Breeding and Feeding the High Genetic Merit Dairy Cow
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The energy and protein requirements according to AFRC (1993) of high genetic merit dairy cows

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Introduction

The Agricultural and Food Research Council (AFRC) (1992 and 1993) metabolizable protein (MP) system for the calculation of the protein requirements of ruminants introduces several new factors into the model proposed, by making both rumen outflow rate and microbial protein synthesis dependent on feeding level (L). Oldham and Sutton (1979) showed that according to the earlier Agricultural Research Council (ARC, 1980) protein requirement model, the predicted degradability of the dietary crude protein (CP) fell from 0·75 to about 0·65 in a diet to support milk yields of 30 and 50 kg/day respectively. This conclusion, that increased amounts of undegraded dietary protein (UDP) are needed to support high milk yields, particularly when the cow is in negative energy balance, is widely believed and used to support the inclusion of protein foods high in undegradable protein in diets for high yielding cows in early lactation. AFRC (1993) only gave the calculated metabolizable energy (ME) and MP requirements for milk yields up to 40 kg/day, and live-weight losses in early lactation did not exceed 1 kg/day. In view of the high (>50 kg/day) milk yields being achieved with high genetic merit dairy cows, the AFRC (1993) models for energy and protein requirements were used to calculate ME and MP requirements for milk yields up to 70 kg/day. This required that assumptions were made about feasible dietary energy concentrations and the scale of energy deficits that high genetic merit dairy cows are likely to experience in early lactation, so as to calculate dry matter (DM) intakes that were regarded as feasible in practice.

Assumptions

The dietary energy concentration (M/D) was raised in steps to a maximum of 13 MJ/kg DM, assuming a minimum of 300 g/kg DM of high quality forage and that dietary fat did not exceed 60 g/kg DM. As a consequence, dietary fermentable ME/ME rises from 0·79 at 30 kg milk per day to 0·83 at 50 kg milk per day and above. The amount of energy mobilized from body reserves was assumed to reach a maximum of about 70 MJ/day for a milk yield of 70 kg/day. Cows in good condition can mobilize a total of 100 kg fat during early lactation, and Flatt, Moe, Munson and Cooper (1965) recorded the mobilization of 40 to 80 MJ/day by a Holstein cow, Lorna, which was producing 40 kg milk per day. The amount of body protein that could be mobilized was calculated, not assumed, being based on the energy (EV_g) and protein content (NP_g) of live-weight change specified by AFRC (1993), 19 MJ and 138 g/kg live-weight change respectively.

Material and methods

The software used to calculate Table 5.1 of AFRC (1993) was used to calculate ME and MP requirements for milk yields up to 70 kg/day, using the assumptions given above. The results for a cow of 650 kg live weight producing milk with a butterfat content of 40 g/kg, a protein content of 34 g/kg and a lactose content of 48 g/kg are given in Table 1.

Results

Dry matter intake increases almost linearly to a maximum of 27·9 kg/day for a milk yield of 70 kg/day. These figures are a result of the calculated ME requirements and the M/D value used to calculate them.

Live-weight change is predicted to increase to a maximum of 3 kg/day, based on an (EV_g) of 19 MJ/kg, whilst a consequential mobilization of up to 414 g/day of body protein is also predicted, ([NP_g] = 138 g/kg). As it is suggested that a maximum of 15 kg protein can be mobilized in early lactation, (i.e. 200 g/day) this prediction seems unlikely.

Feeding level rises to over five times maintenance, resulting in a predicted rumen outflow rate of 0·11 per h. Such a high outflow rate significantly reduces the predicted mean residence time of ingested food in the rumen to below 7 h.

Microbial protein synthesis (y) is predicted to rise to 12·1 g microbial CP per MJ FME, which for a fermentable ME/ME ratio of 0·83 is equivalent to 10·0 g microbial CP per MJ ME, in line with US and Nordic recommendations for dairy cows. The rise in M/D, fermentable ME/ME and microbial yield (g microbial CP per MJ fermentable ME) means that high yielding cows have an increased need for effective rumen degradable protein (ERDP).

Digestible undegraded protein (DUP) increases in amount per day and as g/kg diet DM as milk yields and energy deficits increase, but expressed as a proportion of CP, DUP/CP is almost constant at 0·18.

