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Using clover/grass silage as a protein feed for dairy bull calves

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Abstract Soybean meal (SBM) is globally used as a protein feed of good nutritional quality, e.g. for calves. However, the environmental impact of soybean cultivation is often questioned and SBM can therefore of ethical reasons be replaced by nitrogen-fixing forage and grain legumes and rapeseed products. In two experiments (exp.), we examined whether feeding dairy bull calves forages with a high inclusion of red clover together with cold-pressed rapeseed cake (CRC; exps. 1 and 2) and field bean (FB; exp. 2) met their protein requirement for proper growth, and calculated the profitability of using these diets. The calves were allocated to one of three protein feed treatments per experiment and studied from 97 to 275 kg live weight. In exp. 1, red clover/grass silage was combined with either smaller or greater amounts of CRC, which was compared with SBM. In exp. 2, red clover/grass silage, CRC and FB were combined with silage constituting 40, 50 or 60 % of DM in the total diet, to find the best combination. The profitability was calculated as value of calf gain minus feed costs. Soybean meal gave the highest live weight gain (LWG) and profitability in exp. 1, closely followed by the diet with greater amount of CRC together with clover/grass silage. In exp. 2, the diets with 40 or 50 % silage resulted in similar DM intake and LWG, both higher than with 60 % silage. At conventional prices, the 40 % silage diet had the highest profitability, whereas at organic prices, the 50 % silage diet was more profitable.

Keywords Clover silage · Cattle · Beef production · Feed intake · Live weight gain · Profitability

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Introduction

Feeding high levels of forage to ruminants is consistent with the principles of organic production. After the milk feeding period, calves in organic production should be fed with at least 60 % forage on a daily basis (EU 2008) or at least 70 % forage after 6 months of age (KRAV 2014). However, calves need high dietary concentrations of protein with high protein quality, i.e. rumen undegradable protein, especially in the first 6 months after weaning. Soybean meal is widely used globally as a protein feed of good nutritional quality, but the environmental impact of soybean cultivation is often questioned, since it can result e.g. in felling of rainforests and contamination of water. Furthermore, hexane-extracted soybean is not permitted in organic production (EU 1999). Instead, forage legumes and grain legumes and rapeseed products can be used, to make the production system more ethically acceptable. Forage legumes, including red clover (*Trifolium pratense*), have many advantages, not at least environmentally, but feeding only forage legumes can result in low weight gain, as legumes contain a high proportion of rumen degradable protein (Dewhurst et al. 2003). However, feeding forage legume silage has been shown to increase dry matter intake (DMI), with accompanying higher live weight gain (LWG), in growing cattle compared with feeding grass silage (Thomas et al. 1981; Fraser et al. 2007; Dewhurst et al. 2009). Studies with steers have shown that the higher the proportion of red clover silage relative to grass silage fed to these animals, the higher the LWG (Fraser et al. 2003, 2007). Also, in feeding experiments with growing lambs, a higher LWG has been reported with red clover silage than with grass silage (Speijers et al. 2004; Marley et al. 2007). Forage legumes are easily broken into small particles in the rumen, an effect which is associated with susceptibility to bloat (Dewhurst et al. 2009). Furthermore, the high amount of rumen degradable protein may lead to inefficient nitrogen (N) use (Dewhurst et al. 2009). However, higher N use efficiency has been reported in lambs fed clover silage than in lambs fed grass silage (Marley et al. 2007).

In Swedish case studies, locally produced feeds other than forage legumes, such as rapeseed and field beans, have been shown to be environmentally better than imported feeds (Flysjö et al. 2008; Strid 2010). The use of raw beans and oilseed cakes is generally well-accepted, and the mechanically processed, solvent-free cake is well suited for organic production (Johansson and Nadeau, 2006; Rinne et al. 2014). However, few studies have examined the performance of young calves fed cold-pressed rapeseed cake (CRC) and/or field beans (FB) as a supplement to diets based on clover/grass silage.

The aim of the present experiments (exps.) was to examine whether feeding calves silages with a high inclusion of red clover together with two different amounts of CRC (exps. 1 and 2) and FB (exp. 2) met their protein requirement for proper growth. This was done by comparing DMI, LWG and feed efficiency (FE). The profitability of calf rearing based on these diets was also estimated. A further aim of exp. 1 was to test the possible weight gain on high levels of forage.

