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**THE MAINTENANCE VALUE FOR COWS OF HAY
FROM SIX DISTRICTS IN THE NETHERLANDS**

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I. INTRODUCTION

In three earlier papers (BROUWER et al., 1961, 1964a, b) we studied the maintenance value for cows of early and late cut hay from the same fields. Moreover, the dependence of maintenance requirement on crude fibre and on the metabolisability of the hays was examined; the metabolisability is the percentage of the gross energy which is metabolisable.

In the present paper the maintenance value of six hays as used in practical farming is determined. With this purpose 33 experiments were conducted with six non-pregnant dry cows. Each hay was fed to five or six animals in amounts approximately sufficient for maintenance. During the experimental periods respiration trials were conducted with each animal. The total number of 24-hour trials was approximately 200. A preliminary account of this work has been published in 1964 (VAN ES et al., 1964). In that paper it has already been pointed out that the whole material was also being treated with other statistical methods. These methods, with some refinements, are similar to those in chapter IV of our above mentioned paper 1964b. The results are to be found on the following pages.

II. MATERIALS AND METHODS

II.1. ARRANGEMENT OF THE EXPERIMENTS

The experiments were performed in nine periods (R42 = PI, R43 = PII, ..., R50 = PIX. In every period four experiments were conducted simultaneously, thus with four cows. The total number of experiments was therefore $9 \times 4 = 36$. Unfortunately, three of them with a pregnant cow had to be dropped so that 33 valid experiments with six non-pregnant dry cows remained.

Every experiment consisted of a preliminary period lasting about 17 days and an experimental period of 16 days. In the latter six 24-hour respiration trials were performed with each cow. Moreover digestibility and N-, C- and energy balances were determined in this period. Particulars on the arrangements of the experiments are given in table II.1.

II.2. THE HAYS

The hays have been collected without regard to chemical or botanical composition from six dairy farms all over the country (table II.2). Four of these farms (I, IV, V, and VI) were private enterprises; farm II and III were experimental farms. We extend our thanks to the managements of the farms for their co-operation and for their informations on the particulars of the hays.

The hays consisted of mixed grasses and had been harvested in the spring of 1960 and 1961. Most of the hays have been cured by spreading the grass on the field. Only one of them (HII) has been barn-dried with cold air and a second one

TABLE II.1. Number of the hays (H); number, month and year of the experimental periods (P); number, name, age and body weight of the cows (K)

Animal	Hay Hi Friesland	Hay Hu N. Holland	Hay Hun Utrecht	Hay Hiv N. Brabant	Hay Hv Overijssel	Hay Hvi Z. Holland
KI, Hinke 14 (4 years)	PI, 428 kg, 9/10-1961	PII, 436 kg, 10/11-1961	PIII, 447 kg, 12-1961	PV, 464 kg, 2-1962	PIX, 479 kg, 7-1962	PVII, 471 kg, 4-1962
KII, Albertje 87 (4 years)	PII, 481 kg, 10/11-1961	PI, 484 kg, 9/10-1961	PVI, 477 kg, 3-1962	PIII, 484 kg, 12-1961	PIV, 475 kg, 1-1962	PVIII, 482 kg, 5/6-1962
KIII, Roosje (8 years)	PII, 536 kg, 10/11-1961	PI, 525 kg, 9/10-1961	PVI, 537 kg, 3-1962	PIII, 553 kg, 12-1961	PIV, 546 kg, 1-1962	PVIII, 538 kg, 5/6-1962
KIV, Roosje 5 (3 years)	PIV, 479 kg, 1-1962	PVIII, 476 kg, 5/6-1962	PVII, 479 kg, 4-1962	PVI, 487 kg, 3-1962	PV, 473 kg, 2-1962	PIX, 490 kg, 7-1962
KV, Lamkje 5 (8 years)	PIV, 498 kg, 1-1962	PVIII, 477 kg, 5/6-1962	PVII, 477 kg, 4-1962	PVI, 486 kg, 3-1962	PV, 483 kg, 2-1962	PIX, 476 kg, 7-1962
KVI, Zwaarte (9 years)				PV, 500 kg, 2-1962	PIX, 490 kg, 7-1962	PVII, 497 kg, 4-1962

TABLE II.2. Some data on the hays

Hay, District and locality	Month and year of harvest	Soil	Curing of the hays		Heating in mow
			Days outdoors	Drying	
HI, Friesland (Siegerswoude) HII, N. Holland (Hoom)	June 1960 May 1960	sand peat	± 13 days ± 8 days	spread on field, some rain at first spread on field (with some rain), later barn drying (with cold air)	some none
HIU, Utrecht (Hoogland) HIV, N. Brabant (Gilze) HVI, Overijssel (Kampen) HVI, Z. Holland (Lekkerkerk)	June 1960 June 1961 June 1961 June 1961	sand sand clay peat	? ± 7 days ± 9 days ± 10 days	on frames, hardly any rain, little sun spread on field, good weather, baled when dry spread on field, first day some rain, occasionally sun spread on field, good weather with little rain	none none some none

(HIII) has been dried on frames. Weather conditions during curing have been tolerably good although there has been some rain. In the mow little or no heating has occurred.

II.3. THE ANIMALS

Originally, six cows, 3–9 years old and supposed to be non-pregnant, have been used. Cow Anna, however, turned out to be pregnant and had to be replaced by an additional animal: cow Zwarte. The experiments with cow Anna were performed while she was in her 5th, 6th and 8th month of pregnancy and for this reason the results of these experiments have been left out.

All animals were healthy and in tolerably good condition, neither fat nor thin, with live weight between 428 and 553 kg (average 488 kg).

The animals were trained to the experimental routine practised during the experimental periods. In the course of each of the experiments they were weighed four times. Roosje and Lamkje 5 had been used in earlier experiments. Some data referring to the cows are given in table II.1.

II.4. THE RATIONS

The rations consisted of hay only, with 30 g of NaCl a day. In preliminary trials with sheep approximate digestion coefficients of the hays had been determined. With the aid of these approximate digestion coefficients and the results of preceding respiration trials with the same cows we succeeded in feeding such quantities of hay that maintenance requirement was met approximately. Consequently the energy balances were only small.

In the first week of the preliminary periods each cow received in total 14 g of $\text{CuSO}_4 \cdot 5\text{aq}$ and 350 mg of $\text{CoSO}_4 \cdot 7\text{aq}$, and in addition, from period PV (R46) onwards, 1 500 000 IU vitamin A and 250 000 IU vitamin D_3 .

II.5. METHODS

Essentially the same techniques and methods have been used as in earlier work of this laboratory (VAN ES, 1961; BROUWER et al., 1964b).

The difference between the energy balance computed from C- and N-balances, and the energy balance computed from intake of metabolisable energy and heat expenditure was in two experiments +1.5% and in all other experiments between +1.1 and -0.3% of the gross energy.

