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Feeding Dairy Calves and Replacement Heifers in South-western Sweden: A Survey

Hessle, A., Nadeau, E. and Svensson, C. (Department of Animal Environment and Health, The Swedish University of Agricultural Sciences, P.O. Box 234, SE-532 23 Skara, Sweden). Feeding dairy calves and replacement heifers in south-western Sweden: a survey. Accepted May 13, 2004. Acta Agric. Scand., Sect. A, Animal Sci. 00: 1–9, 2004.

Daily feed rations, their nutrient contents and live weight gains were recorded for calves and replacement heifers from birth to calving in 122 Swedish dairy herds. Preweaned calves were fed whole milk (45% of the herds), milk replacer alone or milk replacer combined with whole milk. Calf starters were the most frequently used concentrates for preweaned calves, whereas grain dominated for weaned calves and heifers. Grain was supplemented with protein concentrates until 6 months of age and at calving. Grass/clover hay was the dominant forage for preweaned calves, whereas grass/clover silage alone or in combination with hay was the most common forage for calves and replacement heifers from 6 months of age. Heifers grazed permanent grass, leys or a combination of permanent grass and leys in 33, 15 and 52% of the herds, respectively. According to Swedish recommendations, calves in the majority of the herds received inadequate amounts of crude protein from weaning to 6 months of age and calves were fed with a metabolizable energy content inadequate for a daily weight gain of 700 g at weaning. Median live weight gain from birth to calving was only 567 g per day. Correct feed ration formulations and strategic grazing management could be means to increase weight gain and hence to decrease rearing costs of calves and replacement heifers in Swedish dairy herds.

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Key words: feed ration, heifer management, live weight gain, nutrient content, rearing.

Introduction

Rearing of replacement heifers is very expensive and, therefore, is economically significant in dairy production. Consequently, correct feeding strategies are of considerable importance to obtain satisfactory weight gain in young cattle and, thereby, also for decreasing the length of the rearing period and production costs (Nordgren, 1998; Tozer & Heinrichs, 2001). Recently, Pettersson et al. (2001) conducted a survey on feeding of calves and replacement heifers from birth to calving in 1500 randomly selected Swedish dairy herds, each having 28–94 cows. Data were collected through a questionnaire and were based on feed ration estimates by farmers. However, nutritive values of forages were not recorded in the study. Bernes et al. (1986) studied weighed feed rations and calculated nutritive values for heifers in dairy herds in the county of Västerbotten in

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DOI: 10.1080/09064700410032013

northern Sweden. However, Swedish dairy production has undergone considerable rationalisation during the last decade, and the county of Västerbotten has a very different climate compared to southern Sweden, where the majority of the dairy herds are kept, resulting in different crops conserved, different forage qualities and thus different feeding regimes. In Norway, Simensen (1983) studied feeding of heifers up to 12 months of age kept indoors. More recently, Mourits et al. (2000) studied preweaned calves in the Netherlands, whereas Hough & Sawyer (1993) and Spence & Woodhead (2000) studied heifers from weaning to calving in grazing systems in Australia. Hence, there is a shortage of consistent information on indoor feed rations and grazing regimes for calves and replacement heifers during their whole rearing period from birth to calving in commercial herds, where both feed rations and their nutrient contents are described. Feeding regimes and feed ingredients vary among different geographical areas, and results from other nations may not be applicable in Sweden.

The primary aim of this study was to investigate indoor feed rations and their nutritive values for dairy calves and replacement heifers from birth to calving in herds in south-western Sweden. Further aims were to study grazing regimes, weight gains, and finally to suggest possible improvements in the feeding regimes.

Materials and methods

Herds and animals

This study was part of a larger project investigating housing, health, feeding and management of dairy calves and replacement heifers. All dairy farmers in the county of Skaraborg in south-western Sweden who were associated with the official milk recording programme, had between 28 and 94 cows, and were considered capable of keeping thorough records of the performance of their heifers by the large animal veterinarians and advisors, were sent a request to enrol in the project. Because the effects of housing systems also were to be studied, all farms which housed their young calves in individual pens or in group pens and which volunteered to participate in the study were selected. Heifer calves born in these 122 herds during 1998 (median: 48 cows per herd; total: 3081 calves consisting of 49.5% Swedish Holstein Breed, 46.8% Swedish Red and White Breed, and 3.6% other breeds or crossbreeds), were monitored from birth until calving. During the last period of data collection, 9 farms went out of business and 5 farms dropped out of the study because their owners could no longer participate for various reasons, resulting in data retrieval from only 108–118 farms at the last three recordings.