Material and methods

Animals, experimental design and diets

The experiments were approved by the Research Animal Ethics Committee (Swedish Board of Agriculture) and conducted at Götala Beef and Sheep Research Station, Swedish University of Agricultural Sciences, Skara. Two experiments, including Swedish Red and Swedish Holstein dairy bull calves (79 and 75 calves in exps. 1 and 2, respectively), were conducted during 2 years, with one experiment per year. Exp. 1 was carried out from November 2011 to April 2012 and exp. 2 lasted from May to October 2013. In exp. 1, the calves were kept in pens (41 m^2) with deep straw bedding in a non-insulated barn, with four pens per treatment and six to seven animals per pen. In exp. 2, the animals were housed in an insulated barn with 16 slatted concrete floor pens (11 m^2). Five pens, each containing five calves, were used for each treatment combination.

In all experiments, the calves were randomly allocated to one of three diet treatment groups, regardless of breed. Feed was offered at ad libitum intake (5–10 % refusals) and feeding was done once a day. The protein feeds studied in exp. 1 were red clover (*T. pratense*)/grass silage (50 % clover), combined with either a smaller amount of CRC (treatment CGRS) or a greater amount of CRC (treatment CGRG), which were compared with imported soybean meal (treatment SBM) (Table 1). A grass-based silage was also included in the basal diets for all treatments in exp. 1, and therefore, a total mixed ration (TMR) consisting of grass silage (90 % grass, 10 % clover), rolled barley and vitaminised minerals, together with either CGRS, CGRG or SBM, was fed daily to the calves (Table 1). The diets were not isonitrogenically balanced, as the aim was to test the possible weight gain on feeding high levels of forage. The forage constituted 54, 66 and 84 % of DM in the TMR for the SBM, CGRG and CGRS calves, respectively.

In exp. 2, the calves were fed the same feeds in three different combinations, with silage constituting 40, 50 or 60 % of DM in the TMR (Table 1). The TMR consisted of clover/grass silage (70 % clover), rolled barley, CRC, FB and vitaminised minerals. All diets were isonitrogenically balanced in exp. 2.

In both experiments, the diets were rebalanced four times during the rearing period to match the change in nutrient requirements due to the increased live weight of the calves (Spörndly 2003).

Data collection

Live weight and feed intake The calves were weighed once every fortnight during the experimental period and

Table 1 Average daily feed intakes of the experimental (exp.) diets; either clover/grass silage with smaller amount of cold-pressed rapeseed cake (CGRS), clover/grass silage with a greater amount of cold-pressed rapeseed cake (CGRG), soybean meal (SBM) or clover/grass silage, cold-pressed rapeseed cake and field beans in combination with 40, 50 or 60 % silage of the total DM diet

	Exp. 1			Exp. 2		
	CGRS	CGRG	SBM	40 %	50 %	60 %
Grass silage[a], kg DM	0.66	1.38	2.72			
Clover/Grass silage[b], kg DM	2.65	1.89		2.36	2.92	3.25
Cold-pressed rapeseed cake, kg feed	0.20	0.46		0.72	0.62	0.50
Soybean meal, kg feed			0.53			
Field bean, kg feed				0.72	0.62	0.50
Barley, kg feed	0.54	1.46	2.17	2.38	1.91	1.29

[a] Botanical composition 10 % clover and 90 % grass

[b] Botanical composition 50 % clover and 50 % grass in exp. 1, 70 % clover and 30 % grass in exp. 2

on two consecutive days at the start and end of the experiments. The average daily LWG of the animals was calculated from the start and end weights. The DMI was recorded at pen level, while LWG was recorded for the individual calves, and FE was therefore calculated for each pen.

Feed sampling Silage samples were taken daily and pooled to one composite sample per week for analysis of DM and to one sample per month for analysis of nutrients on a DM basis. However, silage samples for fermentation quality were only taken weekly and pooled to one bulk sample per silo. Samples of CRC, FB and SBM were collected weekly and pooled to one composite sample per month for chemical analysis, whereas for barley, the weekly samples were pooled to one composite sample every second month. All samples were stored at −20 °C until analyses (Table 2).

Feed analyses and calculations The DM concentration of silage was determined at 60 °C for 24 h (Volden 2011), while the DM concentration of concentrates was determined at 103 °C for 24 h (EU 2009). Crude protein (CP) and neutral detergent fibre (NDF) in forages and concentrates, crude fat in concentrates and fermentation characteristics of the silages were analysed at Eurofins Laboratories Inc. (Lidköping, Sweden), as described by Johansson and Nadeau (2006). The metabolisable energy (ME) content of silage was calculated from in vitro rumen organic matter digestibility.

