milk production of Angus 3-year-old cattle was 980 kg per 180-day lactation (range 820 to 1,140 kg) and Hereford \times Angus 1,050 kg per 180-day lactation (range 750 to 1,360 kg). These results appear to be slightly higher than U.S. results with suckled beef cows (reviewed Barton, 1970) — range 550 to 1,500 kg milk corrected to a 180-day lactation period (average 770 kg).

If it is assumed that the average beef cow weighs 450 kg, produces 980 kg milk in 180 days (5.4 kg/day), and neither loses nor gains weight over this period, then from the published results on feed requirements of dairy cattle, the following requirements can be calculated for beef cattle:

	<i>Mcal ME/day</i>
Wallace (1956)	30.1
Wallace (1961)	25.1
Hutton (1962)	31.2
A.R.C. (1965)	16.8
N.R.C. (1963)	26.0
N.R.C. (1970)	20.4

The A.R.C. (1965) and N.R.C. (1970) requirements are considerably lower than the other four estimates (average 28.1 Mcal ME/day). On the basis of the A.R.C. requirements, beef cattle of this weight and consuming 28.1 Mcal ME/day, with a diet concentration of 2.6 Mcal ME/kg DM, should produce 13.75 kg milk per day, which would be equivalent to a 180-day lactation yield of 2,475 kg milk — *i.e.*, 150% higher milk production.

On a yearly basis, the standard beef cow weighing 450 kg, lactating over 180 days and producing 980 kg fat corrected milk (FCM) would be anticipated to have the following requirements:

	<i>Mcal ME</i>
Maintenance (Hutton, 1962: 13.5 Mcal day; A.R.C., 1965: 10.5; N.R.C., 1970: 12.6; average 12.2 Mcal ME/day) for 185 days	2,257
Pregnancy requirement additional to maintenance (Hutton, 1963: 3.7; N.R.C., 1963: 3.8; A.R.C., 1965: 6.1; average 4.5 Mcal ME/day) for 30 days	135
Lactation: 180 days at 5.4 kg FCM/day, 28.1 Mcal ME/day	5,058
Yearly total	7,450

Comparable calculations by Hutton (1963) and Coop (1965) indicated that the total yearly requirement by the breeding cow was 9,990 and 9,340 Mcal ME. These figures, however, must be corrected for:

- (1) Inclusion of the pasture consumed by the calf from birth to weaning.

- (3) Hutton (1963) allowed for 0.45 kg gain/day over the 180-day lactation period.
- (4) Hutton (1963) calculated his requirements for a 520 kg beef cows.

When these allowances have been deducted, their estimates of the ME requirement over the year for the breeding cow are reduced from 9,990 and 9,340 Mcal ME to 7,390 and 7,730 Mcal ME/year, respectively — requirements very similar to that predicted. No doubt some allowance should be made for the energy costs of climate and grazing and for the feed requirements of the calf until weaning. Using the results of Hall and Brody (1934), obtained from energy cost of horizontal walking studies with cattle, it can be shown that a 450 kg cow would expend 359 kcal for each mile of walking and an additional 940 kcal for every 1,000 ft of ascent. On flat areas assuming a beef cow walks 3 miles (Johnston-Wallace and Kennedy (1944) — 2½ miles/day with beef cattle; Hancock (1954) — 1¾ miles/day with Jersey cattle in 1 acre paddocks), this would amount to 1.08 Mcal/day or 394 Mcal/year ignoring the vertical workload. Estimates of the energy cost of grazing (Graham, 1962) and eating (Blaxter and Joyce, 1963) suggest that any additional allowance for the cost of grazing would be unwarranted.

If 600 Mcal ME are allowed for walking and 1,250 Mcal ME for the feed requirements of the calf (see Section 2), then the total feed requirement for the lactating cow over the complete year and her calf up to 180 days of age would be 9,300 Mcal ME.

2. REQUIREMENTS FOR ENERGY AND PROTEIN OF CALVES FROM BIRTH UNTIL 100 kg LIVEWEIGHT

With the increasing number of calves of dairy origin being raised for beef, any review of feeding standards would not be complete without mention of the feed requirements of the young calf. However, only very generalized feed requirements for calves are possible in view of the results of Tkacev and Taranenko (1963) which show considerable variation would be expected between breeds. Their results indicate that calves of beef breeds have lower basal metabolic rates than those of breeds usually considered to be of a dairy type (10% lower at 2 months of age and 19% at 12 months).

