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Maintenance requirements for energy in cross-bred cattle*

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1. Twenty-seven energy and protein balances were done using nine cross-bred (Brown Swiss × Sahiwal) mature bullocks in a series of three balance trials. The bullocks were fed 75, 100 and 125% of the metabolizable energy (ME) and digestible crude protein standard values recommended by the (US) National Research Council (1966). Heat production was estimated by indirect calorimetry, by collection and analysis of respiratory gases.

2. Utilization of energy for maintenance and fat production was estimated by computing regression of energy balance *v.* digestible energy (DE) and ME separately on a metabolic body size (kg body-weight $(W)^{0.75}$) basis. Maintenance energy requirements and efficiency of utilization of ME for lipogenesis were estimated using multiple regression of ME intake, also. Heat production (and thus energy balance) was corrected for excess nitrogen intake.

3. An attempt was made to measure basal heat production of bullocks so that the net energy requirements for maintenance could be estimated. Extrapolation of the regression line of energy balance *v.* ME intake below maintenance on a $W^{0.75}$ basis gave a basal metabolism of 348·09 kJ/$W^{0.75}$ per d.

4. Energy requirements for maintenance were (kJ/kg $W^{0.75}$ per d): 539·43 DE, 448·81 ME and 348·09 net energy. The results of multiple regression gave a requirement of 432·15 kJ ME/kg $W^{0.75}$ per d for maintenance.

5. The efficiency of utilization of ME for maintenance was 81·34% while for lipogenesis it was 54·5%.

The feeding standards at present used in India (Sen & Ray, 1964) are the same as those evolved in temperate countries, although the results of work carried out in India on nutrient requirements of Indian breeds of cattle (Mullick & Kehar, 1952, 1959; Mullick, 1959*a*, *b*; Mudgal, 1963, 1969; Gopal Krishna, 1971) have suggested that the energy requirements for these animals are different from those recommended as the standard feeding values. With the launching of a cross-breeding programme, more high-producing cows are being bred for which the feeding standards for economic and optimum milk production are yet to be estimated. At present no systematic results are available on nutrient requirements of these cattle. Energy requirements for maintenance are of fundamental importance in correct feeding of any animals.

EXPERIMENTAL

Design of experiment

Nine cross-bred bullocks (Brown Swiss × Sahiwal), castrated at 1·5 years and ranging in age from 4 years 4 months to 5 years 5 months, were selected and were divided into heavy-, medium- and low-weight groups of three bullocks each. From these three groups one heavy-, one medium- and one low-weight bullock was

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Table 1. *Experimental design and details of the bullocks used in the balance trials*

Animal no.	Date of birth	Live weight at start of experiment (kg)	Energy levels: Period 1* (January–February 1970)	Period 2* (February–March 1970)	Period 3* (March–April 1970)
			Low-protein (LP) group†		
57	21 July 1965	538	ME	HE	LE
74	3 July 1966	460	HE	LE	ME
72	7 May 1966	428	LE	ME	HE
			Medium-protein (MP) group†		
60	30 July 1965	590	LE	ME	HE
59	28 July 1965	515	HE	LE	ME
83	23 August 1966	376	ME	HE	LE
			High-protein (HP) group†		
14	12 February 1964	548	LE	HE	ME
70	17 March 1966	464	HE	ME	LE
69	9 May 1966	464	ME	LE	HE

LE, ME and HE represent 75, 100 and 125 % of the (US) National Research Council (1966) metabolizable energy requirements for maintenance.
* Each period included 7 d adjustment, 21 d preliminary, 7 d collection and 9 d respiration periods.
† LP, MP and HP represent 75, 100 and 125 % of the (US) National Research Council (1966) digestible crude protein requirements for maintenance.

randomly selected to constitute one protein group. The three groups of bullocks thus formed were called low-, medium- and high-protein groups. The experimental design was in three 3 × 3 Latin squares with three bullocks and three levels of energy intake for each level of protein intake. The three levels of protein intake and three levels of energy intake used were 75, 100 and 125 % of the digestible crude protein and metabolizable energy (ME) standards for maintenance recommended by the (US) National Research Council (1966). The 75, 100 and 125 % digestible crude protein levels were termed LP, MP and HP levels and the 75, 100 and 125 % ME levels were termed LE, ME and HE levels. The details of the animals and the experimental design are shown in Table 1.

