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Effects of winter feeding strategies with alternative feeds on the performance of mature suckler cows and their progeny

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The present study evaluated the effects of feeding strategies with alternative feeds on the performance of mature suckler cows and their progeny during indoor feeding and subsequent grazing. In both experiments, a 2 × 2 factorially arranged design consisted of two feeding strategies (Step-up, S; Flat-rate, F) and two diets (Control, C; Alternative, A). The aim of Strategy F was to offer the cows the same amount of energy as offered on Strategy S, but at a constant daily level. In Experiment 1, cows on Diet C were offered grass silage and straw and on Diet A grass silage and a flour-mill industry by-product. On Strategy S, feeding was stepped with barley (0, 1.5 and 3.5 kg d^{-1}). On Strategy F, barley was offered 1.43 kg per head daily. In Experiment 2, cows were offered either grass silage (C) or whole-crop barley silage (A) as a sole feed. Strategy S was carried out by offering 68, 95 and 119 MJ metabolizable energy (ME) per cow daily. On Strategy F, roughage was given daily 97 MJ ME. In both experiments, there were no significant differences between treatments in the cow live weight, body condition score, calf pre-weaning live weight gain and cow reproduction. Strategy F can be practised in the nutrition of mature suckler cows in marginal circumstances. Flour-mill industry by-product can partly replace grass silage and straw in the winter diet. Whole-crop barley silage can be offered as a sole feed to suckler cows with good body condition score in autumn.

Key words: beef, feeding, by-products, milk, whole-crop silage, body condition

Manuscript received December 2003

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Introduction

With dairy cows, the term flat-rate feeding strategy refers to a similar daily allocation of concentrates throughout lactation (Poole 1987). With suckler cows, presumably the traditional feeding strategy for the herd during the indoor feeding period is an allotment of the feeds taking into account the estimated calving date of the cow, in other words, the step-up feeding strategy. However, in many cases the estimated calving date might be unknown due to the absence of a pregnancy diagnosis. Step-up feeding is not difficult for a single cow but even the best managed beef herds usually calve over an eight to ten weeks period (Broadbent 1984). Therefore, more simple feeding strategies are needed. Although the flat-rate feeding system for mature beef cows, involving the entire diet, is successfully practised on some farms, no scientific study on this subject is available. For dairy cows, the flat-rate feeding system for concentrates has been widely reported (Poole 1987, Andries et al. 1988) but the results reported for dairy cows cannot be utilized for the suckler cows.

Indoor feeding of beef cows is usually based on inexpensive, low-energy feeds such as straw, treated straw (Mann et al. 1988, Fike et al. 1995, Manninen et al. 2000) or straw with protein or energy supplements (Alawa et al. 1986, Alawa et al. 1987, Alawa et al. 1988, Beck et al. 1992). Good quality grass silage is not used for beef cows *ad libitum* due to its high energy content, especially for cows in good body condition score pre-calving. Sometimes the availability of straw may be limited due to the weather conditions in the autumn or the geographical situation of the farm, or the available straw has to be reserved for litter. Results reported concerning the effects of flour-mill industry by-products or other alternative feeds such as whole-crop silages are common in the feeding of dairy cows (Hameleers 1998, Sutton et al. 2001) and beef cattle (O'Kiely and Moloney 1995, Komprda and Dolezal 1996, Moloney and O'Kiely 1997, Varhegyi et al. 2000), but not in the feeding of suckler cows. Therefore, beef cow producers need more information about alternative feeds suitable for indoor feeding. In addition, the utilization of flour-mill industry by-products for cattle, when possible, is important for the feed industry.

The following two experiments were undertaken to evaluate the effects of flat-rate vs. step-up feeding strategies with alternative feeds on the performance of mature suckler cows during a long indoor feeding period and subsequent grazing. The aim was to study if flat-rate feeding strategy instead of step-up feeding can be successfully carried out during the indoor feeding period, and if grass silage and straw can be replaced with other feeds. In Experiment 1 (Exp1), the influence of feeding strategy on the performance of Aberdeen Angus × Ayrshire (AbAy) and Charolais × Ayrshire (ChAy) cows was studied using either straw or a flour-mill industry by-product (BP) in the winter diet. In Experiment 2 (Exp2), the effects of feeding strategy on the performance of the Hereford (Hf) cows were studied using either grass silage (GS) or whole-crop barley silage (WCBS) as a sole winter feed. The effects of treatments on cow feed intake, diet digestibility (Exp2), live weight (LW), body condition score (BCS), milk production (Exp1), incidence of dystocia and calf performances are discussed in this paper.

Material and methods

Animals and experimental design

Twenty-four AbAy cows with an initial LW of 537 kg and 32 ChAy cows with an initial LW of 589 kg on 1 November, and 56 Hf cows with initial LW of 692 kg on 1 December were selected for Exp1 and Exp2, respectively. All animals were mature and pregnant to a Limousin (Li, Exp1) and Hf (Exp2) bull. In both experiments, four treatments in a 2 × 2 factorially arranged design consisted of two feeding strategies (Step-up, S; Flat-rate, F) and two diets (Control, C; Alternative, A). Initial LW, predicted calving date (gestational age assessed by ultrasonographic foetometry) and breed (Exp1) were used to allocate animals to groups and after that the treatments were randomly assigned to groups.

