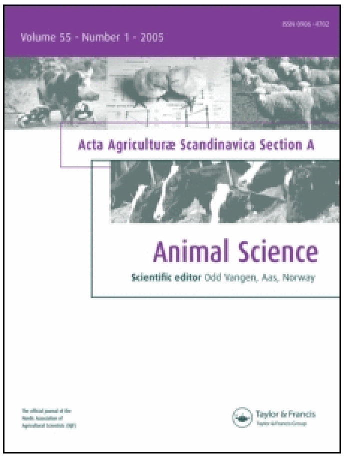

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ORIGINAL ARTICLE

Cold-pressed hempseed cake as a protein feed for growing cattle

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Abstract

Cold-pressed hempseed cake was investigated as a protein feed for young calves and finishing steers. Half of the animals were fed cold-pressed hempseed cake, whereas the other half were fed a mixture of soybean meal and barley. Effects on feed intake, liveweight gain (LWG), faecal traits and carcass traits (steers only) were studied. Neutral detergent fibre intake was higher for animals fed hempseed cake than for those fed soybean meal ($P<0.05$). In addition, the number of long particles in faeces was lower ($P<0.05$) and faecal dry matter content and consistency were higher from animals which were fed hempseed cake ($P<0.05$; steers only). Higher feed intakes in calves fed hempseed cake ($P<0.05$) combined with similar LWG resulted in lower feed efficiency in hemp-fed calves ($P<0.05$). In conclusion, hempseed cake compared to soybean meal as a protein feed for intensively fed growing cattle results in similar production and improved rumen function.

Keywords: *Beef, faeces, hempcake, hempmeal, protein supplement, soybean meal.*

Introduction

In the shadow of the debate on effects of livestock production on climate (Steinfeld et al., 2006), interests in alternatives to soybean meal as a protein feed have increased. Dominating domestic protein feeds in the Nordic countries are peas, field beans and rapeseed (Information Centre of the Ministry of Agriculture and Forestry, 2006; Official Statistics of Norway, 2007; Official Statistics of Sweden, 2007; Statistics Denmark, 2007). Unfortunately, these feeds generally have low concentrations of rumen undegradable protein (RUP). For example, the RUP values for peas, field beans and cold-pressed rapeseed cake are 290, 170 and 460 g kg^{-1}of crude protein (CP), respectively (Hedqvist & Udén, 2006; Chaudhry, 2007). Furthermore, these feeds cannot be grown successfully in the northern part of the region (Official Statistics of Sweden, 2007).

Hemp, *Cannabis sativa* L., was historically grown for fibre and seed production in the Nordic countries, but was prohibited due to a high Δ-9 tetrahydrocannabinol (THC) content. In 2003, hemp strains with low concentrations of narcotic substances were once again allowed to be grown in the European Union (EU Council Directive, 2003). Hemp can be grown successfully at high latitudes, but the hempseed yields can vary considerably (600–2000 kg seed ha^{-1}; Callaway, 2002; Callaway, 2004; Finell et al., 2006).

From the hempseeds, oils with fatty acid profiles favorable for human health (Kuhn et al., 1997) are extracted for food and cosmetic purposes, whereas the remaining hempseed cake can be used as animal feed. The CP concentration in cold-pressed hempseed cake is around 320 g kg^{-1}, which is higher than in peas and normally also higher than in field beans and cold-pressed rapeseed cake (Hedqvist & Udén, 2006; Johansson & Nadeau, 2006; Chaudhry, 2007; Martinsson, 2008). Furthermore, the proportion of CP consisting of RUP can be superior in the hempseed products compared to other commonly grown protein feeds in Scandinavia. Hempseed meal in a study of Mustafa et al. (1999) and hempseed cake in a study of Martinsson (2008) contained 774 and 420 g RUP kg^{-1} CP, respectively. However,

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content of RUP in various protein feeds can vary considerably, probably related to maturity at harvest, conditions during extraction of the oil and sample preparation before analysis (Åman & Graham, 1987; de Marichal et al., 2000). In general, when using feeds with high proportions of rumen degradable protein to ruminants, synchronisation of protein and carbohydrate sources is very important for optimal nitrogen utilisation (Børsting et al., 2003).