Each experimental period was preceded by a 7 d adjustment period during which all animals were fed according to (US) National Research Council (1966) standards. The experimental period consisted of 7 d adjustment, 21 d preliminary, 7 d collection and 9 d respiration periods. During the 'collection' period, a total collection of faeces and urine was made. During the 'respiration' period the heat production was measured by indirect calorimetry using Douglas bags for collection of respiratory gases which were analysed using the Haldane gas analysis apparatus. Energy balances were calculated by subtracting heat production from ME intake. A total of twenty-seven energy balance determinations were completed using nine bullocks at different feeding levels.

Table 2. *Composition (g/kg) of the concentrate mixtures given to bullocks during balance trials*

	Mixture		
Ingredients	A	B	C
Wheat bran	674	774	874
Groundnut cake (decorticated)	270	170	70
Mineral mixture*	28	28	28
Sodium chloride	28	28	28
DCP	180	150	120
ME (MJ/kg)	10·01	9·93	9·81

DCP, digestible crude protein; ME, metabolizable energy; calculated from values reported by Sen & Ray (1964). ME has been calculated on the basis that 1 g total digestible nutrients contained 15·0995 kJ ME.

* The mineral mixture contained (g/kg): calcium 236, phosphorus 114, copper 1·8, cobalt 0·3, manganese 0·51, iodine 1·0, sulphur, 7·5, iron 2·4, sodium chloride 300.

Diets

Feeding-stuffs used were green berseem (*Trifolium alexandrinum*), oat straw (*Avena sativa*), Bengal gram husk (*Cicer arietinum*) and concentrate mixtures. Oat straw and gram husk were used only as energy sources, on the assumption that these foods contained no digestible crude protein (Sen & Ray, 1964). The composition of the concentrate mixtures is given in Table 2 and the feeding regimen for the experimental animals in Table 3. Feeding was at 12.00 hours each day throughout the experimental period. Concentrates and gram husk were offered first, followed by roughages. Water was offered at 08.00, 13.00 and 18.00 hours daily.

Housing and management

The bullocks were housed in a well-ventilated byre, spaciously partitioned with iron bars. During the collection period the animals were housed in metabolism stalls. All animals were weighed every 2 weeks and before and after each metabolism trial for 3 consecutive days. Weighings were done before the animals had any access to water or food.

Analytical methods

Faeces were collected manually and the urine was collected using collecting funnels held against the navel of the bullocks by means of rubber belts. Sampling of the faeces and urine was done every day at 07.30 hours. For nitrogen estimation, faeces were preserved in 5 ml 18 M-sulphuric acid and the urine in 10 ml concentrated sulphuric acid. For the estimation of energy, the urine sample was preserved with 1 ml potassium dichromate–mercuric chloride solution (Blaxter, Clapperton & Martin, 1966). The methods described by the Association of Official Agricultural Chemists (1960) were used to determine moisture, diethyl-ether extract, crude fibre and N in food and faeces, except for the estimation of the moisture content of the faeces, when the method of Bratzler & Swift (1959) was used. The energy content of the food, faeces and urine were estimated using a ballistic bomb calorimeter (A. Gallenkamp & Co. Ltd, London).

Table 3. *Composition and daily intakes (kg) of rations of bullocks during periods 1–3* of balance trials*