The animals were group-fed, once daily in the morning. Seven animals were kept per pen and there were two pens per treatment. In Exp1, each pen contained three AbAy cows and four ChAy cows. Exp1 and Exp2 consisted of two main periods, an indoor feeding period averaging 212 and 177 days and a grazing period averaging 74 and 102 days, respectively. On Strategies S, the indoor feeding comprised three periods which were from the start to 60 days pre-calving (95 and 58 days), the last 60 days pre-calving (64 and 57 days) and from calving to grazing (52 and 62 days) in Exp1 and Exp2, respectively. In Exp1, the indoor feeding ended 9 days before grazing commenced due to a shortage of one of the experimental feeds. For this interim period feed consumption data is not available. Grazing commenced on 1 June and on 26 May and the experiments ended on 14 August and 5 September in Exp1 and Exp2, respectively. The animal housing facilities were documented by Manninen et al. (1998). The experiments were carried out at Tohmajärvi Research Station located in eastern Finland. The average vegetation period is 155 days and grazing period 100–120 days.

Feeds and indoor feeding

In both experiments, wilted meadow fescue-timothy-red clover (*Festuca pratensis – Phleum pratense – Trifólium praténse*) GS was made using a mower conditioner and a precision chopper. Whole-crop barley silage was made at the dough stage using a double chopper. Silages were ensiled in bunker silos and clamps using a formic acid based additive, applied at 5 l t^{-1}. Pelletted and crushed BP included (g kg^{-1}) oat hull (850), dried grass meal (80), wheat molasses (50) and calcium lignosulfonate (20). Wheat molasses is hydrolysed wheat-starch including water-soluble carbohydrates approximately 60% of the dry matter (DM). Barley and barley straw were harvested conventionally.

The amount of feed offered and refused was recorded daily for each group. In Exp1, animals on Diet C were given GS and straw in the proportions 0.55 and 0.45 and on Diet A GS and BP in the proportions 0.30 and 0.70 on a DM basis, respectively. On Strategy S, milled barley was offered individually with three steps which were none from the onset of the experiment to 60 days pre-calving, 1.5 kg d^{-1} for the last 60 days pre-calving and 3.5 kg d^{-1} post-calving. On Strategy F, 1.43 kg d^{-1} milled barley was offered per animal during the entire indoor feeding. In Exp2, the animals were offered either GS (Diet C) or WCBS (Diet A). The energy content of the GS and WCBS was evaluated prior to the experiment by measuring *in vitro* organic matter (OM) digestibility. Subsequently, the measured energy value of 11.1 MJ metabolizable energy (ME) kg^{-1} DM was used both for GS and WCBS when the diets were formulated. Strategy S involved three steps which were from the onset to 60 days pre-calving, the last 60 days pre-calving and post-calving when 68, 95 and 119 MJ ME per animal were offered, respectively. On Strategy F, roughage was given at a constant daily level of 97 MJ ME d^{-1} during the indoor period. In both experiments, the aim of Strategy F was to offer the cows an equal amount of energy during the entire indoor feeding period as that offered on Strategy S but at a constant daily level. On Strategy S feed was offered according to Finnish recommendations which are based on those for dry dairy cows (Salo et al. 1982, Tuori et al. 1996). During indoor feeding cows received daily 100 g of a mineral mixture rich in phosphorus (Fosfori Hertta-Minera Muro: Ca 105, P 116, Na 70, Mg 75 g kg^{-1}), salt lick and water. A vitamin mixture (Exp1: Karjan Teho-Vitan: A 2 000 000 IU kg^{-1}, D_3 200 000 IU kg^{-1}, E DL-α-tocopheryl 1 800 mg kg^{-1}, Se 10 mg kg^{-1} and Exp2: Xylitol ADE-Vita: A 2 000 000 IU kg^{-1}, D_3 400 000 IU kg^{-1}, E DL-α-tocopheryl acetate 1 000 mg kg^{-1}, E DL-α-tocopheryl 900 mg kg^{-1}, Se 10 mg kg^{-1}) was given at 200 g per animal weekly.

Sampling and analyses

During the indoor period, roughage feed samples for chemical analyses were taken at every feeding

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and pooled over a four-week period. Barley and BP samples were pooled over an eight-week period. In Exp2, whole tract apparent OM, neutral detergent fibre (NDF), nitrogen (N) and starch digestibility coefficients were estimated using indigestible NDF as an internal marker (Lippke et al. 1986). Spot faecal samples were collected from each cow once per day on three consecutive days, twice (17–19 January and 15–17 March) before the calving period. The samples were pooled on the pen basis, thoroughly mixed, subsampled and stored at –20°C. During the faecal collection days, extra feed samples were collected daily.

Feed DM content was determined by oven drying at 105°C for 16 hours. Silage DM was corrected for volatile losses according to Huida et al. (1986). Feeds and faecal samples were analysed for ash (AOAC 1990), for total N by the Dumas method using a Leco FP 428 nitrogen analyser (Leco Corp., St Joseph, USA) and for NDF according to Van Soest et al. (1991). Starch was measured according to McCleary et al. (1994) from WCBS and faecal samples collected during the faecal collection days. The *in vitro* OM digestibility of the GS, WCBS and straw was estimated according to Friedel (1990). Fresh silage samples were analysed for pH, water-soluble carbohydrates by the method of Somogyi (1945), lactic acid (Haacker et al. 1983), volatile fatty acids (Exp1: Huida 1973, Exp2: Huhtanen et al. 1998), ammonia N (McCullough 1967), ethanol with an enzymatic kit (Cat No. 981680, KONE Instruments Corporation, Espoo, Finland) and soluble N by the Kjeldahl method using Cu as a digestion catalyst (AOAC 1990).