Indoor feed quotas

Farmers were interviewed by project researchers visiting the farms. The interviews dealt with the indoor feed rations offered to calves and replacement heifers at 4 weeks of age, weaning, 1–2 months after weaning, 6 months of age, 10–16 months of age, less than 4 months of pregnancy, 4 months of pregnancy, and during the first 3 days after calving. For each specific age group, interviews were made twice (spring and autumn), except for calves 1–2 months after weaning and calves at 6 months of age, in which interviews were conducted in the autumn only. During the farm visits, the researchers also weighed the amounts of feed ingredients given for one day to the calves and heifers within the specific age group of concern. When both spring and autumn recordings were carried out, an average of the two feed weights was calculated. Minerals were recorded and defined as having low (ca. 1.0), medium (ca. 1.5) or high (ca. 2.0) calcium: phosphorus ratios.

Concentrations of dry matter (DM), metabolizable energy (ME), crude protein (CP), amino acids absorbed in the small intestine (AAT), and balance between ruminally degradable protein and microbial protein synthesis (PBV) of forages were recorded from analysis reports that were based on samples taken by the farmers after conservation. The AAT and PBV values are calculated values (Lindberg, 1985; Madsen et al., 1995) and ME is calculated from *in vitro* organic matter digestibility (Lindgren, 1979). When forage data from analysis reports were missing, the average nutritive values of forage fed to the heifers in the relevant age group were used. Average analyses from The National Feed Table (Spörndly, 2003) and from The Feedstuff List by The Swedish Dairy Association (Anonymous, 1999) were used for grains and protein concentrates, respectively. Total daily dietary nutrient contents and nutrient concentrations per kg of DM were calculated.

Grazing regimes

Farmers were interviewed about grazing regimes for their first-season grazing calves (FSG) during the grazing periods of 1998, 1999, and 2000, and for second-season grazing heifers (SSG) during the grazing periods of 1999 and 2000. The questions concerned the age of FSG at turn-out to pasture, the type of pasture, the number of animals and paddocks per group of cattle and per herd, supplementary feeding, sources of water, and mineral supplements.

Weight gain

Recordings of the calves' heart girth (HG) were undertaken individually at birth, weaning, 6–9 months of age, first service, calving, and at turn-out to and housing from pasture in their first and second grazing season. To control the variability in measurement methods, the farmers were instructed on how to perform the measurements using a small balance equivalent to a weight of 2 kg to ensure that the measuring tape was consistently and uniformly stretched in all measurements. They were to record two measurements that differed by no more than 2 cm and the mean value of the two measurements was recorded. The HG was transformed to live weight according to Heinrichs (1992) and Pönniäinen (1989) for the Swedish Holstein Breed and Swedish Red and White Breed, respectively. Birth recordings not measured at birth day were corrected to birth date. Calves with a corrected birth weight less than 20 kg were excluded from the analysis. Measurements of HG at weaning, first service and calving conducted more than 61 days from the actual event were excluded from the analysis, as well as recordings at calving less than 230 days after first service. Recordings of HGs at turn-out to and housing from pasture undertaken more than 31 days from the actual event were also excluded from the analysis.

Daily weight gains were calculated individually for the periods from birth to weaning, from weaning to 6–9 months of age, from 6–9 months of age to first service, from first service to calving, from birth to calving, as well as during the first and second grazing period. These individual weight gains were then used to calculate average daily weight gains for each herd.

Statistical analysis

Median values and the 80% central range (CR, i.e. excluding 10% of the values at each end of the distribution) were calculated for the amounts of milk, concentrates, forages and total feed rations, as well as for the dietary nutrient contents and concentrations, and for the number of animals and paddocks on pasture, using Microsoft Office Excel 2000. Results are presented as median values with CR within parenthesis unless stated otherwise.

Indoor feed rations during the preweaning period, at 6 months of age, at first service and at calving were compared to feed ration data from a national study by Pettersson et al. (2001). The types and amounts of milk, concentrates and forage fed were compared using a two-proportion test or Mann-Whitney test (Minitab, 2000), and 95% confidence intervals (CI) for differences between amounts were calculated accordingly.

Results

Information regarding milk volume, milk type, concentrates and forage fed to calves and replacement heifers of different age categories was recorded for 89 to 100% of the 122 herds, whereas information on amounts of concentrates was recorded for 70 to 96%, and amounts of forages for 51 to 93% of the herds. Owing to missing information regarding some ingredients, it was possible to calculate nutrient contents and nutrient concentrations of total feed rations for calves and replacement heifers at different age categories in only 50 to 70% of the herds. Weight gains of calves and heifers during different periods were obtainable from 83 to 98% of the herds. Data on the number of animals and paddocks per group were recorded for 98 to 100% of the FSG and for 64 to 66% of the SSG. Information about type of pasture and management on pasture was recorded for 83 to 100% of the herds.