				Rations						
Group no.	Level of feeding	Period no.	Animal no.	Oat straw	Berseem (*Trifolium alexandrinum*)	Mixture† A	Mixture† B	Mixture† C	Gram husk (*Cicer arietinum*)	Refusals‡
1	LP–LE	1	72	2·8	5·5	—	—	1·0	—	—
		2	74	2·8	5·5	—	—	1·0	—	—
		3	57	3·0	8·5	—	—	1·0	—	—
2	LP–ME	1	57	3·5	8·5	—	—	1·0	—	—
		2	72	3·0	4·5	—	—	1·0	—	—
		3	74	3·0	7·0	—	—	1·0	1·4	—
3	LP–HE	1	74	4·0	5·5	—	—	1·0	2·0	—
		2	57	4·0	7·0	—	—	1·0	2·3	—
		3	72	4·0	5·5	—	—	1·0	2·0	0·4 gram husk
4	MP–LE	1	60	2·0	12·6	—	1·0	—	—	—
		2	59	2·0	12·0	—	1·0	—	—	—
		3	83	2·0	7·0	—	1·0	—	—	—
5	MP–ME	1	83	2·5	7·0	—	1·0	—	1·0	—
		2	60	3·0	12·6	—	1·0	—	1·1	—
		3	59	3·0	12·0	—	1·0	—	1·0	0·5 oat straw
6	MP–HE	1	59	4·0	10·0	—	1·0	—	1·6	0·4 oat straw
		2	83	3·0	7·0	—	1·0	—	2·0	0·2 oat straw, 0·6 gram husk
		3	60	4·2	12·6	—	1·0	—	2·0	—
7	HP–LE	1	14	1·0	15·4	1·0	—	—	—	—
		2	70	1·0	13·0	1·0	—	—	—	—
		3	69	1·0	13·0	1·0	—	—	—	—
8	HP–ME	1	70	3·1	13·0	1·0	—	—	—	—
		2	69	3·1	13·0	1·0	—	—	—	—
		3	14	3·3	15·4	1·0	—	—	—	—
9	HP–HE	1	69	3·0	13·0	1·0	—	—	1·7	0·2 oat straw
		2	14	3·0	13·0	1·0	—	—	2·0	0·3 gram husk
		3	70	3·0	13·0	1·0	—	—	1·7	—

LP, low-protein; MP, medium-protein; HP, high-protein; LE, low-energy; ME, medium-energy; HE, high-energy; representing 75, 100 and 125 % respectively of the digestible crude protein and metabolizable energy requirements recommended by the (US) National Research Council (1966). For details, see Table 1 and p. 128.

* For details, see Table 1; each period included 7 d adjustment, 21 d preliminary, 7 d collection and 9 d respiration periods.

† For details of composition, see Table 2.

‡ Average values for 7 d collection period.

