Net requirements for maintenance as dependent on weight, feeding level, sex and genotype, estimated from balance trials

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Abstract

In the introduction attention is paid to the ratio of maintenance feed to total feed in growing animals which is seldom less than 0.4 This shows the need for an accurate estimate of maintenance requirements.

The various methods to derive or predict this requirement are critically discussed. Attention is paid to protein turnover rate, work of growth and the physical activity of growing animals ; an attempt is made to develop a model which takes account of these aspects. Finally a survey is given of most estimates of maintenance requirements of growing cattle and comments are made regarding the reliability of these estimates.

Résumé

Estimation des besoins énergétiques nets d'entretien à partir des résultats de bilan : variations en fonction du poids, du niveau d'alimentation, du sexe et du genotype

Dans l'introduction, l'auteur attire l'attention sur l'importance des besoins d'entretien des animaux en croissance, qui représentent rarement moins de 40 p. 100 des besoins totaux ; ce qui montre l'intérêt d'une estimation précise des besoins d'entretien.

Ensuite, l'auteur présente et discute les différentes méthodes utilisées pour déduire ou prévoir les besoins d'entretien. Il souligne l'importance de l'intensité du renouvellement des protéines, du « travail de croissance » et de l'activité physique chez les animaux en croissance et propose un modèle mathématique tenant compte de ces facteurs. Enfin, l'auteur fait une revue de la plupart des estimations des besoins d'entretien des bovins en croissance et discute leur validité.

Abbreviations

W; W_e; $W^{3/4}$; DWG	— liveweight (kg); W at mature age (kg); metabolic weight($W^{3/4}$); daily liveweight gain (kg).
T; T^*	— intake of dry matter (kg/day); $T/W^{3/4}$;
ME; ME_m; ME^*; ME_m^*	— metabolisable energy (kJ/day); ME needed for maintenance; $ME/W^{3/4}$; $ME_m/W^{3/4}$;
q	— ME as a percentage of gross energy intake;
k_m; k_g; k_f; k_p	— efficiencies of the utilisation of ME for maintenance, growth, fat deposition and protein deposition, respectively;
RE; RE_p; RE_f	— energy retained in the body (kJ/day) total, as protein or as fat;
APL	— animal production level equal to the ratio of total net energy to net energy for maintenance;
H; H^*	— heat production (kJ/day); $H/W^{3/4}$;
F; F^1	— H at fasting, either measured or calculated.

Introduction

Maintenance metabolism of growing animals, even of those growing very rapidly, makes up a large part of total metabolism. Chickens, young pigs and veal calves seldom use less than one third of the energy of their ration to maintain themselves, usually maintenance requires more, especially at low rates of daily gain (NIJKAMP et al., 1973 ; VERSTEGEN, 1971 ; THORBEK, 1975 ; VAN ES et al., 1967). In growing, ruminating cattle and sheep maintenance metabolism is seldom less than 40 per cent of total metabolism and usually more (GEAY et al., 1973 ; SCHULZ et al., 1974). At a higher weight during growth the feed intake potential per unit of metabolic weight decreases slowly. The same is the case with the percentage of the energy retained as protein which may be as high as 65 per cent at a low weight, 50 per cent in young ruminating ruminants decreasing to 10 - 15 per cent near maturity (BÖHME et al., 1976 ; VAN ES et al., 1967 ; BLAXTER et al., 1966 ; JOSHI, 1972 ; GRAHAM, 1970). For both reasons maintenance energy- and N- metabolisms become a more important part of total metabolism at higher body weights and of course the more so at low rates of gain.

Thus the large part of the feed used for maintenance purposes easily explains the interest in having good estimates of this part of total metabolism. In addition, from a good understanding of the physiology of maintenance metabolism some means might be derived which lowers the amount of food required for it.