Farms in our study did not differ significantly from those examined by Pettersson et al. (2001) with regard to type and daily volume of milk for preweaned calves. Except for a smaller amount of forage (CI: 0.60–1.60; $P < 0.001$) at 6 months of age, also amounts of concentrates and forages were similar. Furthermore, types of concentrates and forages were similar, except for grass/clover silage which was more commonly fed to calves from 6 months of age ($P < 0.02$).

Newborn heifer calves were fed a median amount of 5.0 (CR: 4.0–6.0) l of colostrum daily for 4.0 (CR: 3.0–5.5) days. They were then fed whole milk until weaning in 45% of the herds, and in the other herds they received milk replacer alone or milk replacer combined with whole milk. Calves were given 5.0 (CR: 4.0–6.0) l of whole milk or milk replacer daily divided into two feeds per day. In 28% of the herds, milk type was changed during the preweaning period and the exchange occurred at 13 (CR: 9–31) days of age. The animals had access to water from 2.5 (CR: 0.1–8.5) weeks of age, whereas grass/clover hay was offered from 1.0 (CR: 1.0–7.0) day of age, concentrates from 1.0 (CR: 0.5–2.5) week of age, and when grass/clover silage was fed, it was offered from 2.5 (CR: 0.9–7.7) months of age. The median weaning age was 9.0 (CR: 8.0–11.4) weeks and weaning occurred abruptly from one day to another in 77% of the herds.

At 4 weeks of age, feed rations consisted mainly of hay and calf starter (Table 1). The main ingredient in the solid feed rations was concentrates, which were fed in 97% of the herds and constituted 71 (CR: 51–84)% of total feed DM, excluding milk intake (Table 2). Starting at weaning, hay was gradually replaced with grass/clover silage, and calf starter was replaced with grain combined with different types of protein concentrates. Concentrates were fed in 99% of the herds

Table 1. Percentage of 122 Swedish dairy herds feeding different types of concentrates such as calf starters, grain (G) combined with protein concentrates (PC) for calves, for dairy cows, with other protein feed or a mixture of protein feed, grain only, complete feed for dairy cows, or different types of concentrates at spring and autumn recording occasions, and different types of forage such as grass/clover hay alone, grass/clover silage alone including some silage with small grain, a combination of hay and silage, and different types of forage at spring and autumn recording occasions to calves and replacement heifers at 4 weeks of age, weaning, 1–2 months (mo) after weaning (a. w.), 6 mo of age, 10–16 mo of age, less then 4 mo pregnant (preg.), 4 mo preg., and calving

	Concentrate								Forage				
Age category	Calf starter	G+PC calves	G+PC cows	G+prot. feed	Grain only	Compl. feed cow	Different conc.	n^1	Hay	Silage	Hay +silage	Different forage	n^2
4 weeks	45	5	22	7	7	7	7	118	92	4	3	0	116
Weaning	27	8	28	11	11	5	10	109	71	6	21	2	121
1–2 mo a. w.	6	8	46	18	17	4	–	121	29	25	46	–	122
6 mo	2	6	39	13	38	3	–	119	14	44	42	–	122
10–16 mo	1	1	15	8	34	2	40	118	3	56	23	19	120
<4 mo preg.	1	3	16	10	50	1	19	115	7	58	22	11	113
4 mo preg.	1	2	10	8	38	1	41	113	3	58	16	23	118
Calving	0	1	53	17	5	4	20	104	1	45	36	19	112

n^1 = number of herds feeding concentrate of a total of 104–121 herds.
n^2 = number of herds feeding forage of a total of 112–122 herds.

Table 2. Daily feed rations (median and 80% central range (CR)) fed to calves and replacement heifers in 122 Swedish dairy herds at 4 weeks of age (milk intake excluded), weaning, 1–2 months (mo) after weaning (a. w.), 6 mo of age, 10–16 mo of age, less then 4 mo pregnant (preg.), 4 mo preg., and calving; and percentage of herds (%) where they were fed *ad libitum* intake

	Concentrate					Forage					Total feed ration		
	Amount (kg of DM)			*Ad libitum* intake		Amount (kg of DM)			*Ad libitum* intake		Amount (kg of DM)		
Age category	Median	(CR)	*n*	(%)	*n*	Median	(CR)	*n*	(%)	*n*	Median	(CR)	*n*
4 weeks	0.5	(0.3–1.0)	86	88	122	0.2	(0.05–0.4)	67	89	122	0.7	(0.4–1.5)	67
Weaning	1.3	(0.7–1.8)	108	81	122	0.8	(0.4–1.7)	82	95	122	2.0	(1.3–3.4)	79
1–2 mo a. w.	1.7	(1.1–2.6)	111	3	116	1.7	(0.8–3.1)	63	82	116	3.6	(2.4–5.2)	63
6 mo	1.7	(1.1–2.9)	115	1[1]	114	2.7	(1.4–4.8)	62	78	114	4.7	(3.2–6.5)	63
10–16 mo	1.7	(0.9–3.0)	121	0[1]	113	4.5	(3.0–6.6)	86	58	113	6.5	(4.6–8.7)	86
<4 mo preg.	1.7	(0.9–3.0)	117	0[1]	74	5.8	(3.6–7.5)	72	62	74	7.3	(5.5–10.1)	72
4 mo preg.	1.5	(0.6–2.9)	116	0[1]	96	6.1	(4.6–7.5)	78	55	96	7.8	(6.0–10.0)	78
Calving	3.9	(1.8–6.0)	106	0[1]	90	7.0	(5.0–8.8)	84	56	90	10.8	(7.5–14.5)	84