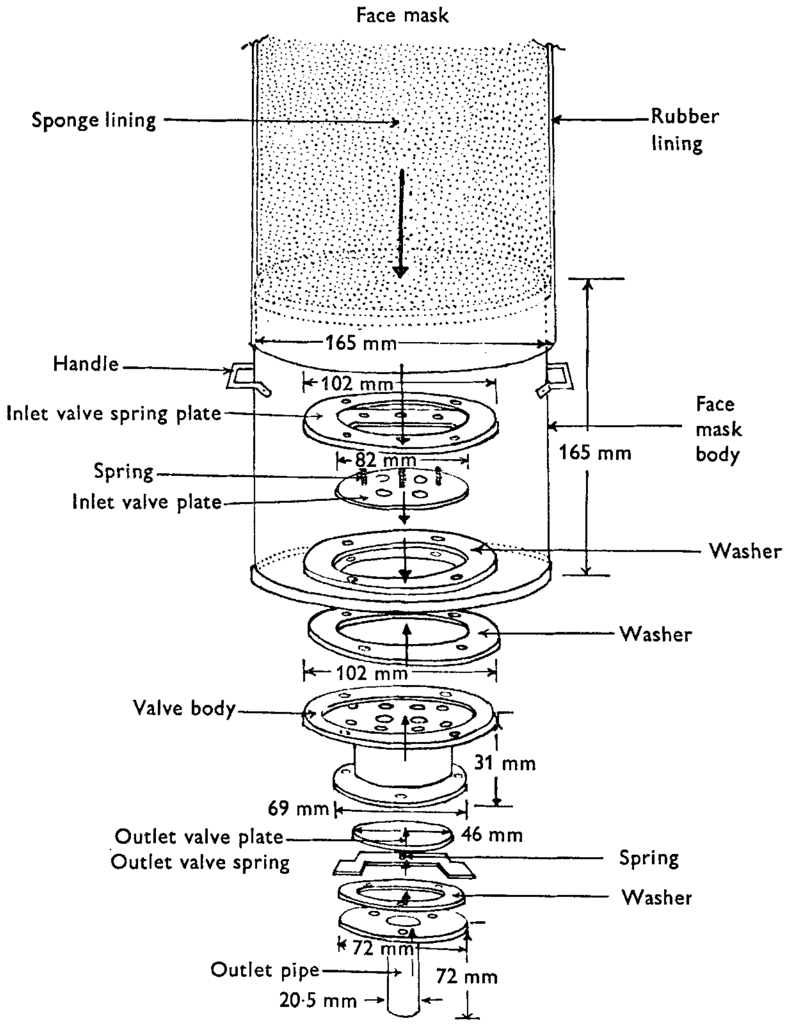

Fig. 1. Diagrammatic representation of the face mask constructed for use with the open-circuit metabolism apparatus used to measure respiratory gases in balance trials using bullocks.

For each animal, the respiratory gas exchange was measured for 3 consecutive days at 09.00, 15.00, 18.00 and 21.00 hours (i.e. 3, 6, 9 and 21 h after feeding). An open-circuit metabolism apparatus was used for respiratory measurements. During measurements air was inspired through the inlet valve and the body of the mask and was expired through the body of the mask and outlet valve to a 200 l Douglas bag (Daval Rubber Co., Philadelphia, USA). The face mask, which was constructed locally, is shown in Fig. 1. The volume of the bag allowed the collection of the expired gas to be made for about 4–5 min. The expired gas volume was measured using a water-sealed gas meter as described by Shepherd (1955). The gas samples were analysed for carbon dioxide and oxygen content by the Haldane method (Brody, 1968). Methane was estimated from the digested carbohydrates using the formula of Bratzler & Forbes (1940): $E = 4.012x + 17.68$; where E is methane produced (g) and x is carbohydrate digested (g × 100). To obtain values for methane production in l the values were divided by 0.716 (Brouwer, 1965).

Heat production was calculated from the respiration results and urinary N excretion using the equation of Blaxter (1970): $H = 16.18(O_2) + 5.02(CO_2) - 2.17(CH_4) - 5.99(N)$; where H is heat production (kJ); (O_2) is oxygen consumption (l); (CO_2) is carbon dioxide production (l); (CH_4) is methane production (l) and (N) is urinary nitrogen (g).

The heat production values obtained at 3, 6, 9 and 21 h after feeding were then averaged to represent daily heat production.

RESULTS

The average nutrient intakes per d and the live-weight changes per d for the various groups of bullocks are shown in Table 4. The ME intake ranged from 333.6 kJ/kg metabolic body size ($W^{0.75}$) per d in group HP–LE to 669.2 kJ/kg $W^{0.75}$ per d in the LP–HE group. These values were 67.42 and 135.27%, respectively, of the recommended standards of the (US) National Research Council (1966). The digestible crude protein intake ranged from 2.055 g/kg $W^{0.75}$ per d in group LP–HE to 3.851 g/kg $W^{0.75}$ per d in group HP–ME. These values were 72.42% and 135.75% of the recommended values of the (US) National Research Council (1966) respectively.

The energy balance results, with statistical analysis, are shown in Table 5. Losses of energy in faeces, methane and heat production and energy retention increased significantly ($P < 0.01$) as the level of energy in the diet increased. Protein level did not affect these losses significantly ($P > 0.05$). Loss of energy in the urine was not affected by either the energy or the protein level. Maximum energy retained and lost by the bullocks was +128.5 and −82.3 kJ/kg $W^{0.75}$ per d. Heat production ranged from 411.4 kJ/kg $W^{0.75}$ per d in group MP–LE to 540.7 kJ/kg $W^{0.75}$ per d in group LP–HE.