In this respect there are two subjects which need special attention : the physical activity and the rate of N turnover of the young animals. Young animals often show a somewhat higher physical activity than older ones, they are also more easily stressed (WENK and VAN ES, 1976). Physiological studies suggest that N turnover during rapid growth has an increased rate (MILLWARD et al., 1976 ; VAN ES, 1978 ; WEBSTER, 1979). Both phenomena increase total energy costs, for physical activity this is immediately apparent, for the rate of N turnover it should be considered that each time that a gram of existing body protein is hydrolysed to amino acids the resynthesis of this protein from the free amino acids resulting from its hydrolysis requires energy (ATP).

The measurement of maintenance requirements
of the growing animal

Many ways exist to determine maintenance requirements for energy (VAN ES, 1972 ; HENCKEL, 1976).

The animals can be fasted for a number of days at the end of which estimates of maintenance metabolism are derived from heat production and urinary energy loss (Method A).

The animals can also be fed approximate maintenance rations ; from their average daily liveweight gain (Method B1) or energy balance (Method B2) it can be computed how much of the ration is needed for maintenance only.

Finally regression methods can be used to derive maintenance estimates from measurements of liveweight gain or energy balance at two or more levels of intake at all liveweights followed by extrapolation to zero production (Method C).

Such regressions are often also applied to data from growing animals fed *ad libitum* or nearly so. The feeding level of such animals decreases with body weight, thus theoretically the condition for regression and for extrapolation to zero energy retention, i.e. having data from two or more feeding levels, is fulfilled. However, there is a bias, the data at high and at moderate feeding levels relate to young animals and old animals, respectively, so maintenance estimates thus obtained should be looked at with some caution.

In growing animals Method A fails because the animals may show an abnormal behaviour due to fasting, since these young animals are easily stressed.

Even in mature animals too high fasting values are obtained when the fasting trial is not preceded by a period during which a maintenance ration only is fed. Such a period on maintenance feeding prior to fasting might reduce the stress of fasting to the young animal. However, it might also allow metabolism more time to adapt to the low feeding level so that a fasting value is obtained which does not tell much about the animal's maintenance requirements during rapid or moderate growth.

A similar objection holds true also for Method B. Both HOFFMANN *et al.*, (1977) and WEBSTER (1978) consider these two methods of doubtful value for the prediction of maintenance requirements of rapidly growing animals. Instead they prefer to derive such estimates from measurements made during rapid or moderate rates of growth. This leads to the various regression methods of Method C, usually based either on model C1 or model C2 :

$$\text{production} = a \times \text{intake} + b \qquad \text{(C1)}$$
$$\text{intake} = c \times \text{production} + d \qquad \text{(C2)}$$

In these models intake may be expressed in kg feed per day. This would result in a great residual variation when applied to results of trials in which diets with different digestibilities or metabolisabilities are used.

For this reason intake is usually expressed as intake of metabolisable energy (ME). Very often, unfortunately, ME is calculated rather than measured during the growth of the animals. The calculation uses chemical composition or digested nutrients measured with the animals themselves at maintenance or at production level or with sheep at maintenance level, and methane losses are often estimated rather than measured. Production is generally expressed as daily energy gain, occasionally as daily liveweight gain. In the first case either the balance or the

comparative slaughter technique is used. The two techniques do not always give the same results. Energy balances slightly, and nitrogen balances often considerably overestimate actual balances, moreover their nonsystematical errors are fairly high as all errors made in measuring input and output accumulate in the balance. In the slaughter technique errors are easily increased when the animal's energy and N content is determined indirectly, e.g. by density, by analysis of ribcuts and when only a small initial slaughter group is used in trials of a short length. This means that both the intake and the production data may have errors of which the size can be considerable depending on the kind of methods used and on the care with which the measurements are performed.

Production is often partitioned in daily protein and daily fat gain, either expressed in grams or in kilojoules (C3) :

$$ME = e' \times P + f' \times F + g \text{ and } ME = e\, RE_p + f\, RE_f + g \qquad (C3)$$

in which P and F are daily protein and fat gain in grams and RE_p and RE_f are daily retained energies as protein and as fat.

In all models the constants b, d and g give an estimate of maintenance.