The maintenance requirements in terms of net energy for the pre-ruminant calf appears to be 43 kcal NE/kg

liveweight/day (Tomme and Taranenko, 1939; Blaxter and Wood, 1951; Roy *et al.*, 1958) and for the post-ruminant calf 32.5 kcal NE/kg liveweight/day (Preston, 1963; Stobo and Roy, 1963). If 96% of the gross energy of milk is metabolized (Blaxter, 1952) and the net availability of ME is 82%, then the requirement for maintenance in terms of ME of the pre-ruminant calf is 52.4 kcal ME/kg LW/day. Similarly, for the ruminant calf using a net availability of ME for maintenance of 74.5% (Stobo, 1964), the calculated requirement for ME is 43.6 kcal ME/kg LW/day.

The requirements for liveweight gain range from 2.68 to 3.07 Mcal DE/kg LW gain with an average of 2.92 Mcal DE (Blaxter and Wood, 1951; Brisson *et al.*, 1957; Roy *et al.*, 1964). This would be equivalent to 2.85 Mcal ME for the pre-ruminant calf and 2.37 Mcal ME for the ruminant calf.

Khouri and Pickering (1968) in their experiments on the nutrition of the milk-fed calf related growth rate to milk powder consumption. Their results, transposed into terms of ME, are compared to the above estimated requirements in Table 1. While the estimated requirements for the two lower feeding levels were higher than actually fed, those at the two higher levels were very similar.

TABLE 1: INTAKES OF ME FOR CALVES FED MILK FOR 98 DAYS (Khouri and Pickering, 1968)

Whole Milk (% Body Weight)	Mean LW (kg)	LWG (kg)	Intake ME (Mcal)	
			Actual	Estimated
12	54.8	43.0	343	432
15	56.6	47.7	417	455
18	57.2	66.7	474	484
<i>ad lib.</i>	69.6	75.9	574	574
		Mean	452	486

With the use of milk replacement diets for the raising of calves, the level of protein feeding could be an important factor limiting growth. Protein requirements are usually defined in terms of available protein rather than apparently digested crude protein. Available protein allows for both the metabolic faecal loss of nitrogen and the biological value of the protein fed. The conversion factors suggested by the A.R.C. (1965) for transposing avail-

able protein intakes (g/day) into digestible crude protein intakes (g/day) are:

Calves fed liquid diets based on milk Add 3.9 D

All other cattle Add 13.4 D

Where D = dry matter intake in kg/day

Tables 2 and 3 show estimated requirements of pre-ruminant and ruminant calves for available protein. In general, there appears to be little difference between pre-ruminant and ruminant animals in their available protein requirements. The N.R.C. (1966) recommendations, although not laid out in the same form as those of the

TABLE 2: MINIMUM AVAILABLE PROTEIN REQUIREMENTS (g/day)

Calves on milk based diets (BV = 80)
(A.R.C., 1965)

Liveweight (kg)	Liveweight gain (kg/day)		
	0.0	0.5	1.0
50	30	125	220
75	35	135	220
100	45	140	230

TABLE 3: MINIMUM AVAILABLE PROTEIN REQUIREMENTS (g/day) RUMINANT CALVES

Liveweight (kg)	Liveweight Gain (kg/day)					
	0		0.5		1.0	
	a*	b*	a	b	a	b
50	35	36	145	121	250	205
75	40	—	150	—	260	—
100	50	88	155	173	260	257

*a = A.R.C. (1965); b = Stobo and Roy (1963).

N.R.C. (1966) RECOMMENDATION

Liveweight (kg)	Liveweight Gain (kg/day)	Available Protein (g/day)
50	0.7	254
75	0.9	374
100	1.1	564

A.R.C. (1965) and Stobo and Roy (1963), appear to be considerably higher. However, the N.R.C. (1966) recommendations are for optimal feeding levels while the other two are minimal levels and feeding levels should probably be considerably higher than this minimum under normal practice.