III. EXPERIMENTAL

Data referring to the single experiments on live weight, feed intake, digested feed constituents, digestion coefficients, urine, gaseous exchange, metabolisable energy and balances (N-, C- and energy balances) are given in table A joined to the end of this paper. The smaller tables are inserted in the text.

III.1. COMPOSITION OF THE HAYS

The composition of the hays as administered to the animals is given in table III.1. The figures for each hay are the weighted means of the analyses of three duplicate samples. Each duplicate sample was obtained while weighing the rations for an experiment with two animals. The agreement between the three duplicate samples referring to the same hay was very good.

Although the six hays have been collected from various districts in the Netherlands without regard to chemical composition the crude fibre content in the organic matter was very similar (34.0 to 36.2%). The crude protein content of the organic matter varied much more (9.2 to 18.0%). This discrepancy is not surprising because already many years ago it was shown that the correlation between the contents of crude protein and crude fibre in grass and also in hay is rather low (BROUWER et al., 1938; DIJKSTRA et al., 1939).

Our hays were of only moderate quality as judged from the crude fibre contents in the hays of KELLNER-BECKER's table (1959). The average crude protein content of the organic matter in our hays (13.3%), however, corresponds in KELLNER-BECKER's table with a quality lying between good and very good. A still better quality is shown by the digestion coefficients of the organic matter amounting in our hays to 65.4 on an average (table III.2) whereas for very good quality KELLNER-BECKER's table gives 65.

III.2. DIGESTIBILITY, DIGESTIBLE NUTRIENTS AND METABOLISABLE ENERGY

We just mentioned that the digestibility of the six hays was rather high (table III.2); most digestion coefficients of the organic matter were lying between 65.5 and 69.5. The figures for hay HIV and HVI were however definitely lower (62.4 and 61.1), which, nevertheless, corresponds in KELLNER-BECKER's table with quality: good.

The apparent digestibility of the crude protein varied a great deal (44.2–60.6%). As usually, the digestibility increased with increasing crude protein content. The digestible crude protein content in the organic matter varied from 4.0 to 10.9% (table III.3). The revised formula:

$$\text{dig.cr.prot.} = 0.771 (\text{cr.prot.} - 14) + 7.76$$

of BROUWER and DIJKSTRA (DIJKSTRA, 1951, 1954) gives a good approximation as is shown in the following table.

TABLE III.1. Composition of dry matter and of organic matter in the hays

Hay	Dry matter (%)	On dry matter basis								On organic matter basis							
		Organic matter (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	N-free extr. (%)	Mineral matter (%)	Car-bon (%)	Calorific value (kcal %)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	N-free extr. (%)	Car-bon (%)	Calorific value (kcal %)		
H _i , Friesland	86.60	90.18	15.22	2.03	31.95	40.98	9.82	44.76	436.39	16.88	2.25	35.43	45.44	49.63	483.91		
H _{ii} , N.Holl.	86.16	87.99	15.83	2.69	29.92	39.55	12.01	43.49	425.13	17.99	3.06	34.00	44.95	49.43	483.16		
H _{iii} , Utrecht	88.47	92.36	14.53	2.43	32.72	42.68	7.64	46.02	447.23	15.73	2.63	35.43	46.21	49.83	484.22		
H _{iv} , N.Brab.	88.83	94.34	8.80	1.96	34.10	49.48	5.66	46.24	445.62	9.33	2.08	36.15	52.44	49.01	472.36		
H _v , Overijssel	88.61	89.84	9.53	2.23	31.95	46.13	10.16	44.06	423.23	10.61	2.48	35.56	51.35	49.04	471.09		
H _{vi} , Z.Holl.	89.14	90.94	8.32	1.54	32.00	49.08	9.06	44.42	426.15	9.15	1.69	35.19	53.97	48.85	468.61		
Average (not weighted)	87.97	90.94	12.04	2.15	32.11	44.64	9.06	44.83	433.96	13.28	2.36	35.29	49.07	49.30	477.22		

TABLE III.2. Digestion coefficients

Hay	Dry matter	Organic matter	Crude protein	Crude fat	Crude fibre	N-free extr.	Mineral matter	Carbon	Gross energy	Metabolis. energy	
										% of gross energy	% of dig. energy
H _i , Friesland	64.5	65.5	58.5	33.9	75.4	61.9	55.5	61.3	60.1	47.1	78.4
H _{ii} , N.Holland	67.3	69.5	60.6	47.6	79.3	67.0	52.4	65.3	64.0	50.5	78.9
H _{iii} , Utrecht	66.1	67.4	59.2	39.1	74.5	66.3	50.9	63.5	62.3	49.2	79.0
H _{iv} , N.Brabant	61.6	62.4	49.4	42.1	66.0	63.2	47.6	58.8	57.9	46.0	79.4
H _v , Overijssel	63.3	66.7	44.8	50.6	73.3	67.4	33.8	62.9	61.7	49.2	79.7
H _{vi} , Z.Holland	58.4	61.1	44.2	42.8	62.5	63.6	27.6	57.7	56.7	45.1	79.6
Average (not weighted)	63.5	65.4	52.8	42.7	71.8	64.9	44.6	61.6	60.4	47.8	79.2

Dig.cr.protein in org. matter	Hay	Hr	Hr	Hm	Hv	Hv	HvI
	{ calculated estimated	10.0 9.9	10.8 10.9	9.1 9.3	4.2 4.6	5.1 4.8	4.0 4.0

Furthermore it is interesting that the digestibility of the crude fibre nearly always was higher than that of the N-free extract (table III.2). This phenomenon has been observed several times before. We are not certain whether it is caused by the properties of the crude fibre as such or by differences in fineness of crude fibre particles in the samples of feed and faeces as analysed. In our case the phenomenon is especially striking in the hays with high digestibility of the organic matter. This is also shown in table III.2 of our earlier paper (BROUWER et al., 1964b).

The metabolisable energy was only 45–50% of the gross energy (table III.2). A very small range (78.4–79.7%, with average 79.2%) was found for the percentage of metabolisable energy in the digestible energy. In our earlier just mentioned paper it was 77.4–79.7% with average 79.0%.