Profitability

The profitability was calculated as value of calf growth minus cost of feeds consumed. Silage net cost was taken as the cultivation costs less environmental payments for ley and organic agriculture, and other prices used were market prices for conventional and organic products. In the basic price situation, costs and prices in Southern Sweden, according to Agriwise (2014), were used. In sensitivity analyses different calf growth rates and feed prices were used. It was assumed that differences in calf weight at the end of the experiments would persist until slaughter at 18 months of age, which was the case for exp. 2 (data not shown, calves in exp. 1 could not be followed until slaughter). Thus, the value per kilogram calf growth was calculated as carcass price multiplied by dressing percentage (standardised at 50 %).

Statistical analyses

To compare the effects of the three protein feeds per experiment, two different procedures in SAS (2010) were used. Analyses of DMI and FE were performed at pen level with the PROC GLM and a model including protein feed as a fixed factor. PROC MIXED was used for analyses of LWG on an individual level, where the model included protein feed as a fixed factor and calf nested within pen (SAS 2010). A level of $P<0.05$ was considered statistically significant and P values between 0.05 and 0.10 were considered to show a tendency towards significance.

Table 2 Nutrient composition of the grass silage, clover/grass silage and cold-pressed rapeseed cake (CRC1 and CRC2 in exps. 1 and 2), soybean meal (SBM) and field bean (FB) used in the experiments

	Exp. 1				Exp. 2		
	Grass silage[c] *n*=6	Clover/grass silage1[d] *n*=5	CRC1 *n*=5	SBM *n*=5	Clover/grass silage2[e] *n*=5	CRC2 *n*=5	FB *n*=5
DM (%)	40 (7)	33 (3)	89 (1)	86 (0)	33 (2)	89 (0)	83 (0)
ME[a] (MJ)	11.2 (1.0)	10.8 (0.4)	16.2 (0.6)	14.0 (1.3)	10.7 (0.3)	15.5 (0.2)	13.5 (0.5)
Crude protein	124 (8)	144 (13)	330 (17)	523 (9)	177 (31)	316 (3)	286 (8)
Crude fat	nd	nd	199 (27)	25 (2)	nd	177 (7)	17 (2)
Ash	63 (11)	83 (10)	64 (3)	65 (2)	104 (14)	65 (0)	35 (1)
NDF[b]	522 (23)	513 (16)	235 (5)	138 (19)	489 (24)	273 (9)	177 (20)

Means and standard deviation, shown as grams/kilogram DM unless otherwise stated

nd not determined

[a] Metabolisable energy

[b] Neutral detergent fibre

[c] Fermentation characteristics (per kg DM); pH 4.5, 54 g lactic acid, 7.5 g acetic acid, 0.9 g propionic acid, 2.1 g butyric acid

[d] Fermentation characteristics (per kg DM); pH 4.3, 56 g lactic acid, 10.5 g acetic acid, 3.2 g propionic acid, 2.1 g butyric acid

[e] Fermentation characteristics (per kg DM); pH 4.4, 71 g lactic acid, 25.0 g acetic acid, 2.0 g propionic acid, 2.1 g butyric acid

Results

Feed intake and live weight gain

Calf live weight averaged 94 (±14 SD) kg at the start of exp. 1 and 202 (±6), 267 (±4) and 290 (±21) kg at the end for CGRS, CGRG and SBM, respectively. In exp. 2, the average initial weight of the calves was 100 (±20) kg and the final weight was 297 (±5), 289 (±4) and 271 (±9) kg for calves fed diets with 40, 50 and 60 % forage, respectively.

In exp. 1, feeding clover/grass silage with a small amount of CRC resulted in lower DMI, LWG and FE than feeding a greater amount of CRC or the SBM diet (Table 3). Feeding the calves CGRG gave the same DMI as the SBM diet, but lower LWG and FE. Intake of ME, CP and NDF was the same for CGRG and SBM calves, but intake of NDF as a percentage of live weight was higher for CGRG calves. In exp. 2, feeding calves the diets with 40 or 50 % silage gave similar DMI, intake of CP and ME, and LWG, but feeding 60 % silage gave lower intake of DM, CP and ME and lower LWG, and resulted in a higher intake of NDF as a percentage of live weight compared with the other two diets. No difference in FE was found between calves fed 40, 50 or 60 % silage (Table 4).

Profitability

The highest profitability per calf in the basic price situation (with organic feed prices for SBM, CRC, barley and silage of 0.75 EUR/kg, 0.62 EUR/kg, 0.25 EUR/kg and 0.14 EUR/kg DM, respectively) in exp. 1 was obtained by feeding SBM (190, 182 and 109 EUR during the study period for SBM, CGRG and CGRS, respectively). However, in organic production with the SBM price above 0.90 EUR/kg or with a combined barley price above 0.28 EUR/kg and silage price below 0.11 EUR/kg DM, CGRG was the most profitable option.