3. REQUIREMENTS OF CATTLE 100 TO 400 kg LIVEWEIGHT

MAINTENANCE

Figure 1 shows, first, the feeding standards for maintenance based on ME (A.R.C., 1965) and NE (N.R.C., 1970) systems and, secondly, requirements estimated

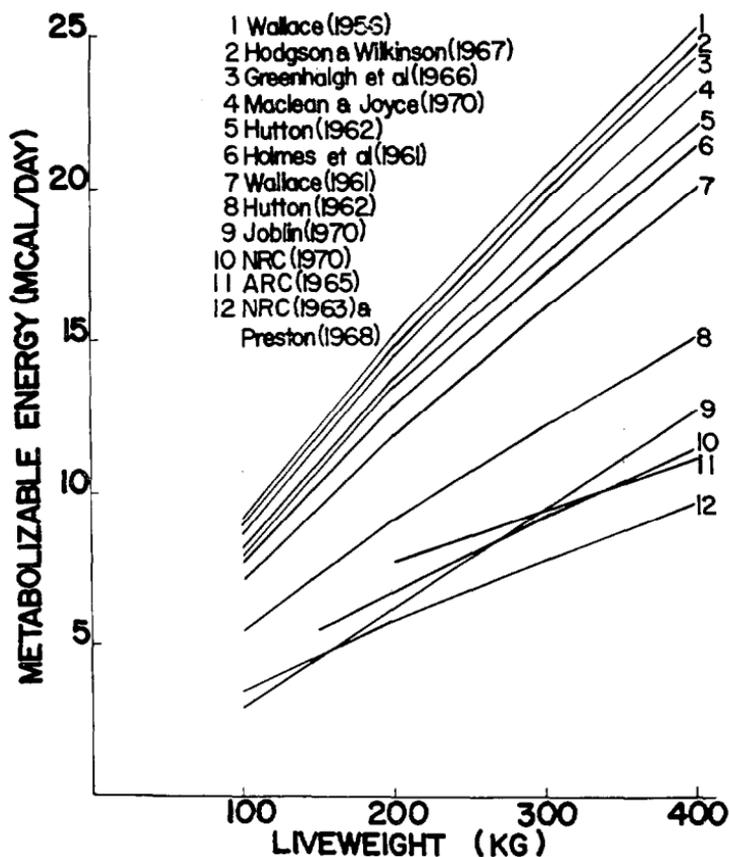


Fig. 1: Metabolizable energy requirements for maintenance of cattle weighing 100 to 400 kg.

from regression equations based on trial results, obtained mainly in New Zealand from indoor feeding and grazing experiments. The validity of applying the equations, derived by Wallace (1956, 1961) and Greenhalgh *et al.* (1966) is doubtful since these equations relate to lactating cattle. The possibility exists that the physiological state of lactation may elevate maintenance requirements.

These results appear to fall into two major groupings:

- (1) Requirements based on published feeding standards.
- (2) Requirements based on direct experimentation.

Other than the results of Hutton (1962), all the higher estimates of maintenance have been based on grazing trials. As a consequence, these higher estimates (approximately 100% greater) may represent an additional feed requirement occasioned by the energy costs of grazing and climate or else may represent the inadequacy of the use of regression relationships in separating the components of intake related to maintenance and liveweight change, respectively. Exceptions to this are those results of Joblin (1970) who used regression analysis methods to separate out the components of intake related to maintenance and liveweight change and those of Hutton (1962) where all cattle were stall-fed. Part of the results of Hutton (1962) have been obtained from one of the few experiments in New Zealand carried out under stall-feeding conditions in which the feeding level was adjusted to maintain cattle at a constant liveweight over an extended period. The results of this latter trial give estimates of maintenance requirements considerably above those of published feeding standards and Joblin (1970), but lower than those derived from experiments in which cattle were allowed to gain weight. One possible explanation of the low maintenance requirements calculated by Joblin (1970), may be that the diets used in that experiment were basically maize silage and hay fed with variable amounts of autumn-saved pasture. Most of these discrepancies in requirements could be accounted for if the feeding of fresh pasture is associated with a high heat increment.

As a consequence, any recommendation other than the maintenance requirements of cattle lies between 90 and 270 kcal ME/kg LW^{0.75}, irrespective of body size, would be a gross oversimplification of the problem. Most published feeding standards appear too low to be applied to maintaining the liveweight of grazing cattle in New Zealand.