TABLE III.3. Digestible nutrients and metabolisable energy in organic matter

Hay	Organic matter (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	N-free extr. (%)	Carbon (%)	Energy (kcal %)	Metab. energy (kcal %)
Hr, Friesland	65.5	9.9	0.8	26.7	28.1	30.4	290.9	228.0
Hr, N.Holl.	69.5	10.9	1.5	27.0	30.1	32.3	309.3	244.0
Hm, Utrecht	67.4	9.3	1.0	26.4	30.7	31.7	301.6	238.3
Hv, N.Brab.	62.4	4.6	0.9	23.9	33.0	28.8	273.5	217.0
Hv, Overijssel	66.7	4.8	1.3	26.1	34.5	30.9	290.5	231.6
HvI, Z.Holl.	61.1	4.0	0.7	22.0	34.4	28.2	265.6	211.4
Average (not weighted)	65.4	7.2	1.0	25.4	31.8	30.4	288.6	228.4

It is well known that the values of metabolisable energy as found by subtracting energy in urine and combustible gases from the digestible energy are somewhat too high in case the protein balance is positive and too low if it is negative. For the correction KELLNER (1900) used 7.45 kcal per gram of stored or lost body-N, that is 1.192 kcal per gram of stored or lost protein ($6.25 \times N$). In our work we neglected this correction because the N-balances were only small. However, in an additional computation, we calculated for our present experiments also the corrected metabolisable energy and its percentage in the digestible energy. For this correction stored or lost body protein (g) was multiplied by the factor 1.2. The next table gives the results computed with uncorrected and with corrected figures of metabolisable energy.

Percentage of metabolisable energy in digestible energy

Hay	H _I	H _{II}	H _{III}	H _{IV}	H _V	H _{VI}	Average
Uncorrected	78.4	78.9	79.0	79.4	79.7	79.6	79.2
Corrected	78.8	79.1	79.1	79.4	79.8	79.7	79.3

The range of the corrected values is indeed a trifle smaller than that of the uncorrected values: 78.8–79.8 versus 78.4–79.7; the averages are practically identical. Moreover, the uncorrected and corrected values of the protein rich hays (H_I, H_{II} and H_{III}) are a trifle lower than those of the protein poor hays (H_{IV}, H_V and H_{VI}).

These results are important for converting figures of digestible energy into figures of metabolisable energy because digestible energy can be determined in simple digestion experiments whereas determination of metabolisable energy is much more troublesome. This requires also determinations of the combustion value of urine constituents and methane. For hays as used in these experiments the conversion factor obviously is 0.79.

Unfortunately, up to now tables of feed stuffs neither contain figures of metabolisable energy nor of digestible energy. However, a reasonable approximation of the digestible energy may be obtained by calculating the calorific value of the digestible nutrients with the aid of the well known conversion factors ($5.7 \times \text{dig.cr.prot.} + 9.5 \times \text{dig.cr.fat} + 4.2 \times \text{dig.cr.fibre} + 4.2 \times \text{dig.NFE}$). In our hays the results were as follows (kcal per 100 g of organic matter).

Hay	H _I	H _{II}	H _{III}	H _{IV}	H _V	H _{VI}
Determined	291	309	302	274	290	266
Calculated	294	316	302	274	294	266

With the data in our earlier paper mentioned above we found:

Hay	1958 early	1958 late	1959 early	1959 late	1960I early	1960I late	1960II early	1960II late
Determined	341	260	350	325	371	270	300	242
Calculated	343	262	350	326	369	272	302	246

In all instances the agreement is good or very good.

III.3. PROTEIN- AND ENERGY BALANCES

Table III.4 shows the balances of protein (calculated as $6.25 \times N$) and of energy (averages per day). 23 protein balances were negative, 8 were positive and two were in equilibrium. In this connection it should, however, be considered that also most of the energy balances were negative. With the hays H_I, H_{II}

and HIII the animals received daily about 500 g of digestible crude protein, with the other hays about 250 g. Notwithstanding this difference the protein balances on the latter hays were not lower than on the former ones, the average being -9 on the low protein hays and -27 on the high protein hays. The average energy balances were somewhat more different: -393 kcal on the protein poor hays and -564 on the protein rich hays. Thus, although the protein provision on the protein poor hays was rather low, a distinct shortage could not be demonstrated.

TABLE III.4. Protein (6.25 × N) and energy balances (averages per day)

Cow	Hay	H _I Friesland	H _{II} N.Holl.	H _{III} Utrecht	H _{IV} N.Brab.	H _V Overijssel	H _{VI} Z.Holl.
		Protein (6.25 × N, g)					
K _I , Hinke 14		-63	+8	+15	+5	+9	+1
K _{II} , Albertje 87		-48	-62	-3	-8	-9	-23
K _{III} , Roosje		-38	-41	-28	-6	±0	-39
K _{IV} , Roosje 5		-57	+8	-18	+6	-22	-16
K _V , Lamkje 5		-41	-15	-18	-5	-38	±0
K _{VI} , Zwarte					+15	-7	-20
		Energy (kcal) ¹					
K _I , Hinke 14		-902	+802	+974	+236	-82	-474
K _{II} , Albertje 87		-463	-1762	-104	-61	-122	-1370
K _{III} , Roosje		+109	-1411	-648	+468	+587	-1534
K _{IV} , Roosje 5		-1434	-781	-1049	-594	-190	-1060
K _V , Lamkje 5		-555	-514	-725	-764	-580	-55
K _{VI} , Zwarte					+5	-116	-1371

¹ Average of balance computed from C- and N-balances, and of balance computed from intake of metabolisable energy and heat expenditure.

As already mentioned, most of the energy balances were negative; 8 were lying between -2000 and -1000 kcal, 18 between -1000 kcal and equilibrium, and 7 between equilibrium and +1000 kcal. We mentioned already that measures had been taken to feed such quantities of hay that the animals were approximately in energy equilibrium.

The balances in the first experiments (period P_I, R42) were lower than most of the later ones because, at that time, the maintenance requirements of the cows was not yet known. Some equally low balances occurred however also in the later experiments of period P_{IV} (R45), P_{VII} (R48), P_{VIII} (R49) and P_{IX} (R50).

IV. REGRESSION ANALYSIS

It has already been mentioned in the preliminary paper (VAN ES et al., 1964) that for making the regression analysis all intakes of metabolisable energy (kcal) and all energy balances (kcal) were reduced to 500 kg body weight by multiplication by $(500/W)^{0.75}$ where W is the actual live weight. The corrected values will be designated by M (metabolisable energy) and G (energy gain) dropping for the sake of simplicity the suffix 500 utilised in the preliminary paper. The actual weights of the cows were not far from 500 kg (428–553 kg with average 488 kg); moreover the animals changed little in weight in the course of the experiments. Therefore, it was not necessary to use in the correction for body weight other exponents than the value 0.75. As far as used in this chapter the same correction factor $(500/W)^{0.75}$ was applied to intake of dry matter and dry matter constituents and also to the nitrogen balances.

A further correction was applied to the positive energy balances, because the efficiency of metabolisable energy for gain is about 0.83 times as high as the efficiency for maintenance, and, thus, the requirement of metabolisable energy is 100/0.83 times as high. Therefore, the figures for *positive* gain were multiplied by 100/0.83. This correction was, however, not important because only 7 out of 33 balances were positive. The average of all 33 corrected balances was -456 kcal. The data corrected as explained above have been used throughout in this chapter on regression analysis.