To account for differences in body weight within the set of data used for regression instead of these constants the terms $h\, W^p$. $i\, W^p$ and $j\, W^p$ are introduced. In other words, it is assumed that the model needs another independent variable, W^p, but does go through the origin so that a constant term is not needed :

$$RE = a \times ME + h\, W^p \qquad (C4)$$
$$ME = c \times RE + i\, W^p \qquad (C5)$$
$$ME = e \times RE_p + f \times RE_f + j\, W^p \qquad (C6)$$

It will be clear that b and h will have a negative value. The exponent p should have a value which best relates maintenance requirement to body weight. Most experimental work with mature or nearly mature animals suggests p to be close to 3/4 (writing the exponent in this way is preferred ; writing it as 0.75 suggests a too high degree of precision). Even with mature animals fed at the maintenance level it is difficult to obtain a precise estimate of p. For a high accuracy the range of W should be great which for the same breed is an impossible condition. A greater range of W in mature animals of different breeds is possible but in that case the estimate of p may be biased by species differences in maintenance requirement. Large variation in weight is easy to obtain in young, growing animals but here we do not have reliable estimates of maintenance requirements. However, we could try to find the best value of p using the models C4-6 in a set of data from growing animals of the same breed showing great variation in liveweight. The best value could be assumed to be the value which gives the lowest residual variation. In all such regression studies internal correlations invalidate the results : with increase of body weight *ad libitum* or restrictedly fed animals show a decrease of intake and of gain per metabolic weight, moreover the composition of their gain shows an increasing fat to protein ratio and their physical activity decreases. These biases are especially great when only *ad libitum* feeding is applied as mentioned above. This means that in all our models C4-6 the data of one independent variable are correlated with the data of the other independent variable(s). The result is that the values of p, but also of a, b, e, f, h, i and j, resulting from the regression computations are biased.

To reduce the effect of these bias factors on the result VAN ES *et al.* (1967) worked with two feeding levels in veal calves, nearly *ad libitum* and some 20 per cent less so that the data on body weight and energy deposition were not so closely correlated. PULLAR and WEBSTER (1977) also used more than one feeding level but in addition selected normal (lean) and genetically obese individuals from the same litter of Zucker rats. At the same ME intake level and body weight the lean rats deposited more protein and less fat than the obese rats, thus the correlation between fat to protein deposition ratio and body weight was diminished. The regression model used was: $ME = k + b\ RE_p + c\ RE_f$, in which k was kept constant only for the same genotype at the same weight. Thus, as in the earlier models the ME costs of deposition of protein and fat were assumed to be constant per kJ deposited, however maintenance requirements (k) were assumed to be similar only within genotype within liveweight but regardless of feeding level.

Some research workers use another approach in which heat production (H) rather than intake is used. According to GARRETT (1970) plotting log (H*) against ME* gives a straight line (the asterisk stands for $/W^{3/4}$). Where ME* on this line equals H* energy retention is zero, so the ME* value at this point is the quantity needed for maintenance. The assumption regarding this curvilinear relation of H* and ME* may be doubted. Most energy balance experiments with mature cattle or sheep fed the same feed at different levels above maintenance and with lactating cows (VAN ES, 1975) show a linear relationship provided H* and ME* apply to the same feeding level and the same diet. In many experiments by GARRETT and co-workers, however, ME was not measured at the actual feeding level but calculated from digestion trials at maintenance. Extrapolation of H* to zero ME* to obtain data on fasting metabolism was done. The reliability of such fasting data may be doubted as only results of trials at or above maintenance were used.

GARRETT also estimated ME_m^* by extrapolating in the plot of RE* against T* (intake of dry matter/$W^{\frac{3}{4}}$), RE* to 0 and converting T into ME.

WEBSTER (1978), much interested in the possible effect of growth on the size of maintenance, tried to exclude all feed effects influencing the results obtained. So he had to work with estimates of basal metabolism, e.g. fasting heat production, during actual growth. He doubted the value of the measured fasting heat production for this purpose and preferred the calculated fasting heat production F^1.