Feeding cold-pressed hempseed products as a protein feed instead of soybean meal has resulted in similar production results in poultry and fish (Hullar et al., 1999; Callaway, 2004; Silversides & Lefrançois, 2005). Despite the potential of hempseed in livestock production, only a few studies on hempseed products as a protein feed for ruminants have been undertaken (Mustafa et al., 1999; Gibb et al., 2005). In beef cattle, studies on cold-pressed hempseed cake are scarce. However, a study using full-fat hempseed improved the fatty acid profile in beef (Gibb et al., 2005). The aim of the present study was to investigate the effects of cold-pressed hempseed cake as a protein feed on feed intake, liveweight gain (LWG), faecal traits and carcass traits in intensively fed, growing cattle.

Materials and methods

Experimental design

The study consisted of two experiments and was conducted at Götala Research Station, The Swedish University of Agricultural Sciences, Skara, southwestern Sweden. Experiments (Exp.) 1 and 2 were carried out from March to September 2006 and from November 2005 to July 2006, respectively. In Exp. 1, calves were fed cold-pressed hempseed cake or soybean meal in a completely randomised design to investigate the effects of protein feed on feed intake, LWG and faecal traits in the animals. In Exp. 2, finishing steers were used in a $2 \times 2 \times 2$ factorial design. Two sources of protein feed (cold-pressed hempseed cake *vs.* soybean meal), two breeds (Swedish Holstein *vs.* Swedish Red), and two levels of targeted liveweight (LW) at slaughter (600 kg *vs.* 650 kg) were used to study the effects of protein feed, breed and LW at slaughter on feed intake, LWG, faecal traits and carcass traits in the animals.

Animals

Prior to the start of the experiments, all cattle had an adaptation period to increasing grain feeding for two weeks. During the experiments, weights of the animals were recorded once every second week, and on two consecutive days at the start and at the end of the experiments. The average daily LWG of the animals were calculated from the start and end weights.

In Exp. 1, 56 bull calves of the dairy breeds Swedish Holstein ($n = 33$) and Swedish Red ($n = 22$) were raised from weaning until 250 kg LW. At the start of the experiment, the calves were six to eight weeks of age with an average LW of 96 (SD 21) kg. The calves were randomly allocated into one of two protein feeds, regardless of breed, and kept in pens (41 m^2) with deep-straw bedding in a non-insulated barn with four pens per treatment and with seven animals in each pen.

In Exp. 2, 51 steers of the dairy breeds Swedish Holstein ($n = 28$) and Swedish Red ($n = 23$) were studied during finishing. The steers were housed for a finishing period after having grazed semi-natural grasslands during the preceding summer. At the start of the experiment, they were 13–15 months of age with an average LW of 365 (SD 37) kg for the Swedish Holsteins and 399 (SD 28) kg for the Swedish Red steers. Within the two breeds, the steers were allocated randomly into one of two sources of protein feed and one of two levels of LW at slaughter. There were two pens with two to four individuals in each pen per treatment combination. The animals were housed in an insulated barn with 16 slatted concrete floor pens (11 m^2).

Except the death of one calf in Exp. 1, no diseases or disorders were found in the experimental cattle.

Feeding

Animals were provided feed on a pen level once a day. All animals were fed mixed rations *ad libitum*, which was defined as the intake at 5–10% orts. Orts were weighed and disposed three times a week. The mixed rations contained 400 g grass/clover silage kg^{-1} DM (Table I) and 600 g rolled barley kg^{-1} DM in Exp. 1. In Exp 2, the mixed rations contained 450 g grass/clover silage kg^{-1} DM (Table I) and 550 g rolled barley kg^{-1} DM. The silages consisted of approximately 90% grass (*Lolium perenne* L., *Festuca pratensis* L., and *Phleum pratense* L.) and 10% clover (*Trifolium repens* L. and *Trifolium pratense* L.). Herbage was wilted to 250 g DM $kg^{-1}$and ensiled in bunker silos. An acidic preservative containing formic acid (420–490 g kg^{-1}), propionic acid (170–230 g kg^{-1}), and ammonia (40–90 g kg^{-1}) (Promyr™, Perstorp Inc., Perstorp, Sweden) was used at four litres per tonne of herbage.

In addition to the mixed rations, two different protein feeds were fed separately in restricted amounts. Half of the animals in each experiment were fed cold-pressed hempseed cake from the oilseed variety Finola (Callaway, 2004), whereas

Table I. Chemical composition (kg^{-1} dry matter) of grass/clover silage provided to 55 dairy calves (Experiment 1) and 51 dairy steers (Experiment 2).