n = number of herds.
[1]Excluding 1–6 recordings with total mixed rations.

from weaning until 6 months of age and constituted 61 (CR: 43–79)%, 49 (CR: 34–70)%, and 37 (CR: 27–67)% of total feed DM at weaning, 1–2 months after weaning and at 6 months of age, respectively. Forages dominated feed rations to replacement heifers from 10–16 months of age. Concentrates were fed in 96 to 99% of the herds from 10–16 months of age until 4 months pregnant, and constituted a median 20–28% of the total feed DM. At calving, grain and protein concentrates for dairy cows were fed five times more often than complete feed for dairy cows. Concentrates were fed in all herds and constituted 33 (CR: 18–47)% of the total feed DM at calving.

Oats was the most commonly used type of grain, and was fed alone or in combination with other grains to preweaned calves in 44% of the herds, to calves at weaning in 56% of the herds and, in the period from 1–2 months after weaning until calving, in 81 to 90% of the herds. Barley, triticale and wheat were fed to preweaned calves in 28, 15 and 13% of the herds, respectively, and in 36, 20, and 15% of the herds during weaning, respectively. In the period from 1–2 months after weaning until calving, barley, triticale, and wheat were fed in 57% (SD 4.4), 24% (SD 5.8) and 22% (SD 2.0) of the herds, respectively. Nutrient analyses were performed on 76% of all grass/clover silages and on 27% of all grass/clover hay (Table 3).

Minerals were fed in 86% of the herds at 1–2 months after weaning and thereafter in 91 to 95% of the herds until calving. From 1–2 months of age until calving, the calcium:phosphorous ratios were medium in a majority (76 to 80%) of the herds, high in 12 to 18% of the herds and low in 2 to 6% of the herds.

Total daily contents and concentrations of dietary ME, CP and AAT varied considerably among the herds (Fig. 1 a, b, c). According to Swedish recommendations (Olsson & Lindell, 2002), dietary ME contents offered to the calves and heifers were sufficient for a daily weight gain of the recommended 700 g in, on average, 59% of the feed quotas. However, at weaning, 80% of the herds had rations formulated for weight gains less than 700 g per day. The CP:ME and AAT:ME quotas of feed rations offered to calves from weaning until 6 months of age were lower than Swedish recommendations (Olsson et al., 1998) in more than 75% of the herds. In contrast, heifers from 10–16 months of age to 4 months of pregnancy were fed sufficient or excessive CP and AAT in 57 to 85% and 88 to 99% of the herds, respectively. At calving, the AAT:ME quota was lower than recommended in 73% of the herds, whereas the CP:ME quota was close to the recommendations.

The overall median daily weight gain of the heifers from birth to calving was 567 g day^{-1} (CR: 491–638; Table 4) and no herd had an average daily weight gain of more than 700 g. The heifers calved at 27.7 months of age (CR: 26.0–33.1) at a live weight of 529 kg (CR: 479–583).

The calves and replacement heifers were 11.2 (CR: 7.5–16.3) months of age when first turned out to pasture. There were 18 (CR: 9–31) FSG divided into one (46% of the herds) or several (54% of the herds) groups per herd each year. Each group consisted of 13 (CR: 7–24) animals, of which 10 (CR: 5–21) were FSG. There were 21 (CR: 10–45) SSG per herd annually, and they grazed a total of 4 (CR: 2–7) paddocks per year. The groups of FSG and SSG grazed permanent grass (32 and 34%, respectively), leys and/or aftermath (16 and 15%, respectively), or a combination of permanent grass and leys and/or aftermath (52 and 51%, respectively). Supplementary feeding, consisting of at least 1.0 kg of forage DM or 0.5 kg of grain per day, was offered to FSG and SSG for at least two weeks in 54 and 37% of the herds, respectively (Table 5). Minerals were supplemented on pasture in 78% of the herds.