Energy retention and ME intake were measured repeatedly during the growth period of cattle at moderate and rapid rates of liveweight gain. F^1 was computed with the following equation — GE = gross energy intake —

$$F^1 = k_m\ (q\ GE - RE/k_f) \tag{C7}$$

The values q, k_m and k_f were from experiments with mature sheep fed the same diet or only q was measured and k_m and k_f were predicted using the ARC (1965) or BLAXTER (1973) equations. In this way both the effect of protein deposition, probably lowering the actual efficiency of the utilisation of the ME for growth k_g of the animal below k_f, any other effects of " work of growth " and increased physical activity would show up in the F^1 values. In other words, F^1 values should not be considered to be true maintenance estimates of growing animals, they are only calculated figures useful to detect a possible higher total heat production caused by growth. Scaled per metabolic weight the greatest differences between the F^1 of growing animals and the F of mature animals will of course be seen in the very young, very rapidly growing animals. WEBSTER proposed as a first approach that the difference between F and F^1, the " work of growth ", might be related to

$\dfrac{W}{W_e} \, ln \, \dfrac{W}{W_e}$, in which W_e is the weight of the animal at maturity. This term is the first differential of the Gompertz equation which might describe the relationship between " work of growth " and stage of maturity W/W_e. A disadvantage of the term is that for a W_e of 750 kg it is fairly constant over the range of 200 to 600 kg and falls off sharply thereafter.

HOFFMANN et al. (1977) and TYRRELL and MOE (1979) proceeded in a slightly different way. Using model C4 they predicted a value for k_g, a value which was applied in the same material to derive ME_m^*:

$$ME_m^* = ME^* - RE^* / k_g \qquad (C8)$$

Since k_g was obtained from growing rather than mature animals, it may be lower than the k_f used by WEBSTER in C7. Thus, still higher values of ME_m^*, better called ME^{*1}, might have been found with the $k_g \,(= k_f)$ of mature animals. As in WEBSTER's approach the purpose of the calculation of such ME_m^{*1} values is only to see if they differ from ME_m^* values found in mature animals of the same breed fed similar diets. Such possible differences might be due to protein turnover, physical activity and other " work of growth ".

In view of our present unfortunately still limited knowledge of protein turnover and physical activity we might extend model C6 by two terms. First k_p might be assumed to be related to the relative rate of protein deposition, i.e. to RE_p/W. Future work on N deposition might show whether this very simple prediction of rate of protein turnover or the main part of the " work of growth " suffices. Secondly part of the physical activity of the animal might be related to youth, i.e. decreasing with increasing degree of maturity $W - W_e$ (W_e values as will be understood are to differ from breed to breed).

This leads to model C9:

$$ME = (a + b \, RE_p/W) \, RE_p + c \, RE_f + \{d + e \, (W - W_e)\} W^p \qquad (C9)$$

Theoretically in this way the constant part of the maintenance estimate (dW^p) will be almost free of the influence of protein turnover and physical activity caused by youth while b and e indicate the size of these influences. The whole term $\{d + e \, (W - W_e)\} W^p$ could be considered as the total maintenance of a young animal consisting of a constant part and a part varying with age.

To my knowledge model C9 has not been used so far. It shares the drawback with model C6 (and also C5 and C2) that independent variables are used which have a low precision (RE, RE_p, RE_f) and this increases the error of the regression coefficients. On the other hand model C9 has the great advantage that its constants can indeed be considered to be constants; the regression constants of model C6 very likely change with body weight and rate of gain. Unfortunately the information given in the publications on experiments with growing animals is too incomplete for a successful application of model C9. Moreover, if the data used are only from ad libitum fed animals the regression will not differentiate between RE_p/W and $W - W_e$, making the values of b and e unprecise.