	Experiment 1		Experiment 2[a]			
			Silo 1		Silo 2	
	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*
Dry matter, g kg^{-1}	246 (10)	15	220 (5)	7	277 (37)	29
Digestible OM, g kg^{-1} OM[b]	740 (30)	4	752 (75)	3	799 (55)	7
Metabolisable energy, MJ	9.9 (0.4)	4	9.1 (1.0)	3	10.6 (0.6)	7
Crude protein, g	174 (–)	1	127 (6)	3	116 (33)	7
Neutral detergent fibre, g	512 (59)	4	560 (34)	3	552 (52)	7
Ash, g	72.1 (6.2)	4	93.4 (4.0)	3	69.8 (3.3)	7
NH_4-N, g kg^{-1} N	165 (–)	1	170 (–)	1	146 (4.7)	3
Sugar, g	– (–)	–	– (–)	–	21.0 (–)	1
Lactic acid, g	76.4 (–)	1	63.8 (–)	1	100.3 (41.4)	3
Acetic acid, g	29.2 (–)	1	19.2 (–)	1	17.6 (7.0)	3
Butyric acid, g	1.6 (–)	1	0.4 (–)	1	0.6 (0.2)	3
Propionic acid, g	4.4 (–)	1	2.3 (–)	1	1.2 (0.5)	3
Ethanol, g	6.8 (–)	1	2.7 (–)	1	10.7 (4.2)	3
pH	4.1 (–)	1	4.2 (–)	1	4.1 (0.3)	3

[a]Silo 1 was fed during the first seven weeks and silo 2 during remaining finishing period. [b]OM, organic matter.

the other half were fed a mixture of 50% soybean meal and 50% rolled barley (Table II). The estimated final diets were formulated to fulfill the CP requirements as recommended by Olsson et al., (1998) and the protein feed concentrations were formulated to be iso-nitrogenic. However, analyses of feed actually fed differed slightly in CP concentrations (Table II).

In Exp. 1, the calves were fed 1.0 kg of protein feed (i.e. 1.0 kg of hempseed cake *vs.* 0.5 kg of soybean meal and 0.5 kg of barley) animal^{-1} day^{-1} throughout the experiment. In Exp. 2, two different amounts of protein feed were fed to the steers due to varying CP concentrations in the silages, resulting in 0.2 kg protein feed (i.e. 0.2 kg of hempseed cake *vs.* 0.1 kg of soybean meal and 0.1 kg of barley) animal^{-1} day^{-1} during the first seven weeks and 1.4 kg (i.e. 1.4 kg of hempseed cake *vs.* 0.7 kg of soybean meal and 0.7 kg of barley) animal^{-1} day^{-1} during the remaining finishing period. Hempseed cake from two different batches was used in the study. Both batches were pressed by a Keller press

Table II. Chemical composition (kg^{-1} dry matter) of feeds provided to 55 dairy calves (Experiment 1) and 51 dairy steers (Experiment 2) fed cold-pressed hempseed cake (Hemp) or soybean meal (Soy) as a protein feed; means and standard deviation (SD) within parenthesis.

	Experiment 1		Experiment 2	
	Hemp[b]	Soy[c]	Hemp	Soy
Mixed ration[a]				
Dry matter, g kg^{-1}	611 (0.9)		617 (20)	
Metabolisable energy, MJ	11.6 (0.5)		11.9 (0.6)	
Crude protein, g	126 (7)		112 (16)	
Neutral detergent fibre, g	339 (29)		339 (31)	
Ash, g	43.3 (2.6)		44.6 (5.7)	
Protein feed				
Dry matter, g kg^{-1}	893 (0.0)	865 (0.8)	890 (2)	859 (2)
Metabolisable energy, MJ	12.1 (0.1)	13.1 (0.3)	13.0 (1.0)	13.7 (0.5)
Crude protein, g	385 (6)	318 (5)	369 (19)	315 (12)
Neutral detergent fibre, g	449 (9)	182 (14)	434 (13)	160 (19)
Crude fat, g	88.9 (0.3)	26.8 (1.0)	104 (32)	26.5 (2.5)
Starch, g	15.0 (0.0)	355.2 (12.7)	15.0 (–)	354.0 (19.0)
Ash, g	64.3 (2.5)	44.6 (0.2)	66.0 (4)	43.2 (1.7)

[a]Contained grass/clover silage and barley. [b]Two batches of hempseed cake were used, one in Experiment 1 and both in Experiment 2. [c]Protein feed "Soy" contained 50% soybean meal and 50% barley.