Table 3. Concentrations of dry matter (DM), metabolizable energy (ME), crude protein (CP), amino acids absorbed in the intestine (AAT), balance between ruminally degradable protein and microbial protein synthesis (PBV) and neutral detergent fibre (NDF) in grass/clover hay and grass/clover silage (median and 80% central range (CR)) fed to calves and replacement heifers in 122 Swedish dairy herds in 1998–2000

	Hay			Silage		
Chemical composition	Median	(CR)	*n*	Median	(CR)	*n*
DM (%)	84	(84–84)	78	30	(23–39)	877
ME (MJ/kg of DM)	9.8	(9.0–10.4)	203	10.5	(10.0–11.3)	817
CP (g/kg of DM)	93	(73–121)	199	135	(107–162)	793
AAT (g/kg of DM)	70	(66–72)	199	70	(69–73)	793
PBV (g/kg of DM)	−19	(−35–17)	199	18	(−12–41)	793
NDF (g/kg of DM)	630	(589–666)	63	515	(449–590)	431

n = number of feed rations.

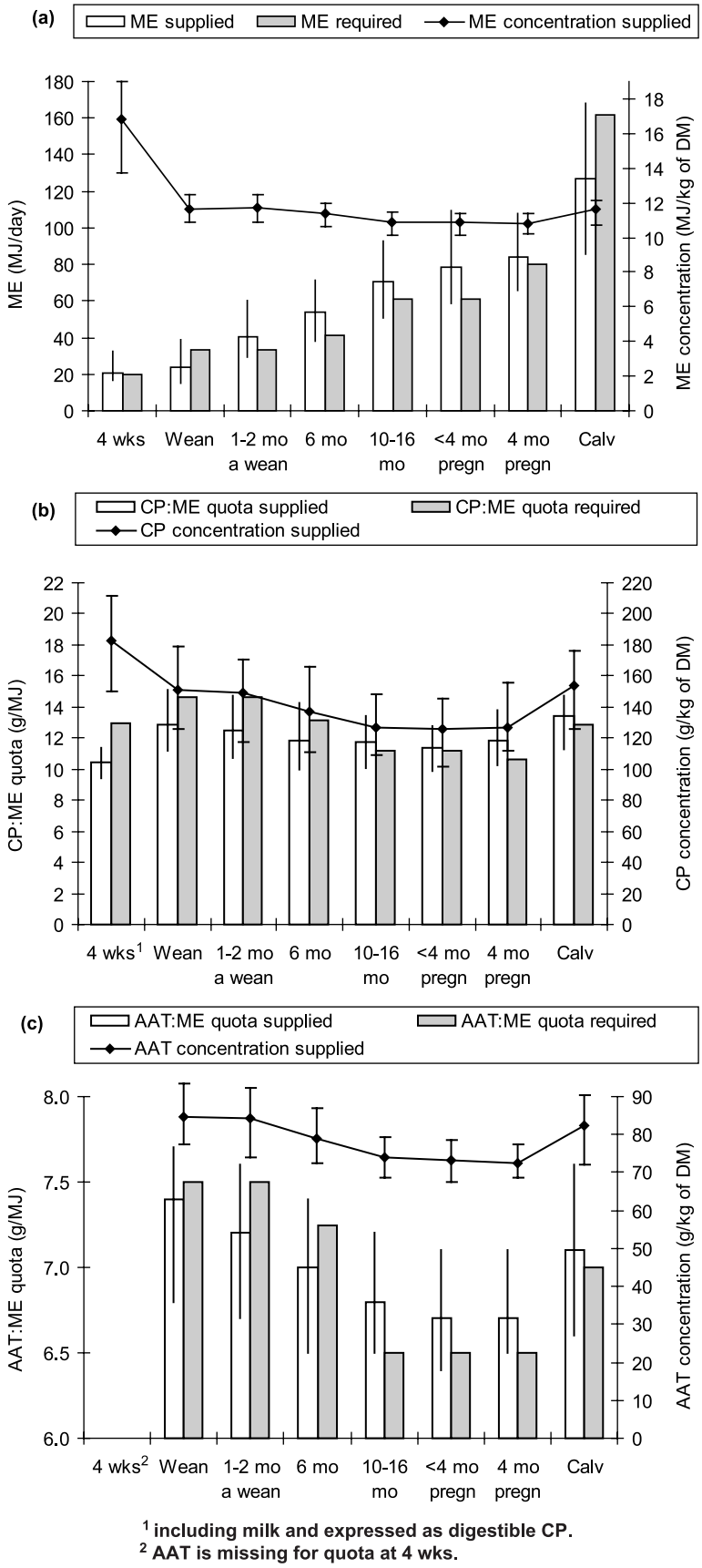

Fig. 1 (*Continued*)

Table 4. Average daily weight gain (g) in different periods (median and 80% central range (CR)) for calves and replacement heifers in 122 Swedish dairy herds in 1998–2000

Period	Median	(CR)	*n*
Birth to weaning	550	(416–681)	120
Weaning to 6–9 months of age	708	(472–846)	120
6–9 months of age to first service	624	(509–735)	114
First service to calving	431	(306–541)	114
First grazing season	524	(319–708)	116
Second grazing season	473	(167–686)	101

n = number of herds.