Just as in the preliminary paper the figures of metabolisable energy intake (M) were reduced to zero balance. Several regression coefficients suitable to this reduction have already been calculated in the preliminary paper (VAN ES et al., 1964). Their accuracy was however low. This was mainly due to the small variance of the energy balances as well as of the composition and metabolisability of the hays although these feeds had been collected without regard to composition from six dairy farms all over the country. Because of this low accuracy of the regression coefficients the reduction of the ingested metabolisable energy to zero balance with the aid of these coefficients presented difficulties so that in the preliminary paper regression coefficients from earlier investigations have been used.

In the present paper the reduction to zero balance has been made in two steps.

The *first step* consisted mainly in the reduction of the metabolisable energy for the single cows to *mean* balance (-456 kcal). Eventually, also in this first step, reductions of the metabolisable energy were made to mean crude fibre (grams ingested or percentage in the organic matter) or to mean metabolisability which is the percentage of the gross energy that is metabolisable.

Afterwards, in the *second step*, the values of the metabolisable energy reduced to mean balance as just mentioned, finally were reduced to *zero* balance. The main conclusions are, however, already drawn after the first step.

For the reduction, in the first step, of the ingested metabolisable energy to mean energy balance and eventually to mean crude fibre intake or to mean

metabolisability we used the partial regression coefficients notwithstanding the fact that these coefficients were considerably lower than expected from our earlier experiments and from the literature. Therefore, their use will be explained with a model, however, for the sake of simplicity, with only one independent variable.

We suppose that there are in total n experiments and put

G_k = energy gain (energy balance) per day in experiment k , with average =

$$\bar{G} = \frac{1}{n} \sum_{k=1}^n G_k.$$

M_k = metabolisable energy intake per day in experiment k , with average = \bar{M} , and

$$G_k - \bar{G} = g_k, \quad M_k - \bar{M} = m_k.$$

The sum of squares of deviations of M from \bar{M} is

$$\sum_{k=1}^n (M_k - \bar{M})^2 = [m^2].$$

This sum of squares will be reduced by correcting the M 's to mean balance, i.e. to average gain \bar{G} . With this intention we first use an arbitrary correction factor β . Considering one pair of variables (G_k, M_k), the corrected M_k -value, say M'_k , is

$$M'_k = M_k - \beta(G_k - \bar{G}).$$

Averaging over all n experiments we find

$$\bar{M}' = \bar{M}.$$

Thus, the reduction to average gain has the advantage that the mean M' -value always equals \bar{M} regardless of the value of β . The value \bar{M}' is, therefore, independent of β .

We now consider the scatter of the M' -values, i.e. of the reduced individual M -values, around their mean value $\bar{M}' = \bar{M}$.

With the arbitrary correction factor β the deviation d_k in the experiment k is

$$d_k = M'_k - \bar{M} = M_k - \beta(G_k - \bar{G}) - \bar{M} = m_k - \beta g_k,$$

so that the sum of squares of deviations is

$$[d^2] = [(m - \beta g)^2] = [m^2] - 2\beta[gm] + \beta^2[g^2],$$

$$\text{or} \quad [d^2] = [g^2] \left\{ \beta - \frac{[gm]}{[g^2]} \right\}^2 + [m^2] - \frac{[gm]^2}{[g^2]}. \quad (1)$$

The value β_0 of β which minimises (1) and, therefore, also the scatter of the M' -values is

$$\beta_0 = \frac{[gm]}{[g^2]}, \quad (2)$$

that is the ordinary regression coefficient, so that the minimum value $[d_0^2]$ of (1) is

$$[d_0^2] = [(M' - \bar{M})^2]_{\min} = [m^2] - \frac{[gm]^2}{[g^2]}, \quad (3)$$

just as in ordinary regression analysis.

We mentioned already that the regression coefficients found in the present investigation proved to be considerably lower than those found in our earlier experiments and also in the literature. This applies also to the regression coefficient β_0 in (2). Nevertheless it will be shown that the correction with the lower regression coefficient (2) giving a minimum scatter of M' may be used.

Before doing so we remind that we had tried to provide the animals with so much feed as seemed necessary for meeting maintenance requirement. Nevertheless it afterwards appeared that the energy balances always were more or less differing from zero. The reduction of the M -values to zero balance would have been very simple if there were a functional relationship between energy balance and metabolisable energy. In reality there is only a correlation because the situation is complicated by the occurrence of physiological and analytical (technical) variations.

The *physiological* variations are due to variation in daily production of faeces, urine, CO_2 , CH_4 and heat, and to errors due to daily changes in digestibility and in the utilisation of digested matter. To these physiological variations belong also differences of the maintenance requirement resulting from differences of the intensity of metabolism. The latter occur between animals (between animal variation) and even occur in the same animal in different periods (between period variation).

The variations of *analytical* character arise while weighing feed, feed residues, faeces and urine and measuring the volume of outgoing air, and also while taking and analysing the samples (VAN ES, 1961; BROUWER et al., 1964b).

The variation of the metabolisable energy is smaller than that of the balances because in the determination of the metabolisable energy the rather variable figures of gas exchange are of minor importance.

These considerations suggest a split up of the energy balance (G_k) and of the metabolisable energy (M_k) in two sets of components: one set (G_k^* and M_k^*) with functional relationship and a second set (u_k and v_k) which are uncorrelated and mainly due to physiological and analytical variation. Moreover G_k^* and u_k are supposed to be uncorrelated as well as M_k^* and v_k .

It is clear that the 'true' relationship between balance and metabolisable energy is the same as the just mentioned functional relationship between G_k^* and M_k^* . G_k^* and M_k^* are, however, not known in distinction from G_k and M_k .

From our definition it follows:

$$G_k = G_k^* + u_k; M_k = M_k^* + v_k; G_k^* - \bar{G}^* = g_k^*; M_k^* - \bar{M}^* = m_k^*.$$

In this way our problem is reduced to a problem of ordinary correlation.

If the functional relationship between M^* and G^* is supposed to be strictly linear we can write

$$m_k^* = \beta_0^* g_k^*,$$

with constant value β_0^* . This involves

$$[m^*g^*] = \beta_0^*[g_k^{*2}], \text{ or } \beta_0^* = \frac{[m^*g^*]}{[g^{*2}]}.$$

β_0^* is, therefore, equal to the ordinary regression coefficient m^* on g^* .

$\Sigma\Sigma (G_{ij} - \bar{G}) = 0$, \bar{M} represents the mean amount of metabolisable energy required under the average conditions mentioned in table IV.1 (live weight = 500 kg, daily balance $\bar{G} = -456$ kcal, etc.), thus not far from maintenance requirement. We found $\bar{M} = 12\,447$ kcal.

This formula (10) was used for the reduction of the original values M_{ij} which had been determined for the single cows in the separate periods and had already been corrected to 500 kg live weight.