The ME value of the barley was calculated according to MAFF (1975, 1984) using the determined chemical composition and average digestibility coefficients reported by Tuori et al. (2000). The ME value of the BP was calculated using the energy table values for each component (Tuori et al. 2000). The ME values for the silages were calculated assuming a ME content of 16 MJ per kg digestible OM for GS (MAFF 1975) and 15.5 MJ for WCBS (Tuori et al. 2000). The content of digestible OM in DM (D value) was based either on *in vitro* (Exp1 and Exp2) or *in vivo* (Exp2) measurement of digestibility. Amino acids absorbed in the small intestine (AAT) were calculated according to Tuori et al. (2000).

Live weight, condition scoring and dystocia

The cows were weighed at the beginning of the experiment, 1–7 days *pre partum*, at the onset of grazing and at the end of the experiment. In Exp1, the cows were weighed 9 days prior to the onset of grazing and this weight was used as the LW at the onset of grazing. The cows were condition-scored (Lowman et al. 1976) when weighed. In Exp1, two cows (CS and AS) were removed from the experiment after calf deaths on 25 April and on 8 July. In Exp2, one cow (CS) was slaughtered after uterine torsion and two cows (CS and AS) did not nurse their calves. Three cows (AF) had premature deliveries. All those cows were omitted from the LW and BCS results.

Calves were weighed immediately after birth and at 50 days of age, at the onset of grazing and at the end of the experiment. In Exp1, data from stillborn twins were omitted. Two male calves (CS) have only birth weight (BW) and one male calf (AS) has BW and LW at 50 days of age. In Exp2, one female calf (CS) died at the age of three weeks and one female calf (AS) has only BW. The incidence of calving difficulties was recorded using the following classification scale which was easy calving with no assistance (1), calving with slight assistance (2), difficult calving (3) and very difficult calving requiring veterinarian assistance or caesarean section (4).

Milk production, grazing and fertility

Milk production and milk composition was measured on 14, 28, 42, 56, 70, 84, 98 and 112 days of lactation in Exp1 for six cows from each treatment using the machine-milking technique earlier described by Manninen and Taponen (2004). The cows were selected on a calving date and breed basis per treatment and per pen, taking into account the sex of the calf and the suitability of the cow for machine-milking.

In Exp1 and Exp2, cows were divided into two mating groups (Group I and Group II) for the grazing period and two Hf bulls ran with the cows from 5 June to 24 August and from 25 May to 28 August, respectively. In Exp1 and Exp2, the rotationally grazed pastures consisted of meadow fescue-timothy swards, with an area of 26.7 and 37.1 ha, respectively. The pasture soil type was sandy soil. Fertilisation rate was 170 and 190 kg N ha^{-1} in Exp1 and Exp2, respectively. The pastures were topped when necessary. In Exp2, pre- and post-grazing sward height (SH) was measured with a sward stick for each rotation. The pre-grazing pasture mass was measured and grass samples were analysed for D value, ash and crude protein (CP) content. Cows had free access to water and a magnesium-rich mineral mixture (Viher Hertta-Minera Muro: Ca 160, P 64, Na 90, Mg 80 g kg^{-1}). Ultrasonographic examinations were performed in Exp1 on 24 August and 4 October and in Exp2 on 10 August and 4 October for assessing the status of pregnancy and gestational age. The ultrasound examinations and measurement of gestational age were as described by Manninen and Taponen (2004).

Statistical analysis

The intake data and *in vivo* digestibility coefficients were evaluated by group and analysed using one-way analysis of variance. The rest of the variables were recorded individually. The between-pens variation was used as an error term when treatments were compared, because treatments were allocated to animals penned together in groups. Therefore the response variable, y, was analysed by the following statistical model:

$$y_{ijk} = \mu + \text{treatment}_i + \text{pen}_j(\text{treatment}_i) + \text{breed}_k + \text{treatment} \times \text{breed}_{ik} + \text{pen}_j \times \text{breed}_k + e_{ijk}$$

where treatment_i, breed_k and $\text{treatment} \times \text{breed}_{ik}$ are, respectively, effects due to the ith treatment, kth breed and their interaction; $\text{pen}_j(\text{treatment}_i)$ is the error term for treatment effect; $\text{pen}_j \times \text{breed}_k$ is the error term for breed; and e_{ijk} is the between-animal variation. Breed_k, $\text{treatment} \times \text{breed}_{ik}$ and $\text{pen}_j \times \text{breed}_k$ effects were not included in the analysis of data from Exp2 because all the animals of that experiment were the same breed. Both experiments had 4 treatments (2 diets and 2 feeding strategies). In the analysis of calf data, the statistical model used contains birth date and sex as a regression covariant. The regression coefficient of birth date was assumed to be equal in all treatment groups. The effect of sex, however, seems to vary from treatment to treatment. Therefore, a sex-by-treatment interaction effect was included in the model. The assumptions of the models were checked by graphical methods which were scatter diagrams for constancy of error variance and box plots for normality of errors. The statistical analyses were performed by SAS (1999) software and the GLM procedure.