Discussion

Compared to recommendations in other countries (Strudsholm et al., 1999; NRC, 2001), Swedish protein recommendations for calves and replacement heifers (Olsson et al., 1998) are low, on average only 90% of the level recommended by NRC (NRC, 2001). Nevertheless, 69 to 86% of the herds in the present study, that were considered to be satisfactorily representative for Swedish herds in general, did not reach the Swedish minimum levels of CP:ME quotas for calves from weaning to 6 months of age (Fig. 1b). Herds at the lower limit of the 80% range had a 20% deficiency of CP:ME quota during this time period. For heifers from 10–16 months of age until calving, the median values of the CP:ME quotas were satisfactory according to Swedish protein recommendations, but herds at the upper limit of the central range had a 15% higher CP:ME quota than recommended. The excess protein sometimes originated from protein-rich forage, but often the animals were fed expensive protein concentrates that may have been unnecessary.

There were considerable variations in energy contents of the feed rations among the herds. Herds at the upper limit of the 80% central range were fed twice as much energy as the herds at the lower limit of the 80% central range. Consequently, there were considerable variations in average live weight gain of the heifers among the herds. Generally, the weight gains were low. No herd obtained an average daily weight gain from birth to calving of 700 g, and in 12% of the herds the average daily weight gain was below 500 g. At calving the average live weight was generally lower and the average age higher than Swedish recommendations

Table 5. Water source and supplementary feeding of concentrates and forage in spring, autumn and during the whole grazing season for first-season grazing calves (FSG; *n* = 120 herds) and second-season grazing heifers (SSG; *n* = 114 herds) in 122 Swedish dairy herds

	% of herds	
	FSG	SSG
Water		
Surface water only	10	19
Well only	68	48
Combination of surface water and well	22	33
Concentrates supplemented		
spring	28	5
autumn	30	7
whole grazing season	23	4
Forage supplemented		
spring	24	3
autumn	45	31
whole grazing season	19	1

(Emanuelson & Widebeck, 2001). Calving at 30 instead of the recommended 24 months of age increases the rearing costs by 25% (Nordgren, 1998). With decreasing prices for delivered milk and therefore smaller financial margins in Swedish dairy production, minimizing costs is very important. For herds with low energy contents in the feed rations, there is a great potential to increase the energy in feeds and thereby decrease the length and the costs of the rearing period.

However, excessive rates of growth during the 'critical period' (about 3 months of age until after puberty) may have adverse effects. Weight gains exceeding 750 g per day stimulate development of adipose tissue and diminish development of parenchymal tissue in the udder (Sejrsen, 1978; Sejrsen et al., 1982; Mäntysaari et al., 1995) and thereby affect future milk production (Sejrsen, 1978; Lammers et al., 1999; Radcliff et al., 2000). To diminish the negative effects of a high feeding level, Radcliff (1997) and Capuco et al. (1995) suggested the feeding of high protein concentrations. In our study, the average daily weight gain during the 'critical period' exceeded 750 g in one-third of the herds. Underfeeding of protein occurred simultaneously in one-third of these herds, and this increases the risks of a reduction in future milk production. To increase the overall daily weight

Fig. 1. (a) Contents and concentrations of metabolizable energy (ME), (b) Crude protein (CP):ME quotas and CP concentrations, and (c) Amino acids absorbed in the small intestine (AAT):ME quotas and AAT concentrations (median and 80% central ranges as error bars) in feed rations offered to calves and heifers in 108–122 dairy herds at 4 weeks (wks) of age, weaning (wean), 1–2 months (mo) after weaning, 6 mo of age, 10–16 mo of age, less than 4 mo of pregnancy (pregn), 4 mo of pregn, and at calving (calv), *n* = 62–81 herds. Requirements according to Swedish recommendations for growing calves and heifers gaining 700 g per day at the same ages and at calving, requirements for a cow (600 kg) with a daily production of 20 kg energy-corrected milk and no weight gain.

gain from birth to calving without increasing the gain during the 'critical period', the energy content of feeds during the indoor preweaning and pregnancy periods may be increased, and also during the grazing periods.

Protein deficiency may limit weight gain (Widdowson & Lister, 1991) and could have contributed to the low weight gains in the preweaned calves as discussed above. The simplest method of increasing feed energy during preweaning period is to raise the quantity of milk fed. Solid feed stimulates rumen development and is, therefore, also important to maximise the daily nutrient intake and to prepare the calves for weaning (Beharka et al., 1996).