Regression lines were calculated to determine the relationships between DE and ME intakes and the energy retained on the basis of kg $W^{0.75}$. As excess N causes a decrease in heat production and thus a decrease in energy retention of 30.55 kJ/g excess N (Tyrrell, Moe & Flatt, 1970), the heat production values were adjusted by subtracting 30.55 kJ for each g excess N. The excess N intake was computed by subtracting the N required for maintenance from digestible N intake. The N required for maintenance was calculated by computing the regression of N balance *v.* digestible crude protein intake (Patle & Mudgal, 1975). The regression equations are shown in Table 6. Zero energy retention represented maintenance energy requirements. The existing points appeared to fit the regression line quite well. The correlation coefficients for energy balance *v.* DE, and *v.* ME intake, were 0.995. This was highly significant. The maintenance energy requirements obtained by extrapolation of energy intake to zero energy retention yielded values of 539.43 kJ DE/kg $W^{0.75}$ per d and 448.81 kJ ME/kg $W^{0.75}$ per d.

Table 4. *Nutrient intakes from different rations by different groups of bullocks during balance trials*

(Mean values with their standard errors for three bullocks/group)

Group no. ...	1		2		3		4		5		6		7		8		9	
Level of feeding ...	LP–LE		LP–ME		LP–HE		MP–LE		MP–ME		MP–HE		HP–LE		HP–ME		HP–HE	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Initial live wt (kg)	448·0	15·2	468·3	25·7	467·3	22·8	507·7	55·1	488·0	57·9	488·7	58·3	498·3	24·9	489·3	25·3	490·7	24·6
Live-wt change (kg/d)	−0·133	0·13	0·099	0·02	0·440	0·07	−0·177	0·02	0·111	0·04	0·388	0·04	−0·444	0·10	0·178	0·02	0·422	0·06
(/kg metabolic body size (body-wt$^{0.75}$))																		
Dry matter (g)	43·00	0·93	57·16	1·45	71·90	2·04	39·80	2·44	57·20	1·26	68·73	3·82	36·23	2·20	55·80	1·61	67·03	2·71
Digestible energy (kJ)	481·00	23·9	636·9	12·2	795·4	35·3	438·4	15·0	614·5	15·5	767·4	42·5	410·4	12·5	650·9	12·9	765·2	35·9
Metabolizable energy (kJ)	401·3	24·2	533·1	9·9	669·2	23·0	361·10	11·0	511·7	16·5	646·7	35·0	333·6	12·0	550·0	16·0	644·1	27·1
Digestible crude protein (g)	2·055	0·106	2·169	0·160	2·055	0·010	2·858	0·049	2·980	0·069	3·055	0·025	3·780	0·104	3·851	0·063	3·731	0·180
(as a percentage of (US) National Research Council (1966) standard values)																		
Metabolizable energy	81·12	4·90	107·75	2·01	135·27	4·65	72·99	2·24	103·42	3·32	130·71	7·09	67·42	2·42	111·17	3·23	130·20	5·49
Digestible crude protein	72·45	3·76	76·44	5·57	72·42	1·09	100·74	1·74	105·04	2·44	107·69	0·99	133·29	2·59	135·75	2·23	131·52	6·35

LP, low-protein; MP, medium-protein; HP, high-protein; LE, low-energy; ME, medium-energy; HE, high-energy; representing 75, 100 and 125 % respectively of the digestible crude protein and metabolizable energy requirements recommended by the (US) National Research Council (1966). For details, see Table 1 and p. 128.

Table 5. *Energy balances (MJ/kg body-wt$^{0.75}$ per d) in different groups of bullocks during balance trials*

Group no. ...	1	2	3	4	5	6	7	8	9	Statistical analysis				
Level of feeding ...	LP–LE	LP–ME	LP–HE	MP–LE	MP–ME	MP–HE	HP–LE	HP–ME	HP–HE	SE_1	SE_2	Protein	Energy	Interaction
Energy intake	0·7938	1·0293	1·2891	0·7360	1·0219	1·2382	0·6732	1·0358	1·2042	0·108	0·118	*	**	NS
Energy in faeces	0·3128	0·3924	0·4937	0·2977	0·4074	0·4707	0·2628	0·3850	0·4389	0·064	0·063	NS	**	NS
Energy in methane	0·0544	0·0765	0·0996	0·0508	0·0713	0·0888	0·0438	0·0707	0·0901	0·003	0·015	NS	**	NS
Energy in urine	0·0252	0·0273	0·0266	0·0265	0·0315	0·0319	0·0331	0·0301	0·0310	0·016	0·013	NS	NS	NS
Heat production	0·4271	0·4793	0·5407	0·4114	0·4650	0·5259	0·4158	0·4907	0·5325	0·086	0·095	NS	**	NS
Energy retained	−0·0257	0·0537	0·1285	−0·0503	0·0467	0·1208	−0·0823	0·0593	0·1118	0·046	0·050	NS	**	NS