Results

Feed value and feed intake

The mean chemical composition of the experimental feeds is given in Table 1 and the *in vivo* apparent digestibility coefficients (Exp2) in Table 2. In Exp1, the GS had a high *in vitro* D value of 708 g kg^{-1} DM but contained on average 3.9 g kg^{-1} DM of butyric acid. The CP content of the BP was 48 g higher than that of the straw, mostly due to the proportion of dried grass meal in the mixture. However, the ME and AAT values were similar for both straw and BP and thus the feeds were comparable. In Exp1, the cows on Diet C did not consume all the straw offered but, despite this, the DM intake was on average 0.31 kg higher ($P < 0.05$) on Diet C than on Diet A (Table 3). The ME, NDF and AAT intake was 17.7 MJ, 899 g and 125 g higher ($P < 0.001$) on Diet C than on Diet A, mainly due to the higher DM intake and the higher proportion of GS on Diet C. In Exp2, cows on Diet C received 1.4 and 11.7 MJ ME more than on Diet A evaluated by the *in vitro* ($P < 0.01$) and *in vivo* method (P <

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0.001), respectively. The digestibility coefficients of the WCBS for OM, NDF and CP were significantly lower than those for the GS (P < 0.01, 0.68 vs. 0.76; P < 0.001, 0.57 vs. 0.74; P < 0.001, 0.59 vs. 0.69).

Live weight, body condition score and dystocial cases of cows

In both experiments treatments had only minor effects on cow LW and BCS (Table 4) and a very low incidence of calving problems were observed. In Exp1, the LW gain (LWG) was similar for all treatments indoors and on pasture averaging –15 and 60 kg, respectively. A slight effect of treatment on the BCS was found at the onset of grazing since cows on Diet C had on average 0.37 unit higher (P = 0.06) BCS than those on Diet A. On pasture the BCS of the cows fed Diet A increased while the cows fed Diet C had a slightly negative change of BCS (P < 0.01, 0.32 vs. –0.04). Two calvings (Diets CF and AS) were classified as difficult with the value 3, eight calvings needed slight assistance and 46 were easy.

In Exp2, the LWG was also similar for all treatments indoors and on pasture averaging –12 and 78 kg, respectively. The treatments had no effect on the cow BCS averaging 3.35, 3.01, 3.15 and 3.35 at the onset of the experiment, at calving, before and after grazing, respectively. One calving was classified with the value 4 due to uterine torsion, two calvings needed slight assistance and the rest were easy.

Live weight of calves

In Exp1, the average calf birth date was 10 April (Table 5). An interaction (P < 0.05) between the

Table 1. Mean chemical composition and feed value of feeds.

	Experiment 1				Experiment 2	
	Barley	Grass silage	Barley straw	Flour-mill by-product	Grass silage	Whole-crop barley silage
Number of samples	5	11	8	4	8	9
Chemical composition						
Dry matter (DM), g kg^{-1}	872	265	876	883	301	335
In the DM, g kg^{-1}						
Ash	23	66	50	57	70	47
Crude protein	122	116	35	83	148	119
Neutral detergent fibre	180	592	853	593	503	432
D-value		708	439		693 / 703	711 / 645
Lactic acid		34			21	27
Acetic acid		15			10	12
Butyric acid		3.9			0.5	2.6
Ethanol		5.5			4.7	6.9
Water-soluble carbohydrates		95			135	40
In total nitrogen, g kg^{-1}						
Ammonia N		59			40	73
Soluble N		593			408	619
pH		4.12			4.18	4.03
Feed value, kg^{-1} DM [1)]						
Metabolizable energy, MJ	13.6	11.3	6.1	6.0	11.1 / 11.2	11.0 / 10.0
AAT, g	105	82	54	49	83 / 84	86 / 80

D-value, digestible organic matter in dry matter
AAT, amino acids absorbed in the small intestine
[1)] Exp1; *in vitro* based, except metabolizable energy and AAT for barley and by-product. Exp2; *in vitro* / *in vivo* based.

treatments and sex was found for the BW of Li × AbAy calves and an interaction ($P < 0.05$) between diet and sex for the BW of Li × ChAy calves. Afterwards treatments had no effect on calf daily LWG averaging 1203, 1353 and 1301 g for pre-grazing, grazing and pre-weaning for all the calves, respectively.

Table 2. Mean treatment effects on the *in vivo* apparent digestibility coefficients in Experiment 2.

Diet (D)	Grass silage		Whole-crop barley silage			Significance[1)]		
Strategy (S)	Step-up	Flat-rate	Step-up	Flat-rate	SEM	D	S	D × S
Number of groups	2	2	2	2				
Digestibility coefficients								
Organic matter	0.75	0.76	0.68	0.67	0.010	**		
Neutral detergent fibre	0.73	0.75	0.58	0.56	0.011	***		
Crude protein	0.67	0.71	0.59	0.60	0.004	***	**	
Starch			0.94	0.93	0.010			

SEM, Standard error of means
[1)] * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 3. Mean daily intake of dry matter, crude protein, neutral detergent fibre, metabolizable energy and amino acids absorbed in the small intestine of cows during indoor feeding.