In the first place we calculated the 33 values

$$Q_{ij} = M_{ij} - 0.4199 (G_{ij} - \bar{G}), \quad (12)$$

that means the underlying M_{ij} -values corrected to average gain (balance) but neither for individual nor for period variation. The figures obtained are plotted in fig. 1.

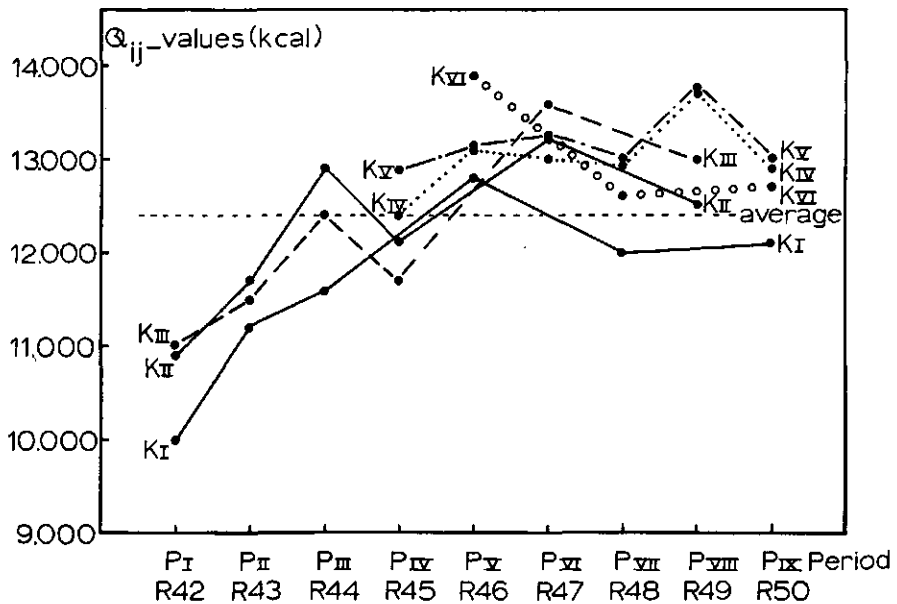


Fig. 1. Q_{ij} -values, that means metabolisable energy requirements M_{ij} reduced to 500 kg live weight and to average balance \bar{G} so that period deviations and individual deviations become more distinct (formula 12).

In this figure it is clearly seen that after this reduction of the M_{ij} -values to average gain there remain considerable period variations. The greatest negative deviations have occurred in the first and second period, i.e. P_I = R42 and P_{II} = R43, especially in the first one. In the later periods the values are fluctuating on a higher level.

Less clear are the individual deviations. Nevertheless, it is striking that in nearly all periods the line of K_I (cow Hinke 14) is distinctly lower than that of the other cows.

TABLE IV.1. Formula (10). Average daily requirement (\bar{M} , kcal) of metabolisable energy, regression coefficient (a) of metabolisable energy (M , kcal) on balance (G , kcal), period deviations (p_i , kcal) and individual deviations (k_j , kcal);
 live weight 500 kg,
 average daily balance -456 kcal,
 average daily crude fibre intake +1946 g,
 average crude fibre percentage in org. matter of hay 35.32%,
 average metabolisability of gross energy of hay 47.75%

Average daily maintenance requirement	$\bar{M} = 12447 \pm 69$ kcal
Regression coefficient M on G	$a = +0.4199 \pm 0.176$
<hr/>	
Period deviation from average	Individual deviation from average
Period PI, R42: $p_1 = -1534 \pm 283$ kcal	KI, Hinke 14: $k_1 = -648 \pm 182$ kcal
Period PII, R43: $p_2 = -724 \pm 231$ kcal	KII, Albertje 87: $k_2 = -58 \pm 165$ kcal
Period PIII, R44: $p_3 = +111 \pm 262$ kcal	KIII, Roosje: $k_3 = -76 \pm 159$ kcal
Period PIV, R45: $p_4 = -232 \pm 185$ kcal	KIV, Roosje 5: $k_4 = +200 \pm 160$ kcal
Period PV, R46: $p_5 = +731 \pm 197$ kcal	KV, Lamkje 5: $k_5 = +312 \pm 147$ kcal
Period PVI, R47: $p_6 = +679 \pm 182$ kcal	KVI, Zwarte: $k_6 = +270 \pm$ not determ.
Period PVII, R48: $p_7 = +93 \pm 213$ kcal	
Period PVIII, R49: $p_8 = +693 \pm 198$ kcal	
Period PIX, R50: $p_9 = +184 \pm$ not determ.	

The same tendencies are shown in table IV.1 containing the individual values p_i and k_j of (10). p_1 , i.e. the average negative deviation in period PI is -1534 ± 283 kcal and p_2 in period PII is -724 ± 231 kcal. On the other hand, p_5 , p_6 and p_8 are rather high. With respect to the cows it is seen that indeed the (negative) deviation k_1 is larger than all the others. Although our data do not satisfy in all respects the prerequisites of sound statistical work it is concluded that fig. 1 as well as table IV.1 show clearly the existence of systematic period deviations and systematic individual deviations.

In the underlying formula (10) there are no unknowns representing the metabolisable energy which is required from the single hays. Nevertheless it is possible to obtain a notion of these amounts. With this intention not only a correction for gain (G) was applied but also for period and for cow by calculating for all 33 single experiments:

$$H_{ij} = M_{ij} - p_i - k_j - 0,4199 (G_{ij} - \bar{G}). \quad (13)$$

Again M_{ij} represents the original M_{ij} -values already corrected to 500 kg live weight as explained in the beginning of this chapter.

As already has been mentioned there were five or six of these H -values for each kind of hay; the six averages H_1, H_2, \dots, H_6 are given in table IV.2, column A. The differences between these averages are rather small; only H_5 and H_6 are somewhat lower than the others. This method of calculation does however not allow the conclusion that the metabolisable energy in all the hays is used with almost equal efficiency.

In order to check this result more exactly we made new computations in

TABLE IV.2. Average daily requirements of metabolisable energy (H_t , kcal) from different hays;
 live weight 500 kg,
 average daily balance - 456 kcal,
 average daily crude fibre intake + 1946 g,
 average crude fibre percentage in org. matter of hay 35.32%,
 average metabolisability of gross energy of hay 47.75%

Hays	Calculated with formula (13)	Calculated with formula (17)	Calculated with formula (19)
	A	B	C
Hi, Friesland	$H_1 = 12448$	12759	12396
Hii, N. Holland	$H_2 = 12656$	13148	13039
Hiir, Utrecht	$H_3 = 12547$	12390	12576
Hiv, N. Brabant	$H_4 = 12507$	12370	12503
Hvi, Overijssel	$H_5 = 12248$	11840	11969
Hvii, Z. Holland	$H_6 = 12328$	12019	12001
Average (not weighted)	12456	12421	12414

which also unknowns for the six hays were inserted. We will discuss only one of these formulae, which is an extension of (10):

$$M = \bar{M} + p_i + k_j + h_t + a(G - \bar{G}), \quad (14)$$

with three conditions: $\sum p_i = 0$, $\sum k_j = 0$ and $\sum h_t = 0$.