GROWTH

Figure 2 shows the amounts of ME, based on the various published estimates, that are required to be fed to obtain a predicted gain of 1 kg per day. Again there occurs a wide range, with published feeding standards in

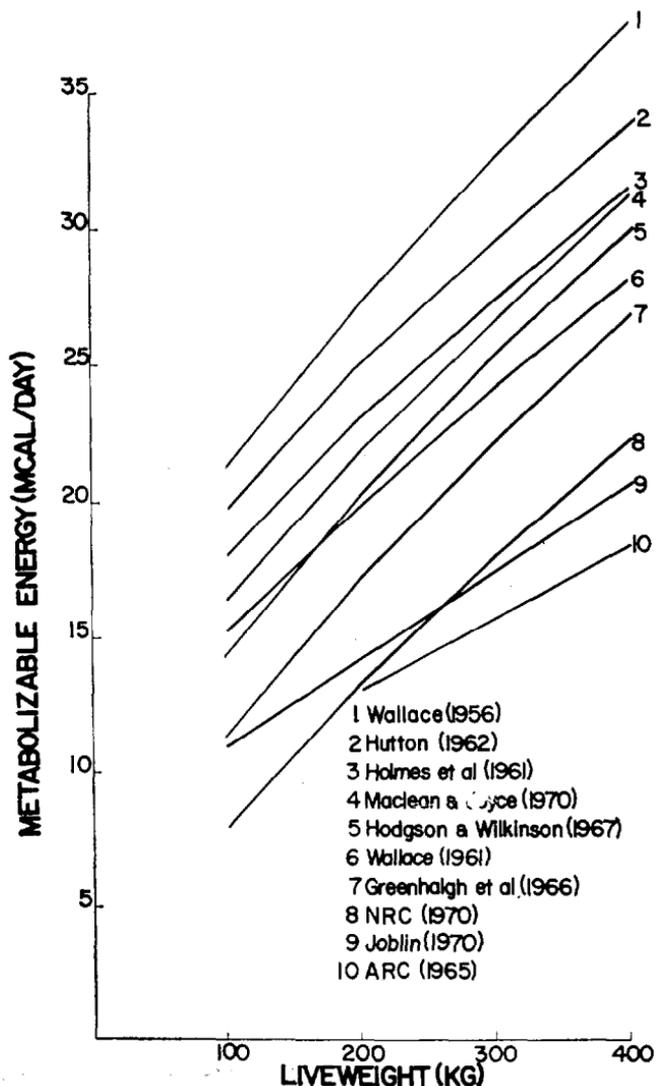


Fig. 2: Published estimates of the metabolizable energy requirements of cattle gaining 1 kg per day and weighing 100 to 400 kg liveweight.

TABLE 4: UTILIZATION OF ME FED ABOVE MAINTENANCE

Source	Mcal/kg LW Gain
Holmes <i>et al.</i> (1961)	10.0
Hutton (1962)	11.7
Greenhalgh <i>et al.</i> (1966)	2.5
Hodgson and Wilkinson (1967)	7.2
Joblin (1970)	7.9
Maclean <i>et al.</i> (1970)	8.0
A.R.C. (1965):	
200 kg LW	5.3
400 kg LW	7.2
N.R.C. (1970):	
200 kg LW	6.6
400 kg LW	13.0