In exp. 2, with organic prices, the profitability was similar among the three diets, with somewhat higher profitability in the basic price situation (with same organic feed prices as in exp. 1 and 0.32 EUR/kg for FB) for the diet with 50 % silage in total DM (172, 167 and 167 EUR during the study period for 50, 40 and 60 % silage, respectively). However, the profitability was sensitive to price changes. The diet with 60 % silage was the most profitable in organic production when the cost of silage production was low (0.11 EUR/kg DM) and the concentrate price was high (barley >0.27 and FB >0.43 EUR/kg). These prices can occur in forest districts in less favoured areas with high subsidies for ley and high costs of grain and field bean production

Table 3 Daily intake, daily live weight gain, total live weight gain and feed efficiency of bull calves in exp. 1 fed a diet containing either clover/grass silage with smaller amount of cold-pressed rapeseed cake (CGRS), clover/grass silage with a greater amount of cold-pressed rapeseed cake (CGRG), or soybean meal (SBM)

	CGRS	CGRG	SBM	SEM	*P*
Intake of dry matter (kg/day)	4.0[a]	4.9[b]	5.0[b]	0.14	***
Intake of dry matter (% of live weight)	3.1[a]	3.0[a]	2.8[b]	0.05	**
Intake of NDF (kg/day)	1.5[a]	1.7[b]	1.8[b]	0.05	**
Intake of NDF (% of live weight)	1.11[a]	1.03[b]	0.97[c]	0.02	***
Intake of metabolisable energy (MJ/day)	46[a]	61[b]	63[b]	1.8	***
Intake of crude protein (g/day)	581[a]	722[b]	778[b]	22	***
Live weight gain (kg/day)	0.72[a]	1.15[b]	1.28[c]	0.04	***
Total weight gain (kg)	110[a]	176[b]	196[c]	6.6	***
Feed efficiency (g gain/MJ ME)	16[a]	19[b]	20[c]	0.3	***

Expressed as least square means with standard error of means (SEM)

**$P<0.01$; ***$P<0.001$, values on the same row with different superscripts (a, b, c) are significantly different ($P<0.05$)

because of poor land consolidation. When using prices for conventional feeds, the 40 % diet resulted in the highest profitability.

Discussion

The calves fed CGRG had similar intake of ME and CP to SBM calves, but lower LWG. This is probably due to the high CP degradability in the rumen of the clover/grass silage. The diets in exp. 1 were not isonitrogenically balanced as the objective was to test the possible weight gain on feeding high levels of forage (54, 66 and 84 % of DM for the SBM, CGRG and CGRS calves, respectively). The forage level in the CGRG treatment is consistent with organic standards and the daily LWG was 0.13 kg lower with rapeseed cake and clover/grass silage as the only protein source, than the LWG for SBM calves.

However, feeding greater amounts of CRC gave a higher LWG than when calves were fed small amounts of CRC. Legume silages contain high levels of rumen degradable N, which may lead to inefficient N utilisation (Dewhurst et al. 2003) and thus high urinary N losses (Cohen et al. 2006). This problem can to some extent be solved by supplementing the silage with low-protein, high-energy feeds such as barley (Cohen et al.

Table 4 Daily intake, daily live weight gain, total live weight gain and feed efficiency of bull calves in exp. 2 fed a diet containing clover/grass silage, cold-pressed rapeseed cake and field beans in combination with 40, 50 or 60 % silage

	40 %	50 %	60 %	SEM	*P*
Intake of dry matter (kg/day)	5.6[a]	5.6[a]	5.2[b]	0.66	***
Intake of dry matter (% of live weight)	3.0[a]	3.0[a]	2.9[b]	0.03	*
Intake of NDF (kg/day)	1.9[b]	2.0[a]	2.0[a]	0.02	***
Intake of NDF (% of live weight)	1.00[c]	1.08[b]	1.12[a]	0.01	***
Intake of metabolisable energy (MJ/day)	71[a]	69[a]	62[b]	0.8	***
Intake of crude protein (g/day)	953[a]	951[a]	893[b]	11	**
Live weight gain (kg/day)	1.40[a]	1.35[a(b)]	1.22[b]	0.05	*
Total weight gain (kg)	197 [a]	190[a(b)]	172 [b]	6.6	*
Feed efficiency (g gain/MJ ME)	19.8	19.7	19.6	0.2	ns

Expressed as least square means with standard error of means (SEM)

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, values on the same row with different superscripts (a, b, c) are significantly different ($P<0.05$) or superscript within parenthesis show tendency to significance ($P<0.10$). *ns* non-significant ($P>0.10$)

2006). In the present experiments, TMR feeding was used and thus energy and protein were offered simultaneously. Therefore, it is possible that the rumen microbes in the CGRG calves produced more microbial protein, which could be enzymatically degraded and absorbed in the small intestine, than the microbes in the calves fed CGRS. Feeding energy and protein at the same time is one way to optimise protein utilisation (Børsting et al. 2003).