(KEK Egon Keller GmBH & Co). Batch no. 1 was used during the first three weeks of Exp. 2, whereas batch no. 2 was used in the remaining part of Exp. 2 and in the complete Exp. 1. To fulfill requirements of minerals and vitamins, vitaminized mineral supplements were fed to the cattle. Animals had free access to water and salt.

Silage samples were taken daily and composited to one sample per week for analysis of dry matter (DM) and to one sample per month for analysis of nutrient content, whereas silage samples for fermentation quality were taken weekly and composited to one sample every second month. Samples of barley, hempseed cake and soybean meal were collected weekly and composited to one sample per feed every second month for analysis of nutrient content.

Chemical analysis of the feed

Silage, barley, hempseed cake and soybean meal samples were analyzed for DM, ash, CP (Tecator Kjeltec Auto sample system 1035 Analyzer, Tecator Inc., Höganäs, Sweden), and neutral detergent fibre (NDF). The DM concentration of silage was determined at 60°C for 24 h whereas ash was determined at 550°C for 5 h. Metabolisable energy (ME) concentration of silage was calculated from *in vitro* organic matter (OM) digestibility (Lindgren, 1979), whereas the ME of barley, hempseed cake and soybean meal were calculated according to Axelsson (1941). Concentrations of NDF in silage were determined according to Goering and Van Soest (1970) and NDF in barley, hempseed cake and soybean meal were determined according to Van Soest et al., (1991). Concentrations of starch and crude fat were determined in barley, hempseed cake and soybean meal (Åman & Hesselman, 1984; EU Council Directive, 1998). In addition, silage samples were analyzed for pH and concentrations of NH_4-N (Tecator Kjeltec Auto sample system 1035 Analyzer, Tecator Inc., Höganäs, Sweden), reducing sugars (Ekelund, 1966), organic acids and ethanol (Andersson & Hedlund, 1983). Extent of degradation for CP of the hempseed cake was performed *in situ* in non-lactating cows on maintenance diets with an incubation period of 48 h and determined as EPD values (Lindgren, 1991).

Faecal analyses

In both experiments, analyses were conducted on faecal samples collected weekly at a pen level for four consecutive weeks from June to July (eight pens) and from March to April (16 pens) for Exp. 1 and 2, respectively.

Consistency, pH and DM content were determined on each individual faecal sample. The consistency was determined visually on a scale from 1 to 5 with 0.5 unit precision, where 1 represents runny, 2 loose, 3 mushy, 4 firm and 5 hard and dry like faecal matter from horse (Zaaijer & Noordhausen, 2003; Steen, 2004). The pH of the faeces was determined by using a litmus paper (MERCK pH-indikatorpapier, Merck KgaA, Darmstadt, Germany), whereas the DM content of faeces was determined at 105°C for 24 h.

Wet sieving was conducted on duplicated samples of faecal material composited of the four weekly samples from each pen. In order to select long particles (>10 mm) and barley kernel fractions in the faeces, 100 g of faeces was placed on a 2.36 mm screen and washed with running tap water until the outwash water was clear (Mgbeahurike, 2007). After washing, the number of long particles and fractions of barley kernels were recorded and their dry weights determined at 105°C for 24 h. Weight proportions of long particles and kernels of total faecal dry weights were calculated.

Carcass measurements

No carcass measurements were undertaken in Exp. 1. In Exp. 2, the steers were slaughtered in a commercial abattoir. Conformation and fatness were graded according to the European Union Carcass Classification Schemes EUROP modified to the Swedish system in which 15 classes are used (SJVFS, 1998; EU Council Directive, 2005). The EUROP classes were transformed to numerical figures for conformation score (1 = P −, poorest, and 15 = E+, best) and fatness (1 = 1 −, leanest, and 15 = 5+, fattest). Cold carcass weight (CW) (0.98 × hot CW) was recorded. At processing, fore and hind quarters were separated between the 10th and 11th ribs. The right hind quarter from each steer was weighed, as well as trim fat and bones from the dissected right hind quarter. Trim fat was defined as subcutanous and intermuscular fat deposits separable with a knife in a standardized cutting up procedure. Bones were weighed together with closely bound connective tissue capsules and without extra cleaning of the bones. The seven most valuable retail cuts in the hind quarter, including strip loin (*m. longissimus dorsi*), fillet (*m. psoas major*), topside (*m. semimembranosus*), outside round (*m. biceps femoris*), eye of round (*m. semitendinosus*), top rump (*m. quadriceps femoris*), and rump steak (*m. gluteus medius*), were weighed. Remaining parts of the hind quarter consisted of a mixture of lean meat and fat and were not weighed.