These considerations lead to the disappointing conclusion that there appears to be no completely correct method for deriving the total maintenance requirement of growing animals ($\{d + e \, (W - W_e)\} W^p$) at present ([1]). All estimates of mainte-

(1) In pigs at various feeding levels WALACH-JANIAK et al. (1979) assumed an increase of maintenance due to protein deposition equal to ($e^{k \cdot RE_p} - 1$), an interesting hypothesis. However, it did not improve the fit of the model to the data, although suggesting a higher value of k, thus a greater influence of protein deposition on maintenance, in boars than in castrated males. This model gives a higher increase of additional maintenance due to protein deposition at higher body weight.

nance published so far should be interpreted with caution as not only may the regression models used be criticised severely but also the data of the variables of the regressions may have large errors. At present we cannot do much better than to reconsider these maintenance estimates in view of the method and models used to derive them, and applying corrections to them. where that seems advisable in the light of the theory underlying model C9.

It will be clear that the greatest doubt on the precision of the maintenance estimate concerns the very young rapidly growing animal. It probably has a high rate of N turnover and is physically rather active. So in cattle and sheep lack of precision will be greatest in the pre-ruminant period. There-after protein energy deposition, except for late-maturing breeds at high feeding level, is usually 30 per cent or less of total energy deposition. Thus N turnover rate probably will not be very high, moreover at this age the animals are more quiet than in their early youth. Feeding them rations near maintenance rather than *ad libitum* does not change their behaviour very much. So we might conclude that for these cattle maintenance estimates obtained with methods B or C will not be too imprecise and will become more reliable with advancing liveweight. Of course, they apply to the situation in which the measurements have been made i.e. animals kept tethered, for those kept in a feedlot, for animals at pasture, etc. For the exception made above, i.e. for late-maturing bulls fed intensively the errors will be greater ; so method C is to be prefered.

Maintenance estimates for cattle obtained so far

The less recent literature has been reviewed by VAN Es (1972). The conclusion reached was that for very young growing cattle, e.g. veal calves under 100 kg, the maintenance requirement was probably somewhat higher than that of older, but still growing, animals and than that of mature animals. Above 150 kg maintenance requirements per metabolic weight appear to stabilise at values between 500 and 400 kJ ME*. The figures obtained with Method A (fasting) were considered to be not very reliable. With regard to values obtained by regression model C4 for veal calves, close to 460 kJ ME_m, it was stated that comparisons of these values with those for older ruminating animals should be based on net energy rather than ME requirements. Probably some 560 kJ ME of rations for ruminating cattle contain the same maintenance net energy as 460 kJ ME of a milk replacer ration for veal calves. It demonstrates the so calculated higher net energy requirement for maintenance of pre-ruminant cattle under 150 kg. However, these high values might be apparent rather than true, so model C9 might better be used to obtain maintenance values. So far this has not been done but it would probably lower the ME_m^* estimate.

The variation of the values 500-400 kJ ME/$W^{3/4}$ for ruminating cattle was said to be due to measurement errors, differences in behaviour and in adaptation to housing and treatment during the experiments as well as to individual variation. Seen in the light of our present knowledge, part of the higher maintenance values of the younger cattle may have been due to a too low estimate of the costs of protein deposition.

More recent work gave results which in general were in agreement with the conclusions reached above. VERMOREL et al. (1974) in male Normand veal calves of 90-240 kg, fed milk replacer at one high feeding level only and found a value of 402 kJ ME_m^* when applying model C4. KIRCHGESSNER et al. (1976) using the

comparative slaughter technique for German Braunvieh veal calves of 55-155 kg calculated ME_m^* values of 431 using model C5 and of 498 using model C4. In experiments with male Friesian calves fed mainly milk replacer *ad libitum* or 25 per cent less, VERMOREL *et al.* (1979) found a value of 452 kJ at an age of 5 weeks, using model C. HOFFMANN *et al.* (1977) obtained for male German Black and White calves below 75 kg, fed a similar diet, a value of 452, calculated by decreasing the ME intake by 0.72 times the energy retention. WEBSTER *et al.* (1976) found in male British Friesian veal calves, fed milk replacer at 3 feeding levels for periods of 2-3 weeks in the weight range of 90-210 kg by regressing RE* on ME* a ME_m^* of 675 kJ. At the highest level the calves gained 1.4 kg/day. They were kept separately and could not see or smell each other which might partially explain this very high value. In the experiments of VAN ES and of those described above the animals could at least smell or see one other calf.