Diet (D)	Control		Alternative			Significance[1)]		
Strategy (S)	Step-up	Flat-rate	Step-up	Flat-rate	SEM	D	S	D × S
Number of groups								
Exp1	2	2	2	2				
Exp2	2	2	2	2				
Dry matter intake, kg								
Exp1								
Grass silage	5.58	5.58	2.79	2.79				
Straw	2.83	2.75						
By-product			5.30	5.30				
Barley	1.10	1.22	1.01	1.22				
Mineral mixture	0.08	0.05	0.10	0.06				
Total	9.59	9.60	9.20	9.38	0.105	*		
Exp2								
Grass silage	8.83	8.82						
Whole-crop silage			8.76	8.74				
Mineral mixture	0.11	0.11	0.12	0.13				
Total	8.94	8.92	8.87	8.87	0.018	*		
Crude protein, g								
Exp1	865	890	873	910	8.0		*	
Exp2	1248	1296	1032	1035	1.9	***	***	***
Neutral detergent fibre, g								
Exp1	5921	5872	4978	5017	72.1	***		
Exp2	4397	4424	3787	3776	6.8	***		*
Metabolizable energy, MJ								
Exp1	95.5	96.7	76.9	79.8	1.04	***		
Exp2	97.8 / 99.2	97.7 / 99.1	96.4 / 87.6	96.4 / 87.4	0.17 / 0.16	** / ***		
Amino acids absorbed in the small intestine, g								
Exp1	726	736	594	618	8.3	***		
Exp2	731 / 739	734 / 742	751 / 696	751 / 696	1.3 / 1.2	*** / ***		

Exp1, Experiment 1; Exp2, Experiment 2
SEM, Standard error of means
[1)] * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

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In Exp2, the average calf birth date was 26 March. An interaction (P < 0.05) between the treatments and sex was found for BW. The treatments had no effect on calf daily LWG but pre-grazing, grazing and pre-weaning the males grew 167, 243 and 213 g d^{-1} better (P < 0.05) than the females, respectively.

Milk production, grazing and conception

An interaction (P < 0.05) between the treatments was found for the average milk production (Table 6). The average daily milk yield was greater for the cows fed Diet CF compared to those fed Diet CS, the opposite being true on Diets AF and AS. The

Table 4. Live weight, live weight gain, body condition score and change of body condition score of cows during indoor feeding and grazing.

Diet (D)	Control		Alternative		SEM	Significance[1)]		
Strategy (S)	Step-up	Flat-rate	Step-up	Flat-rate	min–max	D	S	D × S
N Exp1	13	14	13	14				
Exp2	12	14	13	11				
Live weight, kg								
Initial								
Exp1	565	562	564	558	20.4–21.8			
Exp2	707	692	683	696	7.5–8.8			
Pre partum								
Exp1	641	668	649	660	16.0–17.1			
Exp2	778	779	739	775	14.8–17.4			
End of experiment								
Exp1	600	591	614	604	15.3–16.3			
Exp2	764	764	748	762	13.9–16.3			
Live weight gain, kg								
Start ⇒ Grazing								
Exp1	–13	–7	–16	–28	13.8–14.8			
Exp2	–22	–12	–8	–8	6.3–7.4			
Grazing ⇒ End of experiment								
Exp1	57	55	59	73	6.0–6.4			
Exp2	79	83	73	74	7.2–8.5			
Body condition score								
Initial								
Exp1	2.80	2.72	2.45	2.61	0.151–0.162			
Exp2	3.42	3.43	3.16	3.35	0.093–0.109			
Calving								
Exp1	2.42	2.50	2.22	2.65	0.111–0.119			
Exp2	2.96	3.17	2.89	2.96	0.093–0.109			
End of Experiment								
Exp1	2.53	2.42	2.40	2.53	0.169–0.180			
Exp2	3.38	3.42	3.27	3.26	0.087–0.102			
Change of body condition score								
Start ⇒ Grazing								
Exp1	–0.23	–0.26	–0.30	–0.47	0.080–0.086			
Exp2	–0.24	–0.19	–0.15	–0.21	0.042–0.049			
Grazing ⇒ End of experiment								
Exp1	–0.04	–0.04	0.25	0.40	0.072–0.077	**		
Exp2	0.20	0.18	0.26	0.12	0.042–0.049			

Exp1, Experiment 1; Exp2, Experiment 2
SEM, Standard error of means
[1)] * P < 0.05, ** P < 0.01, *** P < 0.001

Table 5. Mean treatment and sex effects on calf performance.

Diet (D)	Control				Alternative											
Strategy (S)	Step-up		Flat-rate		Step-up		Flat-rate		SEM	Significance[1)]						
Sex (E)	Male	Female	Male	Female	Male	Female	Male	Female	min–max	D	S	E	D×S	D×E	S×E	D×S×E
Initial number of animals																
Exp1	9	6	10	3	7	7	5	9								
Exp2	7	6	7	7	5	9	6	4								
Average birth date[2)]																
Exp1	95	93	105	87	112	96	101	105	4.7–8.8							
Exp2	85	93	87	88	70	91	82	85	3.7–5.9							
Live weight, kg																
At birth																
Exp1; Li × AbAy – n	47.2–2	42.1–4	43.7–4	57.5–1	46.3–4	48.4–2	47.8–3	44.0–3	2.60–5.50							*
Exp1; Li × ChAy – n	45.4–7	44.6–2	51.1–6	41.5–2	46.1–3	52.6–5	45.9–2	47.2–6	2.13–4.15					*		
Exp2; Hf	46.7	44.2	45.9	42.8	45.7	40.7	44.5	44.6	0.52–0.85			**				*
Live weight gain, g d⁻¹																
From birth to 50-d																
Exp1	1363	1048	1175	1220	1192	1290	1189	1162	58.7–111.4							
Exp2	1300	1141	1199	984	1140	956	1114	989	42.0–66.6			*				
Indoors																
Exp1	1338	1046	1161	1169	1191	1307	1178	1191	58.0–110.0							
Exp2	1300	1115	1133	955	1075	921	1104	955	43.4–68.8			*				
At pasture																
Exp1	1422	1318	1377	1427	1282	1310	1463	1235	51.4–97.3							
Exp2	1578	1345	1510	1250	1703	1359	1531	1393	76.0–120.5			*				
Birth ⇒ End of experiment																
Exp1	1396	1212	1299	1318	1260	1310	1341	1214	45.6–86.2							
Exp2	1472	1257	1369	1138	1457	1192	1368	1228	61.1–96.8			*				

Exp1, Experiment 1; Exp2, Experiment 2
SEM, Standard error of means
1) * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$
2) 1 January = 1

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average energy-corrected daily milk yield was 12.0 kg and the milk fat and the milk lactose content on average 40.1 and 49.1 g kg^{-1}, respectively. Milk protein was 1.6 g kg^{-1} higher (P = 0.09) on Strategy S than on Strategy F.