Statistical analysis

In both experiments, three different types of statistical models were used; one for feed intake and feed efficiency (FE) data, one for faecal traits and one for LWG and carcass traits.

Feed intake and FE were analyzed by using the GLM procedure (SAS, 2003):

$$\text{Exp. 1: } y_{ij} = \mu + \alpha_i + e_{ij}$$

$$\text{Exp. 2: } y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + e_{ijkl}$$

In the models, α is effect of protein feed, β is effect of breed, γ is effect of slaughter weight, and e_{ij} and e_{ijkl} are the error terms.

Faecal traits also were investigated by the GLM procedure (SAS, 2003):

$$\text{Exp. 1: } y_{ij} = \mu + \alpha_i + e_{ij}$$

$$\text{Exp. 2: } y_{ijkl} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ijkl}$$

In the models, α is effect of protein feed, β is effect of breed; e_{ij} and e_{ijk} are the error terms. The original model for analysis of consistency, pH and DM content also included the effect of week and its interactions with protein feed and breed. As no significant interactions with week were found, week was excluded from the final model.

The LWG and carcass traits (Exp. 2 only) were recorded on each individual animal nested within pen and analyzed by using the Mixed procedure (SAS, 2003):

$$\text{Exp. 1: } y_{ijk} = \mu + \alpha_i + c_{ij} + e_{ijk}$$

$$\text{Exp. 2: } y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + e_{ijklm}$$

In the models, α is effect of protein feed, β is effect of breed, γ is effect of slaughter weight, c is effect of pen and e_{ijk} and e_{ijklm} are the error terms.

Differences among treatment means were analyzed by using $LSD_{0.05}$-tests and denoted as significant at $P<0.05$ and as a tendency for significance at $0.05<P<0.10$.

Results

Feeds and diets

The grass/clover silage fed in Exp. 1 contained 174 g CP and 512 g NDF kg^{-1} DM, whereas average concentrations of CP and NDF in the grass/clover silage fed in Exp. 2 were 119 and 554 g kg^{-1} DM, respectively. Averaged over Exp. 1 and Exp. 2, DM contents of barley and soybean meal were 852 and 871 g kg^{-1}, respectively. The barley contained 104 g CP, 210 g NDF, 32 g crude fat, 630 g starch and 24 g ash kg^{-1} DM and the ME concentration was 12.9 MJ kg^{-1} DM. The soybean meal contained 525 g CP, 133 g NDF, 44 g crude fat, 86 g starch and 64 g ash kg^{-1} DM and its ME concentration was 13.9 MJ kg^{-1} DM. Rumen degradable protein of the two batches of hempseed cake used were determined to 235 and 253 g kg^{-1} DM, corresponding to 620 and 720 g kg^{-1} CP, respectively.

The high NDF concentration in cold-pressed hempseed cake (449 and 434 g kg^{-1} DM in Exp. 1 and 2, respectively) resulted in final diets with hempseed cake as the protein feed having 17 and 7% higher NDF concentrations than diets with soybean meal (Table III). Likewise, the high concentrations of crude fat (89 and 104 g kg^{-1} DM in Exp. 1 and 2, respectively) and CP (385 and 369 g kg^{-1} DM in Exp. 1 and 2, respectively) in hempseed cake led to 53 and 40% higher crude fat concentrations and 16 and 9% higher CP concentrations in the hempseed diets than in the control diets in Exp. 1 and 2, respectively (Table III). Contrary, due to the low starch concentration in hempseed cake (15 g kg^{-1} DM), hempseed diets had 18 and 8% lower starch concentrations than the control diets in Exp. 1 and 2, respectively. In both experiments, hempseed diets had 1% lower ME concentrations than soybean diets had (Table III).