The deviations (kcal) of the six hays from mean value \bar{M} are indicated by h_t ($t = 1, \dots, 6$). The other symbols have been given underneath the formula (6). There are 20 significant unknowns so that only 13 degrees of freedom are left. The result of the calculations is as follows.

$$M = 12\,421 + p_i + k_j + h_t + 0.3496(G + 456), \quad \sigma = 239. \quad (15)$$

σ is decreased by 1/3 as compared with (10). $\bar{M} = 12\,421$ kcal, thus practically the same as before (12 447 kcal); again $\bar{G} = -456$ kcal. These values are already introduced into (15), in distinction from (10), where \bar{M} and \bar{G} only are mentioned in the text. The complete solution system is given in table IV.3.

As compared with table IV.1 some of the p - and k -values have changed a rather good deal. Nevertheless, p_1 and p_2 are again the lowest and p_5 and p_6 are ranking amongst the highest values, whereas k_1 is again the lowest of all k -values.

It is instructive to calculate again the corrected M_{ij} -values Q_{ij} but now not only corrected for gain, but also for hay (h_t) with the formula

$$Q_{ij} = M_{ij} - h_t - 0.3496(G + 456), \quad (16)$$

derived from (15). After this correction the disturbing influence of differences in gain and hay quality is eliminated as far as possible so that the individual deviations and period deviations become more conspicuous. The results are plotted in fig. 2.

TABLE IV.3. Formula (14) and (15). Average daily requirement (\bar{M} , kcal) of metabolisable energy, regression coefficient (a) of metabolisable energy (M , kcal) on balance (G , kcal), period deviations (p_i , kcal), period deviations (k_j , kcal), individual deviations (h_i , kcal) and hay deviations (h_i , kcal);

live weight	500 kg,		
average daily balance	- 456 kcal,		
average daily crude fibre intake	+ 1946 g,		
average crude fibre percentage in org. matter of hay	35.32 %,		
average metabolisability of gross energy of hay	47.75 %		
Average daily maintenance requirement $\bar{M} = 12421 \pm 46$ kcal			
Regression coefficient M on G $a = +0.3496 \pm 0.153$			
Period deviation from average			
P _I , R42:	$p_1 = -2378 \pm 279$ kcal		
P _{II} , R43:	$p_2 = -1323 \pm 300$ kcal		
P _{III} , R44:	$p_3 = +48 \pm 212$ kcal		
P _{IV} , R45:	$p_4 = -95 \pm 170$ kcal		
P _V , R46:	$p_5 = +1236 \pm 182$ kcal		
P _{VI} , R47:	$p_6 = +725 \pm 185$ kcal		
P _{VII} , R48:	$p_7 = +442 \pm 230$ kcal		
P _{VIII} , R49:	$p_8 = +498 \pm 165$ kcal		
P _{IX} , R50:	$p_9 = +847 \pm$ not determ.		
Individual deviation from average			
K _I , Hinke 14:	$k_1 = -579 \pm 131$ kcal		
K _{II} , Albertje 87:	$k_2 = +207 \pm 137$ kcal		
K _{III} , Roosje:	$k_3 = +211 \pm 125$ kcal		
K _{IV} , Roosje 5:	$k_4 = -54 \pm 118$ kcal		
K _V , Lamkje 5:	$k_5 = +82 \pm 109$ kcal		
K _{VI} , Zwartje:	$k_6 = +133 \pm$ not determ.		
Hay deviation from average			
H _I , Friesl.:	$h_1 = +338 \pm 220$ kcal		
H _{II} , N.H.:	$h_2 = +727 \pm 193$ kcal		
H _{III} , Utr.:	$h_3 = -31 \pm 183$ kcal		
H _{IV} , N.Br.:	$h_4 = -51 \pm 161$ kcal		
H _V , Ov.:	$h_5 = -581 \pm 136$ kcal		
H _{VI} , Z.H.:	$h_6 = -402 \pm$ not determ.		

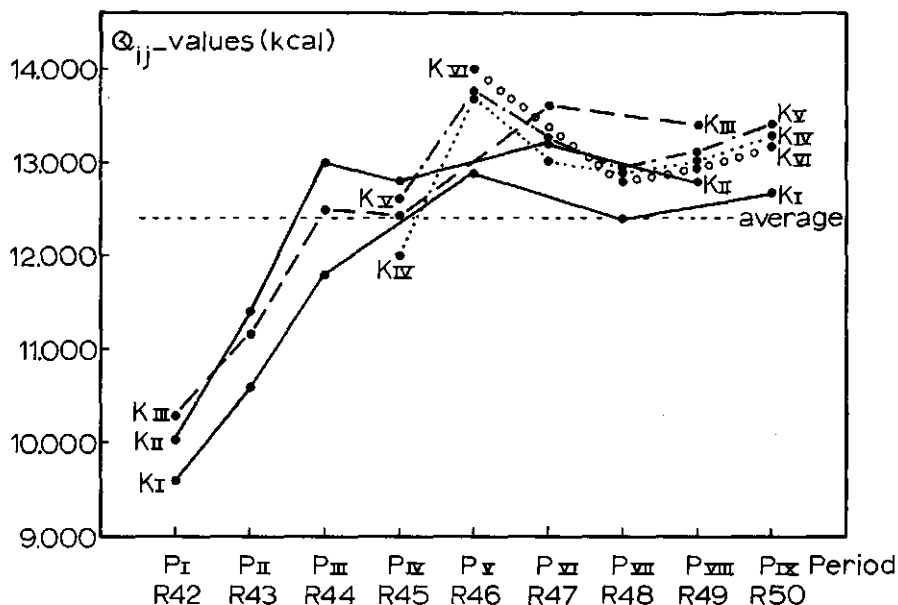


Fig. 2. Q_{ij} -values, that means metabolisable energy requirements M_{ij} reduced to 500 kg live weight and average balance G and corrected for hay deviations so that period deviations and individual deviations become more distinct (formula 16).

Again the low values in period PI and PII (R42 and R43) are conspicuous. The individual deviations are small. Only the curve KI (cow Hinke 14) is distinctly lower than the others; the maintenance requirement of this cow is, therefore, significantly lower than that of the other cows.

Furthermore, from the figures in table IV.3 we calculated for the single hays the values

$$H_t = \bar{M} + h_t, \quad (17)$$

that means the metabolisable energy required for maintenance from each of these hays under the conditions mentioned in tables IV.2, 3 (live weight = 500 kg, daily balance $\bar{G} = -456$ kcal, etc.), individual variation and period variation having been eliminated (table IV.2, column B).