Dietary crude protein levels have been estimated by assuming the digestibility of UDP was about 0·7 and converting (ERDP) to rumen degradable protein (RDP). The results are optimal, in that the supply of both ERDP and DUP are exactly balanced. The estimates show a steady increase in dietary CP from 125 g/kg DM at 10 kg milk per day, rising to 217 g/kg DM at 70 kg/day. The proportions of ERDP and RDP in the CP are nearly constant at about 0·60 and 0·75 respectively.

Conclusions

Predicted microbial protein synthesis increases two-fold as milk yields rise from 30 kg to 70 kg/day, requiring a doubling of ERDP needed to match the fermentable ME supplied to the rumen microbes.

Table 1 *Metabolizable energy (ME) and protein (MP) requirements of high genetic merit dairy cows calculated in accordance with AFRC (1993)*

	Milk yield (kg/day)						
	10	20	30	40	50	60	70
	Estimated ME requirements						
Assumed dietary M/D (MJ/kg DM)	10·5	11·0	11·5	12·0	12·5	13·0	13·0
Diet energy concentration (q)	0·56	0·59	0·61	0·64	0·66	0·69	0·69
ME utilization for lactation (k_l)	0·615	0·625	0·634	0·643	0·653	0·662	0·662
Calculated live weight change (kg/day)	0	–0·5	–1·0	–1·5	–2·0	–2·5	–3·0
Assumed energy deficit (MJ ME/day)	0	–13	–25	–37	–49	–60	–73
ME required (MJ/day)	123	163	202	241	280	319	362
Calculated dry matter intake (kg/day)	11·7	14·8	17·6	20·1	22·4	24·5	27·9
	Estimated MP requirements						
Calculated net protein mobilized (g/day)	0	–69	–138	–207	–276	–345	–414
MP required (g/day)	810	1236	1663	2089	2516	2942	3368
MP/ME ratio	6·6	7·6	8·2	8·7	9·0	9·2	9·3
FME/ME ratio assumed for diet	0·75	0·77	0·79	0·81	0·83	0·83	0·83
Fermentable ME (FME) (MJ/day) (est'd)	92	126	160	195	232	265	300
Feeding level (L, multiples of M_m)	1·8	2·4	3·0	3·6	4·2	4·7	5·3
Predicted rumen outflow rate (per h)	0·043	0·059	0·073	0·084	0·094	0·101	0·108
Estimated rumen retention time (h)	12·0	9·9	8·6	7·8	7·2	6·9	6·6
Predicted microbial yield (y) (g/MJ FME)	9·8	10·4	10·9	11·3	11·6	11·8	12·1
Microbial crude protein (MCP) (g/day)	904	1307	1739	2205	2701	3135	3624
Digestible microbial true protein (g/day)	577	833	1109	1406	1722	1999	2310
Calculated digestible undegraded protein (DUP) requirement (g/day)	233	403	554	683	794	943	1058
Calculated (DUP) (g/kg DM)	20	27	32	34	35	38	38
Assumed digestibility of DUP (dup)	0·7	0·7	0·7	0·7	0·7	0·7	0·7
Estimated undegraded dietary protein (g/kg DM)	28	39	45	49	51	55	54
Calculated effective (RDP) (g/kg DM)	77	88	99	110	121	128	130
Estimated rumen degradable protein (RDP) (g/kg DM)	97	110	124	137	151	160	163
Estimated dietary CP (g/kg DM)	125	149	169	186	201	215	217
(ERDP)/(CP) ratio	0·62	0·59	0·59	0·59	0·60	0·60	0·60
(DUP)/(CP) ratio	0·16	0·18	0·19	0·18	0·18	0·18	0·18
Estimated CP degradability (dg) (RDP)/(CP)	0·77	0·74	0·73	0·74	0·75	0·74	0·75

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The predicted proportion of DUP in CP remains steady at about 0·18. These results suggest that increasing the proportion of DUP in the CP of diets given to very high yielding cows may result in an inadequate supply of ERDP to the rumen microbes. Many of the assumptions used in these model calculations, such as practicable energy deficits, limits on body protein mobilization, rumen outflow rates, microbial protein synthesis and dietary CP, require validation by experiments with high yielding dairy cows.

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