For all these values of pre-ruminant calves it holds true that for comparison with the ME_m^* values of 420-500 kJ of older ruminating cattle they have to be increased by some 20 per cent. Then most values become above or near 500, i.e. fairly high, probably due to the higher physical activity of these calves and due to an underestimation of the costs of protein deposition or " work of growth " at the higher feeding levels.

THORBEK and HENCKEL (1976) found with Method C for growing male Red Danish and Holstein-Friesian calves of 100-250 kg fed a diet of concentrates and hay, values for ME_m^* of 519 kJ at a high and of 423 at a lower feeding level; Method B gave a value of 431.

When the calves of VERMOREL *et al.* (1979) became older and milk replacer was gradually replaced by solid feed, maintenance values decreased from 10 to 34 weeks in 3 groups (414 → 385 kJ — *ad libitum* —; 356 → 318 kJ — 3/4 × *ad libitum* — and 414 → 385 kJ — *ad libitum* —) and increased in one (356 → 385 kJ — 3/4 × *ad libitum* —) when to calculate these values a k_g was used obtained within groups at a given age (10, 23 and 34 weeks) by regressing RE* on ME*. Final weights were about 310 kg for the *ad libitum* groups and about 265 kg for the others. HOFFMANN *et al.* (1977) assumed that the utilisation of the ME for growth of their bull calves at weights of 70-250 kg, receiving more and more solid feed, decreased linearly from 72 to 56 per cent and by using these k_f-values obtained maintenance values of 506 between 75 and 100 kg, 540 between 100 and 225 kg and 510 between 225 and 250 kg.

VERMOREL *et al.* (1979) found k_g values of 51-46 per cent, i.e. much lower than the values of 72 → 56 per cent used by HOFFMANN *et al.* (1977); however the ME_m^* estimates of VERMOREL *et al,* were much lower. The rations of these two studies hardly differed as to metabolisability. The k_g values of HOFFMANN *et al.* were estimates, taking into account a k_g value of 58 per cent obtained with model C4 for all results of their bulls, most of which (77 per cent) weighed more than 250 kg during the measurements. Maybe lower estimates of k_g than 72 → 56 per cent should have been used in view of the higher relative rate of protein deposition below versus above 250 kg. The fact that in the calculations of VERMOREL *et al.* k_g was calculated within narrow age-ranges, might explain their low k_g values, accounting more correctly for the protein deposition costs.

GARRETT (1970) did not detect significant differences in ME_m^* between Hereford steers and heifers weighing 195-520 and 195-430 kg respectively, the estimates being 456 ± 62 and 464 ± 59 for the regression of log H* on ME* and 515 ± 29 and 506 ± 25 for the regression of RE* and T*. Although the same high-concentrate ration was fed both *ad libitum* and near maintenance, lack of information makes

correction of the maintenance estimate in view of present knowledge on costs of protein deposition and physical activity impossible.

Also in a study of most of his comparative slaughter trials GARRETT (1979) found nearly the same values for his calculated F-values for steers and heifers. The study did not contain information on ME_m^*-estimates.

HOFFMANN et al. (1977) derived from all their results with growing bulls in the range of 50-500 kg a k_g-value of 58 per cent by regressing EB* on ME*. Using a k_g-value of 56 per cent for the animals above 250 kg gave maintenance values of 417, 460 and 414 kJ for the weights of 250-300, 300-325 and above 325 kg respectively.

GEAY et al. (1979) using the comparative slaughter technique while assessing final body energy from 11th ribcut and fifth quarter's fat, studied Charolais × Salers bulls and heifers fed ad libitum and restrictedly. Maintenance values obtained by plotting EB* against ME* were close to 450 kJ, slightly more for the bulls than for the heifers.