The between hay variation in this column B is considerably greater than that in column A calculated with formula (13); standard deviation ± 479 versus ± 149 . This increase is not strange because column A is founded upon formula (10) in which there are no unknowns h_t .

Table IV.2 and IV.3 contain only the six values H_t and h_t of the six hays. In addition the standard deviations of the h_t 's are given in table IV.3. Those of the H_t 's are not inserted; this seemed not necessary because they are only slightly different from those of the corresponding h_t 's. The standard deviations of the h_t 's (and H_t 's) seem to confirm definitely that the differences between some of

TABLE IV.4. Metabolisable energy required from the six hays in the single experiments after reduction to mean balance and elimination of period variation and individual variation (formula 18)

Hay	Hi Friesland	Hi N. Holland	Hi Utrecht	Hiv N.Brabant	Hv Overijssel	Hvi Z. Holland	Average
Experiment	K _I , P _I , 12913 K _{II} , P _{II} , 12832 K _{III} , P _{III} , 12630 K _{IV} , P _{IV} , 12509 K _V , P _V , 12906	K _I , P _I , 13202 K _{II} , P _{II} , 12999 K _{III} , P _{III} , 13142 K _{IV} , P _{IV} , 13263 K _V , P _V , 13133	K _I , P _{III} , 12285 K _{II} , P _{VI} , 12254 K _{III} , P _{VI} , 12627 K _{IV} , P _{VI} , 12453 K _V , P _{VII} , 12326	K _I , P _V , 12165 K _{II} , P _{III} , 12654 K _{III} , P _{III} , 12188 K _{IV} , P _{VI} , 12303 K _V , P _{VI} , 12330 K _{VI} , P _V , 12572	K _I , P _{IX} , 11864 K _{II} , P _{IV} , 12084 K _{III} , P _V , 11696 K _{IV} , P _V , 11924 K _V , P _V , 11756 K _{VI} , P _{IX} , 11717	K _I , P _{VII} , 12097 K _{II} , P _{VIII} , 11697 K _{III} , P _{VIII} , 12239 K _{IV} , P _{IX} , 12072 K _V , P _{IX} , 12071 K _{VI} , P _{VII} , 11940	
Average	$H_1 = 12758$	$H_2 = 13148$	$H_3 = 12389$	$H_4 = 12369$	$H_5 = 11840$	$H_6 = 12019$	12421
Relative maintenance value	97.2	94.4	100.1	100.3	104.8	103.2	100.0
Crude prot. in org. matter	16.9%	18.0%	15.7%	9.3%	10.6%	9.2%	13.3%
Dig. cr. prot. in org. matter	9.9%	10.9%	9.3%	4.6%	4.8%	4.0%	7.2%
Best grasses plus clover	60%	48%	66%	73%	72%	52%	62%

the hays are highly significant, for instance between h_2 and h_5 . Still more striking is this with the H values of all 22 single experiments calculated from table IV 2

	Crude fibre, grams ingested	Crude fibre, % in org. mat. ingested	Metabolisability of metab. energy ingested
Present experiments	1946 g	35.32%	47.75%
Earlier experiments	1717 g	33.55%	49.05%
Difference	+229 g	+1.77%	-1.30%

In our earlier paper (BROUWER et al., 1964 b) we found that ingestion of one gram of crude fibre puts such a burden on metabolism that 0.72 kcal of metabolisable energy becomes worthless. Reduction of 1964 g crude fibre ingested to 1717 g would, therefore, imply a correction of metabolisable energy requirement amounting to $-229 \times 0.72 = -165$ kcal.

Furthermore it was found that increase of 1% of crude fibre in the organic matter entails an increase of 70 kcal of required metabolisable energy. This would result in a correction of $-1.77 \times 70 = -124$ kcal.

Concerning the metabolisability it is mentioned in the preliminary paper (VAN ES et al., 1964) that an increase of 1.5% of the metabolisability coincides with a decrease of about 1% of the metabolisable energy requirement, i.e. ± 130 kcal. Equalising the metabolisability would therefore give a correction of $-(1.30/1.50) \times 130 = -113$ kcal.

The three corrections varying from -113 to -165 kcals are very similar. Whichever of these corrections might be chosen, the value of 13 123 kcal would be reduced to approximately 13000 kcal, whereas in our paper on early and late cut hay we found 12000 kcal. All these figures refer to 500 kg live weight.

It appears, therefore, that in spite of equalising crude fibre ingestion (or crude fibre percentage, or metabolisability) the maintenance requirement in the present investigation was found roughly 1000 kcal or 8% higher than in our earlier experiments.

In the paper on early and late cut hay we also pointed out that the maintenance requirement was found very different in various periods and laboratories. Also in the present series of experiments it has been shown that the maintenance requirement of cows is not a fixed magnitude but varies from period to period and from cow to cow. Up to now, on rations consisting of only hay the average value found by us in the earlier and present experiments covering several years is $\frac{1}{2}(12000 + 13000) = 12500$ kcal. This figure refers to 500 kg live weight and to hay with 33.6% crude fibre on organic matter basis.

So far we discussed the maintenance value of the metabolisable energy of our hays. We now will consider the requirements of *organic matter*, *dry matter*, *fresh hay* and *starch units*.

Again we first will study the quantities required under the average conditions of the experiments, thus with balance = -456 kcal per day and 35.32% of crude fibre in the organic matter; all data had already been reduced to 500 kg live weight of the cows.

With this in mind we first calculated from the data earlier mentioned in this paper for the individual hays the quantities of metabolisable energy (*me*, kcal) and, with KELLNER's method, the number of kilo starch units ¹ (*z*) per kg of organic matter in the hay actually eaten (table IV.5), thus while eliminating the feed residues. The procedure was however somewhat different for the content of organic matter in dry matter because the hay actually eaten may have a slightly higher content of organic matter and lower content of minerals than is found in the samples of the original hays taken while weighing out the rations. This is due to the higher content of mineral matter in the feed residues. Consequently, for the content of organic matter (*os*) in the dry matter the analyses of the original hays (table III.1) were used. Basing on these figures we calculated with the subjoined formulae the daily requirements of organic matter (*Os*, kg), kilo starch units (*Z*) and dry matter (*Ds*). In these formulae *M* (kcal) represents the requirement of metabolisable energy already mentioned in tables IV.2, column B and IV.3.

$$Os = M/me, \quad Z = 1/100 (Os \times z), \quad Ds = 100 (Os/os).$$

The results are given in table IV.5, column 4, 5 and 6.