In a majority of the herds, heifers grazed permanent grass, often combined with leys. The numbers of grazing animals and paddocks as well as the use of supplementary feeding in this study were similar to the results of Svensson et al. (2000). Livestock grazing on permanent grass may be exposed to a higher risk of parasitic infections because these grasslands generally are used continuously (Höglund et al., 2001). Furthermore, the herbage production of permanent grass is lower than on leys, and the animals have to forage more intensively for a similar level of forage intake. In this study, the weight gains of the calves and replacement heifers were generally lower on pasture than indoors. By applying strategic grazing management including effective parasite control methods, and also by using aftermath or supplementary feeding in late summer, sufficient weight gains by grazing heifers can be achieved (Höglund et al., 2001). The low weight gains during both grazing periods, especially during the second one, contributed to low weight gains during the pregnancy periods, although the indoor protein feeding was sufficient during this time period.

Results of this study emphasise the significance of formulating feed rations according to protein and energy recommendations, and the importance of strategic grazing management, in order to achieve satisfactory weight gains of calves and replacement heifers, resulting in decreased rearing costs in Swedish dairy herds.

Acknowledgements

The authors are grateful to the participating farmers for their time, interest and support. Sölve Johnsson and Dan-Axel Danielsson, The Swedish University of Agricultural Sciences, are acknowledged for their help in the initial planning of the study, and Per Arnesson and Tauno Turtinen, Skara Semin Dairy Association, for their help with practical arrangements. Karin Lundborg, Lotta Andersson, and Jonica Östlund, The Swedish University of Agricultural Sciences, are acknowledged for their herd visits and data collections, and Ingemar Olsson, The Swedish University of Agricultural Sciences, is acknowledged for his advice regarding protein recommendations. The study was financed by Stiftelsen Skaraborgs läns Nötkreatursförsäkringsbolags Stiftelse, The Swedish Farmers' Foundation for Agricultural Research, The Swedish Council for Forestry and Agricultural Research, Agroväst, Växjö Djurskyddsförening and The Swedish Dairy Association.

References

Anonymous. 1999. Feedstuff lists. Swedish Dairy Association, Hållsta, Sweden. 35 pp. (In Swedish.)

Beharka, A. A., Nagaraja, T. G., Morrill, J. L., Kennedy, G. A. & Klemm, R. D. 1996. Effects of form of the diet on anatomical, microbial, end fermentative development of the rumen of neonatal calves. J. Dairy Sci. 81, 1946–1955.

Bernes, G., Martinsson, K. & Pettersson, T. 1986. Practical heifer rearing: results from a survey in the county of Västerbotten. Report no. 7. The Agricultural Research Station of northern Sweden, Röbäcksdalen, Umeå, Sweden, 11 pp. (In Swedish.)

Capuco, A. V., Smith, J. J., Waldo, D. R. & Rexroad, C. E. 1995. Influence of prepubertal dietary regimen on mammary growth of Holstein heifers. J. Dair. Sci. 78, 2709–2725.

Emanuelson, M. & Widebeck, L. 2001. The replacement heifer: a review. Swedish Dairy Association, Hållsta, Sweden, 20 pp. (In Swedish.)

Heinrichs, A. J., Rogers, G. W. & Cooper, J. B. 1992. Predicting body weight and wither height in Holstein heifers using body measurements. J. Dairy Sci. 75, 3576–3581.

Hough, G. M. & Sawyer, G. J. 1993. Aspects of heifer management which limit productivity on dairy farms in Western Australia: a survey. Aust. J. Exp. Agric. 33, 833–837.

Höglund, J., Svensson, C. & Hessle, A. 2001. A field survey on the status of internal parasites in calves on organic dairy farms in south-western Sweden. Vet. Parasitol. 99, 113–128.

Lammers, B. P., Heinrichs, A. J. & Kensinger, R. S. 1999. The effects of accelerated growth rates and oestrogen implants in prepubertal Holstein heifers on estimates of mammary development and subsequent reproduction and milk production. J. Dairy Sci. 82, 1753–1764.

Lindberg, J-E. 1985. Estimation of rumen degradability of feed proteins with the *in sacco* technique and various *in vitro* methods. Acta Agriculturae Scandinavica, Suppl 25.

Lindgren, E. 1979. The nutritional value of roughages determined *in vivo* and by laboratory methods. Report no. 45. Department of Animal Nutrition, The Swedish University of Agricultural Sciences, Uppsala, Sweden, 61 pp. (In Swedish.)

Madsen, J., Hvelplund, T., Weisbjeg, M. R., Bertilsson, J., Olsson, I., Spörndly, R., et al. 1995. The AAT/PBV protein evaluation system for ruminants. A revision. Norwegian Jornal of Agricultural Sciences, Suppl 19.