LP, low-protein; MP, medium-protein; HP, high-protein; LE, low-energy; ME, medium-energy; HE, high-energy; representing 75, 100 and 125 % respectively of the digestible crude protein and metabolizable energy requirements recommended by the (US) National Research Council (1966). For details see Table 1 and p. 128; NS, not significant; SE_1, standard error of difference between two protein levels at the same or different energy levels; SE_2, standard error of difference between two energy levels at the same protein level.

* $P < 0.05$; ** $P < 0.01$.

Table 6. *Equations describing the relationship between daily energy intake and daily energy retention, and energy intake and heat production by bullocks*

	Linear equations	Correlation coefficient (r)	
1	EB = 0·5219 DE − 281·53	0·995	(all bullocks)
2	EB = 0·6019 ME − 270·14	0·995	(all bullocks)
3	EB = 0·8134 ME − 348·09	0·980	(bullocks in negative balance)
4	EB = 0·5463 ME − 236·50	0·997	(bullocks in positive balance)
5	HP = 0·4016 ME + 268·33	0·997	(all bullocks)
	Multiple regressions	**Multiple correlation coefficient (R)**	
a	MEI = 0·425 MBS + 1·835 EG − 1·287 EL + 0·776	0·998	(all bullocks)
b	MEI = 0·373 MBS − 1·072 EL + 4·715	0·988	(bullocks in negative balance)
c	MEI = 0·429 MBS + 1·818 EG + 0·511	0·998	(bullocks in positive balance)

EB, Energy balance (kJ/kg body-wt $(W)^{0.75}$ per d); ME, metabolizable energy (kJ/kg $W^{0.75}$ per d); MEI, metabolizable energy intake (MJ/d); EG, energy gain in the body (MJ/d); DE, digestible energy (kJ/kg $W^{0.75}$ per d); HP, heat production (kJ/kg $W^{0.75}$ per d); MBS, metabolic body size (kg); EL, energy loss from the body (MJ/d).

The ME requirement for maintenance was also computed by multiple regression using the following model:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3;$$

where Y is ME intake corrected for excess N (MJ); X_1 is $W^{0.75}$ (kg); X_2 is energy retained in the body (MJ) and X_3 is energy lost from the body (MJ).

The energy gain or loss from the body are not separate measurements but are the arbitrary divisions of the energy balance results depending upon positive or negative energy balances. In this model, b_1 represents ME (MJ) required for maintenance/kg $W^{0.75}$ and b_2 represents ME (MJ) required for each MJ of tissue gain: b_3 represents ME (MJ) spared per MJ of body tissue loss. The constant 'a' represents the amount of ME which is not attributable to any specific variable in this model. This amount of energy was assigned to the maintenance term, as logically the normal turnover of the body stores should be attributed to the maintenance requirements (Moe, Tyrrell & Flatt, 1970, 1971). This was done by dividing a by average $W^{0.75}$ and adding it to the coefficient b_1. For bullocks in negative balance the adjustment was as follows: $0.3731 + (+4.715 \div 104.21) = 0.41836$ MJ. The reciprocal of b_2 represents the efficiency of utilization of ME for lipogenesis.

The multiple regression analysis of the ME intake by bullocks is shown also in Table 6. Separate regressions were computed for bullocks in negative balance, for bullocks in positive balance and for all bullocks: their maintenance energy requirements were 418·36, 433·99 and 432·15 kJ ME/kg $W^{0.75}$ per d respectively. The efficiency of utilization of ME as found by multiple regression was 55·01 % for bullocks in positive energy balance and 55·4 % for all bullocks.