Feed intake and LWG

In both experiments, daily intakes of NDF and fat were higher for animals fed hempseed cake than for those fed soybean meal (Table III). Intakes of DM and ME were higher, but intake of starch was lower, for calves fed hempseed cake compared to those fed soybean meal in calves in Exp. 1, whereas no difference in these intakes were found in steers in Exp. 2 (Table III). Protein feed did not affect LWG in neither calves nor steers (Table III). The higher ME intake by hemp-fed calves but similar LWG of the calves regardless of protein source resulted in a lower FE in calves fed hempseed cake compared to calves fed soybean meal, whereas no differences in FE were found in steers (Table III).

In Exp. 2, no main effects of breed, LW at slaughter or interactions among protein feed, breed and LW at slaughter on feed intake, weight gain or FE could be found.

Faecal traits

In both experiments, the number of long particles was less in faeces from animals fed hempseed cake than in faeces from those fed soybean meal (Table IV).

Table III. Daily feed intakes, feed composition, daily liveweight gain and feed efficiency in 55 dairy calves (Experiment 1) and 51 dairy steers (Experiment 2) fed cold-pressed hempseed cake (Hemp) or soybean meal (Soy) as a protein feed; least square means, SEM is standard error of means.

	Experiment 1				Experiment 2			
	Hemp	Soy	SEM	P^a	Hemp	Soy	SEM	P^a
DM intake, kg DM[b]	5.00	4.55	0.11	0.025	11.12	10.57	0.25	Ns
DM intake, g kg^{-1} LW	31.2	28.0	0.4	<0.001	22.1	21.1	0.5	Ns
NDF conc., g kg^{-1} DMI	358	305	0.4	<0.001	375	351	0.7	<0.001
NDF intake, kg	1.68	1.28	0.02	<0.001	4.17	3.70	0.09	0.005
NDF intake, g kg^{-1} LW	10.7	8.0	0.1	<0.001	8.3	7.4	0.2	0.029
Starch conc., g kg^{-1} DMI	304	369	0.5	<0.001	302	329	1.3	<0.001
Starch intake, kg	1.43	1.55	0.02	0.015	3.36	3.47	0.09	Ns
CP conc., g kg^{-1} DMI	177	152	0.4	<0.001	129	118	1.0	<0.001
CP intake, kg	0.83	0.64	0.01	<0.001	1.43	1.24	0.02	<0.001
Fat conc., g kg^{-1} DMI	33.1	21.4	0.1	<0.001	23.3	16.7	0.1	<0.001
Fat intake, kg	0.16	0.09	0.00	<0.001	0.26	0.18	0.40	<0.001
ME conc., MJ kg^{-1} DM	11.7	11.8	0.00	<0.001	12.0	12.1	0.02	0.003
ME intake, MJ	58.6	53.7	1.25	0.032	134	127	3.10	Ns
Liveweight gain, kg	1.34	1.28	0.04	Ns	1.22	1.22	0.05	Ns
FE, g gain kg^{-1} DM	288	315	4.1	0.003	108	114	3.1	Ns
FE, g gain MJ^{-1} ME	24.6	26.4	0.34	0.009	9.0	9.4	0.25	Ns

[a]Ns, non-significance ($P>0.10$). [b]DM, dry matter; LW, liveweight; NDF, neutral detergent fibre; conc., concentration; DMI, dry matter intake; CP, crude protein; ME, metabolisable energy; and FE, feed efficiency.

Hempseed cake also resulted in lower proportions of barley kernels in faeces from calves in Exp. 1 and lower proportions of long particles in faeces from steers in Exp. 2 (Table IV). Furthermore, DM content and consistency score of faeces were higher for steers fed hempseed cake than for those fed soybean meal in Exp. 2 (Table IV).

Carcass measurements

Steers with target slaughter LW of 600 kg were, on average, slaughtered after 195 days of finishing at 604 kg LW and steers with target weights of 650 kg were, on average, slaughtered after 224 days at 647 kg. Steers slaughtered at 650 kg were fatter than steers slaughtered at 600 kg (Table V). No main effects of protein feed on carcass traits could be found (Table V). However, at 650 kg slaughter weight, steers fed soybean meal required a longer finishing period (238 *vs.* 209 days; $P=0.004$) and their dressing percentages were higher (Table V) than for steers fed hempseed cake. There was an effect of breed on the conformation of the carcasses, where average conformation score was 3.8 for Swedish Holstein and 4.6 for Swedish Red steers ($P<0.001$). No further main effects or interactions among protein feed, LW at slaughter or breed on carcass measurements were found. Hind quarters,

Table IV. Faecal traits of 55 dairy calves (Experiment 1) and 51 dairy steers (Experiment 2) fed cold-pressed hempseed cake (Hemp) or soybean meal (Soy) as a protein feed; least square means, SEM is standard error of means.