Pre-grazing herbage mass varied between 450 and 4700 kg DM ha^{-1} during the summer in Exp2. Mean post-grazing SH of the grazed area was 11 cm in both groups and the proportion of the infrequently grazed area was 22%, although there was a large variation during the summer (0–68%). Mean D value of the grass was 725, CP content 218 and the ash content 86 g kg^{-1} DM. The pasture area for each cow-calf pair increased from 0.48 to 0.58 ha as the pasture growth decreased to the end of the grazing season.

In Exp1, one cow fed Diet CF was open after the mating period. In Exp2, 50 cows entered the mating period of which one on Diet AS was observed open. In Exp1 and Exp2, the duration from the calving to conception averaged 75 and 76 days, respectively and the calving intervals were 358 and 360 days.

Discussion

Cow performance

Straw and BP had the same ME content in Exp1. Since the proportion of BP on Diet A was higher than that of straw on Diet C, the ME intake was clearly lower on Diet A. In Exp2, the energy content of GS was similar as evaluated by both *in vitro* and *in vivo* methods indicating the suitability of the *in vitro* method for the evaluation of the energy content of GS. In contrast, the *in vitro* method over-estimated the energy content of the WCBS by one MJ. This lead to lower ME intake with WCBS than GS since the ME value based on *in vitro* measurement was used when calculating the daily rations. The energy content of WCBS depends largely on the stage of maturity of the crop, the proportion of straw in the plant, the variety, the weather conditions and probably also the animal and the level of production (Kristensen 1992). In the present experiment, the digestibility of the

Table 6. Milk yield and milk composition in Experiment 1.

Diet (D)	Control		Alternative		SEM	Significance[1)]		
Strategy (S)	Step-up	Flat-rate	Step-up	Flat-rate	min–max	D	S	D × S
Number of animals	6	6	6[2)]	6				
Milk yield, kg d^{-1}								
Day of lactation								
14	11.5	10.6	11.7	10.9	0.73–0.77			
28	10.5	11.8	12.7	10.3	0.62–0.66			*
42	12.2	13.1	13.8	10.4	0.60–0.63			*
56	11.6	12.5	13.7	11.0	0.84–0.88			
70	11.5	12.6	13.7	12.4	0.45–0.47			
84	12.9	13.6	13.4	12.4	0.46–0.49			
98	12.0	13.3	12.4	12.7	0.53–0.56			
112	11.4	12.7	12.7	13.0	0.50–0.53			
Mean	11.7	12.5	13.0	11.6	0.24–0.25			*
Mean, ECM	11.7	11.9	12.7	11.8	0.44–0.47			
Milk composition, g kg^{-1}								
Fat	41.3	38.2	40.0	42.8	2.23–2.36			
Protein	29.8	28.4	30.6	28.9	0.69–0.73			
Lactose	49.4	48.2	49.1	49.2	0.89–0.94			

SEM, Standard error of means
ECM, Energy-corrected milk
1) * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$
2) One cow lost her calf 8 July

WCBS was considerably lower than that of the GS. However, the *in vivo* apparent digestibility coefficients of the WCBS for starch (0.932), CP (0.594) and OM (0.677) were in good accordance with the values of 0.959, 0.598 and 0.647, measured with steers for whole-crop wheat silage harvested at the hard-dough stage of development (Deschard et al. 1988).

The whole-crop barley silage with a DM content of 335 g kg^{-1} was of moderate fermentation quality, as evidenced by a low pH and low ammonia but rather high butyric acid content. The WCBS proved to be suitable feed for the indoor feeding period in cold conditions because the high DM content conferred a non-freezing property.

The practical feeding occurred satisfactorily in both experiments with all feeds and strategies. Strategy S was uncomplicated to practice since the estimated calving dates were available due to pregnancy diagnosis. The duration of the indoor feeding period was on average seven months in Exp1. During this period the cows on Diets C and A received a total of 20 400 and 16 600 MJ ME per cow, respectively. In Exp2 the experimental winter feeding period was six months, leading to total energy consumption on Diets C and A of 17 600 and 15 500 MJ ME, respectively. Broadbent (1984) advises a total of 12 500 MJ ME from 21 October to end of April during which the cows receive a constant level of 65 MJ ME per day. The amount of energy the cows received in the present study was, however, higher. Especially in Exp2 the BCS of the cows was probably too good for mature cows. In both experiments, there were no significant differences between the treatments in cow LW and LWG. At the onset of grazing in Exp1 the cows were on average 15 kg lighter but at the end of the experiment 41 kg heavier than at the beginning of the experiment. The average LWG from the start to the end of the experiment was quite similar and satisfactory in both experiments. The results suggest that a daily amount of 80 MJ ME during the winter period offered with a flat-rate feeding strategy may be enough for beef cows in marginal circumstances. Implementation of this suggestion, however, requires knowledge of the energy content of the feeds available, knowledge of the size and BCS of the cows, as well as knowledge of the duration of the calving period and the post-calving lactating days indoors before grazing.