Basal heat production or energy lost from the body at zero energy intake represents the net energy requirements for maintenance under idle conditions (Brody, 1945;

Table 7. *The daily maintenance energy requirements (kJ) of cattle and their composition, as obtained in the present experiment with some reported values*

Source of values	Type of cattle used	Requirement (per kg metabolic body size (body-wt$^{0.75}$)) Digestible energy	Metabolizable energy	Net energy
From present experiment	Bullocks (Brown Swiss × Sahiwal	539·43	448·81 (linear equation); 432·15 (multiple regression)	348·09
Garrett, Meyer & Lofgreen (1959)	Angus steers	572·51	467·04	263·65
Hashizume, Kaishio, Ambo, Tanaka, Hamada & Takahashi (1963)	Japanese black cows	422·73	397·32	228·25
	Holstein cows	621·39	473·62	317·01
Flatt, Coppock & Moore (1965)	Dry Holstein cows	—	439·42, 468·72 426·87	—
Agricultural Research Council (1965)	All cattle	—	451·98	334·80
(US) National Research Council (1966)	All cattle	601·55	494·71	—

Blaxter, 1962). Basal heat production may be estimated by extrapolation of the curve obtained by plotting heat production *v.* ME intake/kg $W^{0.75}$ (Garrett, Meyer & Lofgreen, 1959). The basal heat production of bullocks thus found was 268·33 kJ/kg $W^{0.75}$ (equation 5, Table 6). Knox, Crownover & Wooden (1970) suggested that the basal metabolism could be obtained by plotting energy balance *v.* ME intake below maintenance, on a $W^{0.75}$ basis. The theoretical fasting metabolism was 348·09 kJ/kg $W^{0.75}$ per d. The value for b in equation 3 (Table 6) was 0·8134, giving a value of 81·34% for the efficiency of utilization of ME for maintenance.

Separate regression was also obtained by plotting energy balance *v.* ME intake above maintenance on a $W^{0.75}$ basis. The value for b in equation 4 (Table 6) was 0·5463, a giving a value of 54·63% for the efficiency of utilization of ME for fat production.

DISCUSSION

The maintenance energy requirement obtained by multiple regression of ME intake was 432·15 kJ ME/kg $W^{0.75}$ per d, whereas the regression of energy balance *v.* ME intake on the basis of $W^{0.75}$ gave the value 448·81 kJ ME/kg $W^{0.75}$ per d. Brouwer, Van Es & Nijkamp (1965) suggested that regression of energy retention *v.* ME intake might give inaccurate results as energy retention is computed from the difference between ME intake and heat production. Regression of heat production *v.* ME intake on the basis of kg $W^{0.75}$/d was, therefore, calculated. The amount of ME intake which caused an equal amount of heat production represented the ME requirement for maintenance. The value thus obtained was 448·41 kJ/kg $W^{0.75}$ per d which was not different from the value obtained by regression of energy balance *v.* ME intake.

For comparison a few published values for maintenance energy requirements have been presented in Table 7. The maintenance energy requirements obtained for cross-bred bullocks in the present experiment were remarkably similar to those reported by Flatt, Coppock & Moore (1965) and the Agricultural Research Council (1965) for European breeds of cattle. These values were slightly lower than those obtained by Garrett *et al.* (1959), Hashizume, Kaishio, Ambo, Tanaka, Hamada & Takahashi (1963) and those recommended by the (US) National Research Council (1966). However, in the present experiment the bullocks were restricted to stall feeding only, so the values for energy requirements obtained in this experiment represent only the minimum maintenance energy and do not include an allowance for activity. It may, in practice, be necessary to provide an extra allowance for grazing cattle.

Mullick & Kehar (1952) suggested that Indian cattle required about 20% less energy than that recommended for European breeds of cattle. Mullick & Kehar (1959) also estimated the resting metabolism of highland steers and reported that the resting metabolism for Indian breeds of cattle was lower than the resting metabolism for European breeds of cattle. The resting metabolism reported by Mullick & Kehar (1959) was 17246 kJ/d for a 133·0 kg steer, i.e. 449·89 kJ/kg $W^{0.75}$ per d, which compares well with the ME requirements obtained by linear regression (448·81 kJ/kg $W^{0.75}$ per d) in the present experiment. The former value is 90·97% of the standard value recommended by the (US) National Research Council (1966).