TABLE IV.5. Composition of the hays. Requirement of metabolisable energy, organic matter, starch units and dry matter of the hays; live weight 500 kg

Hay	Composition (per kg of organic matter)		Requirement (500 kg live weight)						
			with mean balance = -456 kcal				with zero balance		
	1 metab. energy (megac.)	2 kilo starch units	3 metab. energy (megac.)	4 organic matter (kg)	5 kilo starch units	6 dry matter (kg)	7 organic matter (kg)	8 kilo starch units	9 dry matter (kg)
H I, Friesland	2.279	0.4362	12.76	5.60	2.44	6.21	5.97	2.60	6.62
H II, N. Holland	2.441	0.4881	13.15	5.39	2.63	6.12	5.71	2.79	6.49
H III, Utrecht	2.384	0.4587	12.39	5.20	2.38	5.63	5.55	2.54	6.01
H IV, N. Brabant	2.171	0.4135	12.37	5.70	2.36	6.04	6.09	2.52	6.45
H V, Overijssel	2.315	0.4625	11.84	5.11	2.37	5.69	5.46	2.53	6.08
H VI, Z. Holland	2.115	0.4057	12.02	5.68	2.31	6.25	6.08	2.47	6.68
Average	2.284	0.4441	12.42	5.45	2.42	5.99	5.81	2.58	6.39

Finally we made an estimate of the same magnitudes with zero balance, i.e. for maintenance, by applying a correction to the figures in column 4, 5 and 6 of the just mentioned table IV.5. According to MØLLGAARD (1941) one kilo starch unit corresponding to 2365 NKF is necessary for $2365/0.83 = 2849$ kcal of maintenance requirement. Thus, $456/2849 = 0.160$ kilo starch unit is necessary for the negative balance of 456 kcal found in our experiments. There-

¹ 1 kilo starch unit = one 'starch equivalent' = 2365 NKF.

fore, the corrected requirements (column 8) are $Z' = Z + 0.16$. Thereupon the corrected figures for the organic matter and dry matter (column 7 and 9) were found by multiplying column 4 en 6 by Z'/Z .

The figures in table IV.5 need little comment. Although the variation of the starch values per kg organic matter (column 2) are not very high, they surely should not be neglected. The average is 0.444 and, therefore, the mean value in the dry matter is $0.9094 \times 0.444 = 0.404$, and in the hay as such $0.85 \times 0.404 = 0.343$ supposing that the dry matter content of the hay is 85%.

The average maintenance requirement of kilo starch units (column 8) is 2.58. This differs only slightly from the figure given by MØLLGAARD (1941): 5905 NKF with 500 kg live weight, that is $5905/2365 = 2.50$ kilo starch units; this represents the physiological requirement.

We mentioned already that in the present experiments the maintenance requirement was somewhat higher than in our earlier experiments. The average of all the hay-experiments was ± 12500 kcal of metabolisable energy versus 13000 kcal in the present series. Basing on these figures we multiplied the present average requirement of 2.58 kilo starch units by $12500/13000$. This gives 2.48 kilo starch units which agrees very well with MØLLGAARD's figure: 2.50. Thus the requirement of starch units, calculated after KELLNER and MØLLGAARD, has given a quite satisfactory result.

For practical purposes it usually is recommended to feed for maintenance $1 + 500:3 = 2.67$ kilo starch units to a cow of 500 kg, thus a little more than the theoretical requirement. From table IV.5, column 1 and 2, it is readily seen that this corresponds to $2.67/0.4441 = 6.012$ kg of organic matter. The daily required quantity of dry matter is therefore $6.012/0.9094 = 6.611$ kg which is present in about $6.611/0.85 = 7.78$ kg fresh hay. We could therefore say that 7.5 to 8.0 kg of ordinary well cured and well preserved Netherland hay with 6.6 kg dry matter and 6.0 kg organic matter approximately meet the maintenance requirement of a non-pregnant dry cow weighing 500 kg.

Finally we want to pay our sincere thanks to the Department of Mathematics of the Agricultural University for the computations of the complicated regression equations and to all members of the staff of the physiological laboratory who collaborated in these experiments, for their accurate and sustained endeavour.

V. SUMMARY

In winter, hay is the main cattle feed in the Netherlands. Therefore, with the aid of two identical respiration chambers 33 experiments with in total approximately 200 single 24-hour respiration trials were conducted with six non-pregnant dry cows in order to determine the maintenance value of six hays as used in practical farming. The hays had been collected without regard to chemical or botanical composition from six farms all over the Netherlands. They consisted of mixed grasses with very little clover and most of them had been cured by spreading the grass on the field. The crude fibre content of the organic matter was very similar (34.0 to 36.2%); the crude protein content of the organic matter varied much more (9.2 to 18.0%). The rations consisted of hay only, however with the addition of 30 g of NaCl a day.

The metabolisable energy was only 45–50% of the gross energy and 78.4–79.7% of the digestible energy. Apparently the metabolisable energy of these hays could be calculated with satisfactory accuracy from the digestible energy by multiplication by the factor 0.79. Furthermore, the digestible energy could be calculated with reasonable accuracy from the digestible constituents with the aid of the following formula containing a set of well known conversion factors:

$$\text{Dig. energy} = 5.7 \times \text{dig.cr.prot.} + 9.5 \times \text{dig.cr.fat} + 4.2 \times \text{dig.cr. fibre} + 4.2 \times \text{dig. NFE.}$$

Just as in our earlier experiments the maintenance requirement fluctuated a great deal from period to period. This makes it difficult to fix a definite figure for maintenance requirement.

Up to now the causes of these variations are not clear to us. As respiration trials are very complicated one could suppose that these variations might be due to systematic experimental error varying from period to period. This is however very improbable because all available measures had been taken to reduce the systematic and accidental errors as far as possible.

The individual variations were rather small. Nevertheless, the requirement of one of the cows was distinctly lower than that of the others.

The maintenance values of the hays showed rather small variations. Yet, the hays with higher content of best quality grasses plus clover seemed to have somewhat higher relative maintenance value than the others. As grasses of best quality were considered: *Lolium perenne*, *Festuca pratensis*, *Phleum pratense*, *Poa pratensis* and *Poa trivialis*. It is suggested to repeat the experiments with hays with more varying botanical composition, that means with species considered by practical farmers as very good such as *Lolium* on the one hand, and with low quality grasses such as *Carex* on the other hand.

Taking also into account the results of our earlier experiments we found that the average maintenance requirement of a cow of 500 kg live weight on a ration of only hay with 33.6% of crude fibre in the organic matter amounted to 12500 kcal of metabolisable energy. This quantity corresponded with these hays to 2.48 kilo starch units which agrees very well with MØLLGAARD's figure 2.50. Thus, the requirement of starch units calculated after KELLNER and MØLL-

GAARD has given a quite satisfactory result. Increasing this figure a little bit for practical use as is usually recommended, we could say that 2.67 kilo starch units in ordinary well cured and well preserved Netherland hay approximately meet the energy requirement for maintenance of a non-pregnant dry cow with 500 kg live weight. This quantity of kilo starch units was present in 7.5 to 8.0 kg of the hay just mentioned, with 6.0 kg of organic matter and 6.6 kg of dry matter.

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