The treatments affected the BCS only in Exp1. At the beginning of Exp1, the cows were in moderate condition averaging 2.6 which may be slightly too low for crossbred cows after the grazing season (Lowman et al. 1976). This reflects both the good milk production capacity of the cows and probably the insufficient pasture area the cows had prior to the present experiment (Manninen and Taponen 2004). The BCS at calving indicates the minor effects of the feeding strategy on cow performance. At the onset of grazing cows fed Diet A had an average BCS of 2.1, which may, however, be acceptable (Lowman et al. 1976). At that time the lower BCS on Diet A compared to that achieved on Diet C is in good agreement with the amount of energy the cows received daily during the winter period, 78.4 vs. 96.1 MJ ME, respectively. On pasture, the change of BCS remained constant for the cows fed Diet C and the LWG was at least satisfactory. On Diet A, the animals improved their BCS.

In Exp2, the high post-grazing SH and the large proportion of infrequently grazed area in the middle of the grazing season indicated low pasture utilization. The recommended post-grazing SH for high production dairy cows in Finland is 9–10 cm and the proportion of infrequently grazed area less than 40% (Virkajärvi et al. 2002). Suckler cows in extensive production should manage well with a lower post-grazing SH and a smaller proportion of infrequently grazed area than dairy cows. In this case, the low pasture utilization caused a large amount of wasted grass and an increased need for topping. However, due to non-restricted feeding the cows condition score increased in the present experiment and was well above the recommendation in autumn (Lowman et al. 1976).

Vanzant and Cochran (1993) evaluated the impact of step-up protein supplementation strategies, using soybean meal/sorghum grain or dehydrated alfalfa pellets, on the performance of Hf × Angus cows and their calves when grazing tallgrass prairie in winter. In agreement with the present study, the cows did not benefit appreciably from stagger-

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ing the rate of feeding. The change in LW and BCS was affected somewhat by the immediate level of supplementation but had minor effects on reproductive performance or calf LWG.

The health of the cows was good in both experiments in spite of the three cows on Diet AF with premature delivery due to an infection by *B. Licheniformis* bacteria in Exp2. All three cows were in the same pen and probably the infection spread through the afterbirth.

The differences between treatments in the milk production and milk composition were small in Exp1. The suckling ability, in other words, the vigour of the calves, was good on the basis of the good calf LWG. Although the BCS was rather low on Diets CS and AS at calving and on Diets AS and AF at the onset of grazing, it did not seem to affect the milk production. This indicates the ability of the cows to mobilize body reserves for milk production.

The milk production was fairly constant during the entire experiment. A small increase in milk production was observed after day 28 of lactation, especially on Diets CF and AS, which may largely be due to the turnout to pasture. This observation is in good agreement with the well-known fact that the daily milk yield of beef cows increases slowly after calving and reaches a maximum 1-3 months *post partum*. On the other hand, the average milk production in the present study distinctly exceeded the commonly reported (e.g. Petit and Agabriel 1989) value of 1.0–1.2% of LW, mainly due to high milk production capacity of the beef-dairy crosses. The average milk production measured in this experiment is in good agreement with the results earlier reported by Manninen and Taponen (2004) with the same beef-dairy crosses and with the results of Manninen and Huhta (2001) for Hf × Ay- and Li × Ay-cows, both milk production values being measured by the machine milking technique. In the present experiment the milk fat content was considerably lower than that observed by Manninen and Huhta (2001) and Manninen and Taponen (2004). Milk fat content agrees well with the values measured for Charolais by Petit and Agabriel (1989), but the protein content was lower. The milk lactose content is in good agreement with the results reported earlier (Manninen and Huhta 2001, Manninen and Taponen 2004).

In beef cow production, it is important to maintain the calving interval at about 365 days and the calving period at eight to ten weeks, at the same time of the year. In the present experiments this target was well achieved in all treatments. This indicates that the BCS was at least sufficient for rebreeding in Exp1 in spite of the low BSC values. However, the BCS of 2.3 for cows in Exp1 at the onset of grazing, is higher than the value of 1.5–2.0 suggested by Petit and Agabriel (1989) as adequate for cows calving in late winter (less than 60 days before turn-out) due to the high level of nutrition provided on good quality spring grass which induces a rapid return to heat and good fertility.

Calf performance

The effects of treatments on the calf LW and LWG were not significant. The relatively high BWs for both males and females did not cause calving problems. The primary reason for this finding is undoubtedly the age of the cows and the suitable BCS at calving. In addition, all calvings were monitored carefully which may also explain the low incidence of dystocial cases. The pre-weaning LWG was similar for calves on all treatments in both experiments although in Exp2 the males grew better than the females. The main reasons for the good LWG of the calves in both experiments arises from the good milk production capacity of the cows, although measured only in Exp1, and the good pastures available. The calf LWG measured in this experiment agree well with the earlier studies (Manninen et al. 1998, 2000, Manninen and Huhta 2001, Manninen and Taponen 2004), reflecting strongly the cow's ability to sustain milk production for the calf by using her own body reserves.

In conclusion, the flat-rate feeding strategy can be practised as a simple way of managing the nutrition of mature suckler cows during the long indoor period in marginal conditions. Flour-mill industry by-product with low energy content can replace straw and grass silage in the winter diet of the suckler cows. The effects of the WCBS on the cow performance were comparable to the good quality grass silage. Therefore, non-freezing WCBS with high DM content can be offered restricted as a sole feed for mature suckler cows in a cold environment. The cow BCS before the indoor feeding period must always be considered carefully when planning the winter diet and feeding strategy. A prerequisite for a successful winter feeding strategy is analysis of the energy content of each feed.