WEBSTER (1979) calculated predicted basal metabolism F^1 (discussed above) for Friesian and Aberdeen Angus × Friesian steers, Hereford × Friesian steers and Hereford × Friesian bulls, as being 440 $W^{3/4}$, 676 $W^{0.65}$ and 788 $W^{0.65}$ kJ, respectively. The latter two estimates, if converted to $W^{3/4}$, become for W = 250 kg 389 $W^{3/4}$ and 454 $W^{3/4}$ and for W = 450 kg 367 $W^{3/4}$ and 428 $W^{3/4}$. For comparison purposes these values are divided by the k_m values used to calculate F^1; so we obtain the following values of predicted ME_m^{*1}: 587 (F + A × F steers); for 250 kg 519 and for 450 kg 489 (H × F steers); for 250 kg 605 and for 450 kg 571 (H × F bulls). These rather high values, especially those of the bulls growing on average 1.3 kg per day (versus 0.9 for the steers), will partly be due to the high (mature) values of k_f used. Thus it is probable that actual ME_m^* values were lower but there is insufficient information in the publications to calculate their size e.g. by using model C9.

TYRRELL and MOE (1979) fed 8 Hereford heifers during their growth from 220 to 430 kg at ad libitum and near maintenance feeding levels. Using a common k_f derived from the whole material they estimated average maintenance values of 515 and 456 for the two rations used. There was a tendency toward a decline with increasing age; the values at the high feeding levels were higher than at the maintenance level. For these high feeding levels the value of k_f used might have been too high in view of the greater rate of protein deposition so that their ME_m^* estimates became too high.

Table 1 summarises the more recent results; comments are made to express the author's view that some estimates of ME_m are incorrect in view of the method of computation used. The values of WEBSTER et al. and WEBSTER are high compared to all other estimates. Only part of the discrepancy can be explained. Taking into account the more efficient utilisation of the ME of the diets of pre-ruminant calves, their ME_m estimates are high, most probably because they are not completely free from protein deposition costs or " work of growth " and furthermore perhaps, because of their higher physical activity. The estimates in the weight range of 70-250 kg at high feeding level might also include some protein deposition costs or " work of growth ". This also applies, to a progressively lesser extent, to the cattle above 250 kg. A tentative estimate of ME_m^*, not or hardly containing protein deposition or " work of growth " costs, might be 400 kJ both for pre-ruminant calves and also for older cattle; it should be understood that the 400 kJ ME of the calves is equal to some 500 kJ ME for older cattle.

TABLE 1

SURVEY OF ESTIMATED MAINTENANCE REQUIREMENTS

Source	Weight range (kg)	Sex	Feeding level[1]	kJ ME*$_m$	Comment
VERMOREL et al. (1974)	90-240	bulls	H, M	402)	Add about 20% for comparison with ruminating cattle
KIRCHGESSNER et al. (1976)	35-155	"	H	431, 498)	
VERMOREL et al. (1979)	about 75	"	H, M	452)	
HOFFMANN et al. (1977)	< 75	"	H, M	452)	
WEBSTER et al. (1976)	90-210	"	H, M, L	675	Calves kept single and isolated
THORBEK & HENCKEL (1976)	100-250	bulls	H	519	low due to M
	100-250	"	M	423	low due to L
	100-250	"	L	431	
VERMOREL et al. (1979)	75-310	"	H	414→385	low due to M
	75-265	"	M	356→318	low due to M
	75-265	"	M	356→385	
HOFFMANN et al. (1977)	70-250	"	H, M	506, 540,	too high due to high k$_g$
				510	
GARRETT (1970)	195-520	steers	H, M	456± 62;	interpretation is difficult
				515± 29	
	195-430	heifers	H, M	464± 59;	
				506± 25	
HOFFMANN et al. (1977)	250-300	bulls	H, M	417	
	300-325	"	H, M	460	
	> 325	"	H, M	414	
GEAY et al. (1979)	200-500	heifers	H, M	468	
	200-500	steers	H, M	435	
WEBSTER (1979)	70-480	steers	H	587	high due to high k$_f$
	80-550	"	H	519-489	"
	80-460	bulls	H	605-571	"
TYRRELL & MOE (1979)	220-430	heifers	H, L	515, 456	"

[1]Feeding level: H = ad libitum or nearly so; M = ¾ x H; L = near maintenance

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