Minitab Statistical Software. 2000. Release 13.31. Minitab Inc.

Mourits, M. C. M., Van der Fels-Klerx, H. J., Huirne, R. B. M. & Huyben, M. W. C. 2000. Dairy heifer management in the Netherlands. Prev. Vet. Med. 46, 197–208.

Mäntysaari, P., Ingvartsen, K. L., Toivonen, V. & Sejrsen, K. 1995. The effects of feeding level and nitrogen source of the diet on mammary development and plasma-hormone concentrations of pre-pubertal heifers. Acta Agric. Scand. Sect. A-Anim. Sci. 45, 236–244.

Nordgren, P. 1998. Effect of calving age on economy in the dairy herd. Swedish Dairy Association, Hållsta, Sweden, 11 pp. (In Swedish.)

NRC. 2001. Nutrient requirement tables. In: Nutrient requirements of dairy cattle: 7th ed. National Research Council, National Academic Press, Washington DC, USA, pp. 258–280.

Olsson, I., Ciszuk, P., Hellberg, S. & Widebeck, L. 1998. The AAT/PBV system for growing cattle: proposal for feeding recommendations based on crude protein and AAT. Report no. 246. Department of Animal Feeding and Management, The Swedish University of Agricultural Sciences, Uppsala, Sweden, 23 pp. (In Swedish.)

Olsson, I. & Lindell, L. 2002. Basis of updating recommended energy rations to growing cattle. Report no. 250. Department of Animal Feeding and Management, The Swedish University of Agricultural Sciences, Uppsala, Sweden, 20 pp. (In Swedish.)

Pettersson, K., Svensson, C. & Liberg, P. 2001. Housing, feeding and management of calves and replacement heifers in Swedish dairy herds. Acta Vet. Scand. 42, 465–478.

Pönniäinen, P. 1989. Methods for estimating live weight in heifers of Swedish Red and White breed. Master thesis no. 16. Department of Animal Feeding and Management, The Swedish University of Agricultural Sciences, Uppsala, Sweden, 25 pp. (In Swedish.)

Radcliff, R. P., Vandehaar, M. J., Chapin, L. T., Pilbeam, T. E., Beede, D. K., Stanisiewski, E. P. & Tucker, H. A. 2000. Effects of diet and injection of bovine somatotrophin on prepubertal growth and first-lactation milk yields of Holstein cows. J. Dairy Sci. 83, 23–29.

Radcliff, R. P., Vandehaar, M. J., Skidmore, A. L., Chapin, L. T., Radke, B. R., Lloyd, J. W., et al. 1997. Effects of diet and bovine somatotrophin on heifer growth and mammary development. J. Dairy Sci. 80, 1996–2003.

Sejrsen, K. 1978. Mammary development and milk yield in relation to growth rate in dairy and dual-purpose heifers. Acta Agric. Scand. 28, 41–46.

Sejrsen, K., Huber, J. T., Tucker, H. A. & Alkers, R. M. 1982. Influence of nutrition on mammary development in pre- and postpubertal heifers. J. Dairy Sci. 65, 793–800.

Simensen, E. 1983. An epidemiological study of calf health and performance in Norwegian dairy herds. VI. Effect of calf performance on subsequent health and performance of heifers. Acta Agric. Scand. A-Anim. Sci. 33, 137–142.

Spence, S. A. & Woodhead, A. C. 2000. The relationship between management practices and estimated weight for age of Friesian heifers in north-eastern New South Wales. Aust. J. Exp. Agric. 40, 357–362.

Spörndly, R. 2003. Feeding tables for ruminants. Report no. 257. Department of Animal Feeding and Management, The Swedish University of Agricultural Sciences, Uppsala, Sweden, 95 pp. (In Swedish.)

Strudsholm, F., Aaes, O., Madsen, J., Kristensen, V. F., Refsgaard Andersen, H., Hvelplund, T. & Østergaard, S. 1999. Danish feed recommendations for cattle. Report no. 84. The Danish Cattle Research Centre, Foulum, Denmark, 47 pp. (In Danish.)

Svensson, C., Hessle, A. & Höglund, J. 2000. Parasite control methods in organic and conventional dairy herds in Sweden. Livest. Prod. Sci. 66, 57–69.

Tozer, P. R. & Heinrichs, A. J. 2001. What affects the costs of raising replacement dairy heifers: a multiple-component analysis. J. Dairy Sci. 84, 1836–1844.

Widdowson, E. M. & Lister, D. 1991 Nutritional control of growth. In: Pearson, A.M. & Dutson, T.R. (ed.) Growth regulation in farm animals. Advances in meat research. Elsevier Science Publishers, New York, 7, 67–101