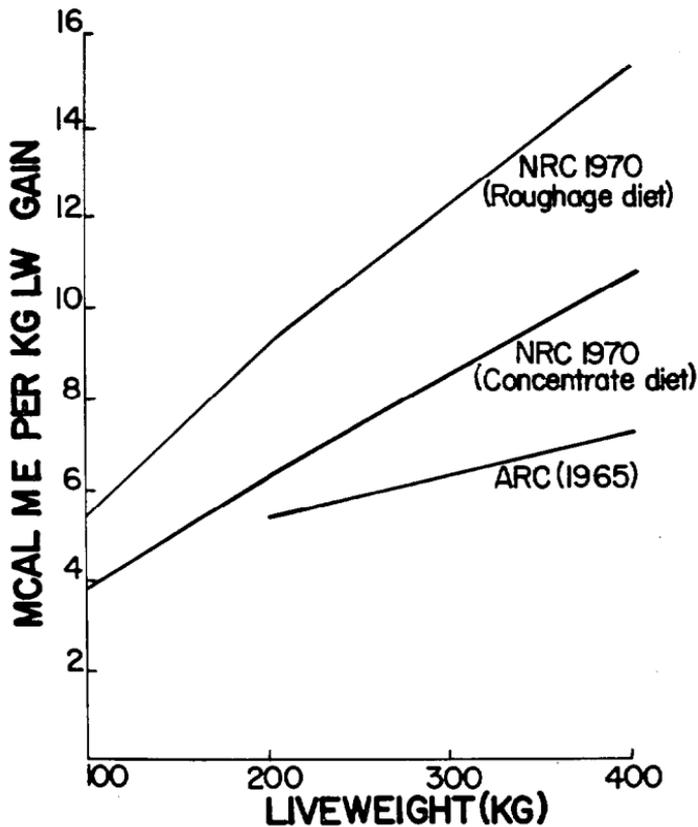


Fig. 3: Estimates of the amounts of metabolizable energy which must be fed above maintenance requirements to allow a daily liveweight gain of 1 kg.

general covering the lower end of the range compared with those predicted directly from experimentation. This variation in requirements for growth is a consequence of two inter-related factors:

- (1) Variation in ME requirements for maintenance.
- (2) Variation in ME requirement, additional to maintenance demands, for growth.

This variation in the estimates of utilization of ME fed above maintenance is shown in Table 4. Excluding the low value of Greenhalgh *et al.* (1966), the range in Mcal ME fed above maintenance per kg liveweight gain was 7.2 to 11.7 (average 9.0) for results obtained directly

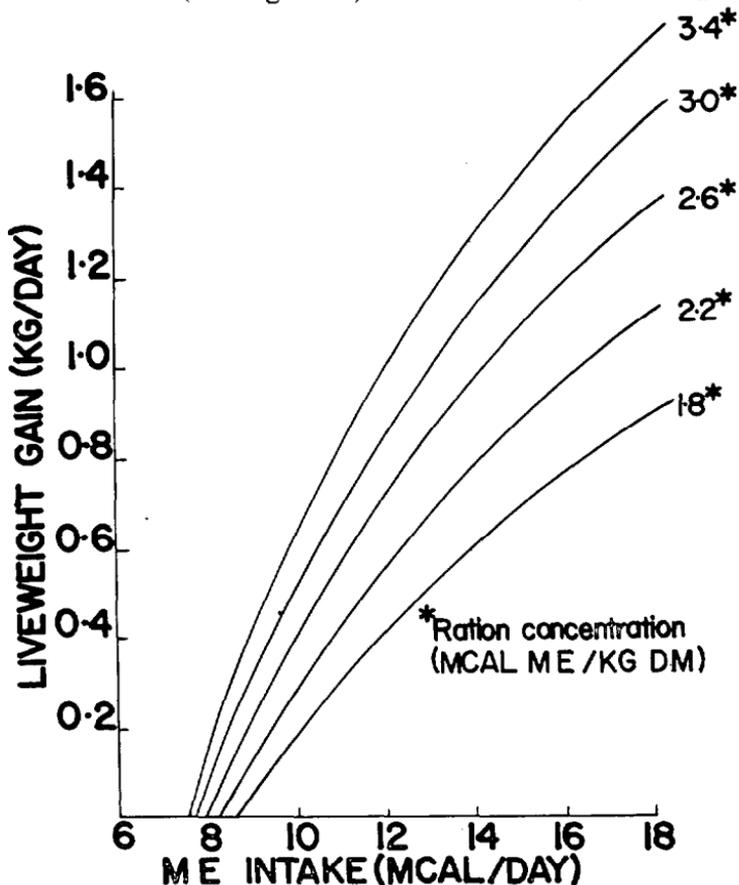


Fig. 4: Effect of ration concentration (Mcal ME/kg DM) on the requirements of a 200 kg steer when gaining at 0 to 1.6 kg/day (A.R.C., 1965).

by experimentation. There is no doubt that, to use a constant utilization of ME fed above maintenance for growth, such as obtained by regression analysis, is basically unjustified since it can apply only to a very narrow range of growth rates. Most feeding standards recognize this fact and vary their requirements according to liveweight, rate of gain, and type of ration.