Besides low live weight gains in calves fed very high amounts of forage, such as CGRS calves, it is important to feed calves to meet their specific requirements, so that malnutrition does not occur. Malnourished calves are in risk of increased incidence of disease, owing to the failure of homeostatic mechanisms that maintain the supply of cellular fuels (Oetzel 1988). Furthermore, high proportions of forage legumes in the diet may result in bloat because of the breakage into small particles in the rumen (Dewhurst et al. 2009). The calves in our experiments showed no signs of bloat.

If the CP concentration in the clover/grass silage had been higher in exp. 1, the LWG would probably have been higher. This was shown in exp. 2, with higher CP in the silage, as the LWG for calves fed 40 and 50 % silage was higher than that of calves fed SBM in exp. 1. When 60 % silage was fed, intake of ME and CP was lower and thus LWG was lower, compared with the diets with 40 and 50 % silage. Intake of NDF, expressed as proportion of live weight, was highest for the CGRS calves in exp. 1 and the 60 % silage calves in exp. 2, which might have restrained their total intake in comparison with the other calf groups. In both experiments, the highest NDF intake as a percentage of live weight was on average 1.12 %, which might be the upper limit for NDF intake by calves between 100 and 300 kg live weight. No difference in FE was found between calves fed 40, 50 or 60 % silage. This supports the use of the highest silage proportion because of less eutrophication from growing lay compared to growing concentrates (Flysjö et al. 2008). But considering cost of labour and of buildings, it is probably more profitable with a higher daily LWG with an accompanying shorter growth period.

Rearing of organic dairy bull calves can give rise to conflicting objectives, as they have a high requirement for quality protein, while at the same time high intake of forage is required by the organic regulations. Using forage legumes is optimal in this case because of the increased DMI relative to feeding grasses (Thomas et al. 1981; Fraser et al. 2007; Dewhurst et al. 2009). The higher intake from legumes has been shown to be linked to both faster fermentation rate and more rapid particle breakdown within the rumen (Wilson and Kennedy 1996; Dewhurst et al. 2009). Further reasons for using legume silages are reduced methane production (Beauchemin et al. 2008) and a higher polyunsaturated fatty acid/saturated fatty acid (PUFA:SFA) ratio in muscle than in cattle fed grass silage (Lee et al. 2009).

Feeding grain legumes, such as field beans and peas, rather than SBM has previously been shown to give similar LWG in young bull calves and also similar, or even improved, profitability (Johansson et al. 2011). Using locally produced protein feeds instead of SBM is of great interest in both organic and conventional feeding because of the environmental advantages. Case studies in Sweden have shown that feeds grown on farm have less impact on the environment than imported feeds, partly due to the lower energy requirements for transportation (Strid 2010) and lower greenhouse gas emissions (Flysjö et al. 2008). Also, Knudsen et al. (2011) showed that transport is a very relevant factor to the environmental footprint of vegetable products. Furthermore, in organic production under some conditions, locally produced protein feeds can be as economically competitive as SBM, as showed in the present calculations. The CGRG option can be more profitable than SBM in organic production, at least in less favoured forest districts with high subsidies for ley production, resulting in low net cost of silage production, and disadvantageous land consolidation, resulting in high costs of grain production. In such districts, the 60 % silage diet can also be more profitable than lower shares of silage. However in conventional production, the SBM diet in exp. 1 and the 40 % silage diet in exp. 2 were most profitable in all reasonable price situations. One reason for locally produced protein competing best in organic production is that organic silage is cheap thanks to subsidies, including the agri-environmental payment for organic production and low real production costs in organic clover silage production. Another reason is that organic SBM is much more expensive than conventional SBM (0.75 and 0.52 EUR/kg, respectively).

Conclusions

Forage legumes contain more crude protein than grass, but this protein is highly rumen degradable. When legume forage is fed together with energy-rich cold-pressed rapeseed cake and field beans, the protein in the feeds can be utilised to a higher extent and satisfactory calf weight gain can be achieved. However, providing forage-fed young calves with only minor amounts of rapeseed cake is not recommended, due to impaired growth and profitability and possible health risks.

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