Acknowledgements. The authors wish to express their thanks to Mrs. Ulla Eronen and her staff for technical assistance during the experiments as well as Juha Hurmalainen, DVM, for his cooperation with the ultrasonic scanning programme. The evaluation of the manuscript by Dr. Seija Jaakkola is gratefully acknowledged. This work was financially supported by the Finnish Konkordia Fund. The flour-mill industry by-product used in Exp1 was received from Raisio Feed Ltd, which is gratefully acknowledged.

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SELOSTUS

Tasaruokinnan ja vaihtoehtoisten rehujen soveltuvuus emolehmien talvikauden ruokintaan

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Osassa Suomea ei ole riittävästi olkea emolehmien talviruokintaan. Kokoviljasäilörehu on puolestaan osoittautunut varteenotettavaksi rehuksi emolehmien talvikauden ruokintaan. Kokoviljasäilörehulla ruokittaessa ruokinnan suunnittelua vaikeuttaa kuitenkin se, että rehun energiapitoisuudelle ei ole täysin luotettavaa määritysmenetelmää.

Pitkän astutuskauden vuoksi poikimiset ajoittuvat emolehmätiloilla monesti usean kuukauden ajalle. Sisäruokintakauden eläimet ovat ryhmissä, jolloin lisäruokinta on hankalaa kohdentaa yksilöllisesti. Tasaisella ruokinnalla eläimen saama energiamäärä on yhtä suuri kuin porrastetulla (ylläpito-tunnutus-herutus) ruokinnalla, mutta energiamäärä jakaantuu tasaisesti koko sisäruokintakauden ajalle. Tasainen ruokinta perustuu siihen, että eläin varastoi ennen poikimista ylimääräisen energian kudosrasvoiksi, joita se sitten hyödyntää mm. maidontuotantoon ennen laidunkautta.

Tämän tutkimuksen tavoitteena oli selvittää oljen ja säilörehun osittainen korvattavuus kaurankuoripohjaisella teollisuuden sivutuotteella (Koe 1) sekä ohrakokoviljasäilörehun soveltuvuus ja tuotantovaikutukset (Koe 2) emolehmillä kylmissä tuotanto-olosuhteissa. Molempia ruokintavaihtoehtoja tarkasteltiin tasaisella ja porrastetulla ruokinnalla.

Kokeessa 1 oli 56 risteytysemoa, jotka kokeen alussa painoivat keskimäärin 567 kg, ja Kokeessa 2 oli 56 herefordemoa, jotka kokeen alussa painoivat keskimäärin 692 kg. Koemalli oli 2 × 2 faktoriaalinen. Faktoreina ruokintastrategia (porrastettu vs. tasainen) ja rehutyyppi (kontrolli vs. vaihtoehtoinen). Kokeessa 1 kontrolliruokinnalla nurmisäilörehun osuus oli 0,55 ja oljen 0,45 kuiva-aineen syönnistä, vaihtoehtoisella ruokinnalla nurmisäilörehun ja teollisuuden sivutuotteen osuudet olivat vastaavasti 0,3 ja 0,7. Ruokinta porrastettiin ohralla, jota annettiin 60 d ennen poikimista 1,5 ja poikimisen jälkeen 3,5 kg/d. Tasaisella ruokinnalla eläimet saivat ohraa koko sisäruokintakauden ajan 1,43 kg/d. Kokeessa 2 eläimet saivat joko nurmisäilörehua tai ohrakokoviljasäilörehua tasaruokintana 97 MJ ME/d tai porrastetusti 68–95–119 MJ ME/d.

Kokeen 1 emot saivat kontrolli- ja vaihtoehtoruokinnoilla keskimäärin 96,1 ja 78,3 ja Kokeen 2 emot vastaavasti 99,2 ja 87,5 MJ ME/d. Ruokintojen välillä ei esiintynyt eroja emojen elopainossa kummassakaan kokeessa. Kokeen 1 porrastetulla ruokinnalla olleet emot olivat poikiessa hieman heikommassa kunnossa kuin tasaisella ruokinnalla olleet emot. Laidunkaudella Kokeen 1 vaihtoehtoisella ruokinnalla olleet emot kuntoutuivat puolestaan hieman kontrolliruokinnalla olleita emoja paremmin. Kokeessa 2 ruokintojen välillä ei kuntoluokissa esiintynyt eroja. Kokeen 1 emojen energiakorjattu maidontuotanto oli keskimäärin 12,0 kg päivässä. Kokeen 1 vasikat kasvoivat keskimäärin 1301 g/d. Kokeen 2 sonnivasikat kasvoivat lehmävasikoita paremmin. Ajanjakso poikimisesta uudelleen tiinehtymiseen kesti 75 päivää Kokeessa 1 ja 76 päivää Kokeessa 2.

Tulosten perusteella tasaruokintaa voidaan suositella täysikasvuisille emolehmille kylmiin tuotanto-olosuhteisiin. Mikäli saatavilla on hinnaltaan kilpailukykyistä teollisuuden sivutuotetta, sillä voidaan korvata olkea ja säilörehua talvikauden rehustuksessa. Kokoviljasäilörehu soveltuu hyvin hyväkuntoisille emolehmille talvikauden ainoaksi rehuksi mm. jäätymättömyytensä ansiosta.