Figure 3 gives some of the estimated requirements for ME, fed above maintenance, for 1 kg liveweight gain with increasing liveweight. Whereas the A.R.C. (1965) standards increase at a rate of only 9.5 kcal/kg LW, those of N.R.C. (1970) increase at a rate of 22 to 33 kcal/kg LW depending on the type of diet fed.

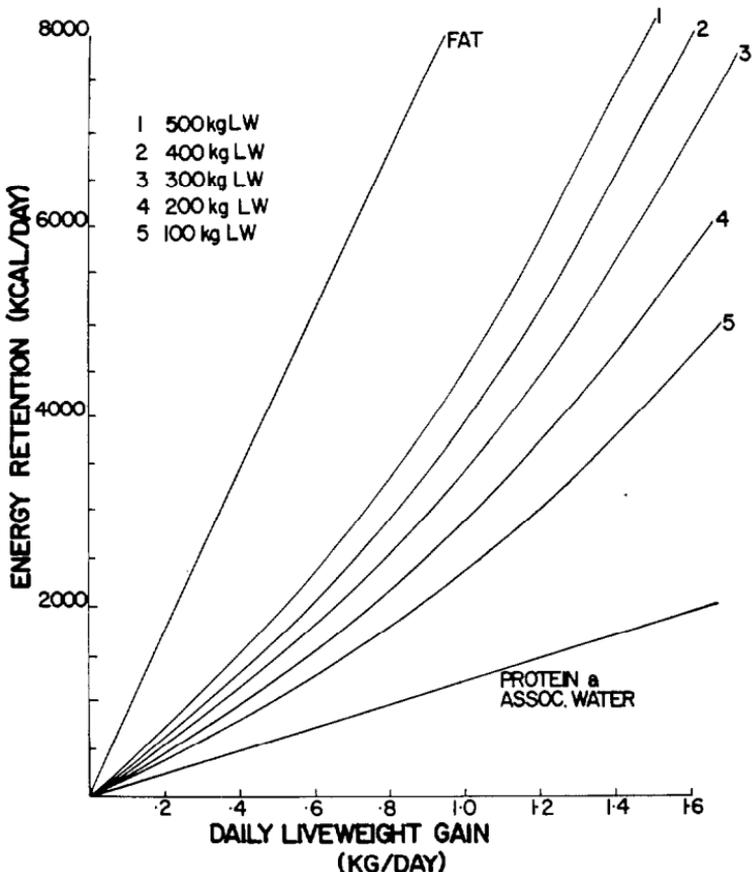


Fig. 5: Effect of liveweight and rate of daily gain on the level of energy retention (A.R.C., 1965).

The A.R.C. (Fig. 4) make a further correction to the ME requirements of cattle based on the ME concentration of the diet. Thus, when cattle are fed diets low in digestibility, the ME requirement for growth increases. The degree of increase is greater the higher the anticipated or desired level of production. At maintenance levels of feeding, the mean efficiency of utilization of ME varies little from 74% although the N.R.C. (1970) uses values of 58% to 67% depending on the proportion of concentrates in the diet.

The increase in the amount of ME required per kg LW gain with increasing liveweight is a consequence of the changes in the energy concentration of tissue deposition with increasing liveweight. This effect, together with the effect of increasing calorific value of tissue deposition with increasing rate of liveweight gain at any particular liveweight, is shown in Fig. 5.

The following tentative conclusions may be drawn regarding feed requirements for growth:

- (1) Results from grazing experiments in New Zealand, while agreeing in general with the utilization of ME fed above maintenance as laid down in feeding standards, indicate that the total feed requirements are considerably in excess of these standards.
- (2) The type of experimentation carried out over past years in New Zealand has not led to any marked advance in defining feed requirements of grazing beef cattle in New Zealand. When cattle feeding experiments are laid down, they should be designed so that intakes can be interpreted in terms of:
 - (a) Liveweight.
 - (b) Rate of gain.
 - (c) Type of diet.

Until this is done, it is doubtful if any worthwhile progress will be made in defining the optimum feeding levels for cattle under New Zealand grazing conditions.

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