Regression of heat production *v.* ME intake on the basis of $W^{0.75}$ gave a value of 268·33 kJ/kg $W^{0.75}$ per d, while extrapolation of the curve obtained by plotting energy balance *v.* ME intake below maintenance on the basis of $W^{0.75}$ (kJ/kg $W^{0.75}$), gave the value 348·09 kJ/kg $W^{0.75}$ per d. The former value is similar to that (273·82 kJ/kg $W^{0.75}$ per d), reported by Garrett *et al.* (1959) for Angus steers after extrapolating the curve of heat production *v.* ME intake. However, Flatt *et al.* (1965) found that there was a marked difference between the theoretical fasting metabolism values obtained by plotting heat production *v.* dry-matter intake (range 232·36–234·36 kJ/kg $W^{0.75}$ per d) and the actual fasting metabolism value (range 299·65–318·90 kJ/kg $W^{0.75}$ per d). These authors have questioned the biological significance of such theoretical values.

Blaxter (1962) indicated that values for heat production of adult ruminants deviate considerably from the interspecific value of basal heat production of 292·95 kJ/kg $W^{0.75}$ per d, values for sheep being lower by about 15% and those for cattle being higher by about 15%. The Agricultural Research Council (1965) summarized the published results and concluded that the fasting metabolism of mature steers produces about 334·80 kJ/kg $W^{0.75}$ per d. This is in agreement with the fasting metabolism value of 348·09 kJ/kg $W^{0.75}$ per d, obtained by plotting energy balance *v.* ME intake below maintenance on the basis of kg $W^{0.75}$ in the present studies.

The ME requirement for maintenance could also be calculated using fasting metabolism and the efficiency of utilization of ME for maintenance values (equation 3, Table 6). The ME requirement for maintenance thus obtained was $100 \div 81{\cdot}34 = 1{\cdot}23 \times 348{\cdot}09 = 428{\cdot}15$ kJ ME/kg $W^{0.75}$ per d. This value is similar to the value 432·15 kJ ME/kg $W^{0.75}$ per d, obtained by multiple regression in the present studies.

The calculation shows that a reliable estimate of fasting heat production could be obtained by extrapolation of the curve obtained by plotting energy balances *v.* ME intake below maintenance on the basis of kg $W^{0.75}$.

The summary prepared by the Agricultural Research Council (1965) shows that cattle and sheep, on average, utilize the ME of food for maintenance with an efficiency of about 74%: Flatt *et al.* (1965) found the efficiency of utilization of ME for maintenance of cattle was 79.0%. These values are similar to that (81.34%) obtained in the present experiment.

The regression analysis of the energy balance *v.* ME intake above maintenance gave an efficiency of 54.63% (equation 4, Table 6) for lipogenesis. The multiple regression analysis of ME intake also gave a similar value ($1 \div 1.835 = 54.50\%$, equation 9, Table 6) for lipogenesis; Flatt *et al.* (1965) reported a value of 50% and Moe *et al.* (1970), 58.7%.

The regression of energy balance *v.* ME intake below maintenance was significantly ($P < 0.01$) different from that of energy balance *v.* ME intake above maintenance, indicating that the efficiency of utilization of ME for maintenance was significantly ($P < 0.01$) different from, and was higher than, that for lipogenesis. This is in agreement with the results obtained by Flatt *et al.* (1965). Similarly, Greenhalgh (1969) reviewing the literature, concluded that the average efficiency of utilization of ME for maintenance was 74%, whereas that for lipogenesis ranged from 43% for a ration containing 9.2 MJ ME/kg to 62% for a ration containing 13.4 MJ ME/kg. The lower utilization of ME for lipogenesis than for maintenance may be due to the lower efficiency of lipogenesis as compared to that of reactions involved in maintenance.

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