	Experiment 1				Experiment 2			
	Hemp	Soy	SEM	P^c	Hemp	Soy	SEM	P^a
DM, g kg^{-1}	191	161	11.2	Ns	166	147	3.8	0.005
Consistency[b]	2.63	2.50	0.17	Ns	2.94	2.63	0.09	0.025
PH	7.68	7.55	0.36	Ns	7.02	7.16	0.15	Ns
Particles[c], no. 100 g^{-1}	46.6	65.0	4.06	0.019	45.3	88.7	4.61	<0.001
Kernels, no. 100 g^{-1}	7.3	10.5	1.36	Ns	8.4	9.4	0.67	Ns
Particles[c], g DM 100 g^{-1}	0.05	0.09	0.02	Ns	0.16	0.21	0.02	Ns
Kernels, g DM 100 g^{-1}	0.18	0.33	0.04	0.023	0.29	0.29	0.03	Ns
Particles[c],% of DM	0.26	0.59	0.14	Ns	0.97	1.44	0.14	0.035
Kernels,% of DM	0.93	2.08	0.24	0.014	1.75	1.99	0.23	Ns

[a]Ns, non-significance ($P>0.10$). [b]Consistency was estimated on a scale from 1 to 5 with a 0.5-unit precision. [c]Number of particles >10 mm in length per 100 g faeces.

Table V. Effects of protein feed [P; cold-pressed hempseed cake (Hemp) *vs.* soybean meal (Soy)] and targeted liveweight at slaughter (W; 600 kg *vs.* 650 kg) on carcass measurements of 51 dairy steers; least square means, SEM is standard error of means.

	Hemp		Soy			P^c		
	600	650	600	650	SEM	P	W	P × W
CW (kg)[d]	310	328	309	339	12	Ns	0.002	Ns
Dressing (%)	51.7[ab]	51.0[b]	51.0[b]	52.1[a]	0.3	Ns	Ns	0.022
Conformation[e]	4.3	4.1	4.0	4.3	0.2	Ns	Ns	Ns
Fatness[f]	8.4	8.5	7.7	8.6	0.2	Ns	0.010	Ns

[a,b]Means within a row with different superscripts differ significantly ($P<0.05$) according to $LSD_{0.05}$-test. [c]Ns, non-significance at $P>0.10$. [d]CW, carcass weight. [e]EUROP system: 4 = O−, 5 = O. [f]EUROP system: 7 = 3−, 8 = 3, 9 = 3+.

accounted for, on average, 49.0% of CWs, comprising of 34.7% valuable retail cuts, 9.4% trim fat and 21.7% bones.

Discussion

The higher DM intake in calves fed cold-pressed hempseed cake compared to calves fed soybean meal shows that the higher NDF concentrations in the diets including hempseed cake did not limit the intake. The reason for the result probably is the generally low NDF concentrations and that, the increased NDF originated from concentrate (hempseed cake) that has a low degree of rumen fill compared to NDF in roughages (Beauchemin, 1991; Allen, 1996). Absence of intake limitations of fibre-rich concentrates, such as barley fibre and sugar beet pulp, can also be caused by high proportions of soluble fibres (Huhtanen, 1987; Huhtanen, 1992; Voelker & Allen, 2003). Consequently, no earlier studies have, to our knowledge, shown an effect of hempseed products on DM intake (Mustafa et al., 1999; Gibb et al., 2005). Gibb et al. (2005) found similar feed intakes when feeding steers full-fat hempseed up to 14% of DM intake compared to soybean meal as a supplement to barley-based finishing diets. Mustafa et al., (1999) did not either find any effects of feeding hempseed meal to lambs at levels up to 20% of the dietary DM on their DM intake. Protein utilization of hempseed meal by dairy cows and lambs has been found to be similar to that of heat-treated rapeseed meal (Mustafa et al., 1999).

The absence of effects of protein feed on LWG and carcass traits in our study was in agreement with findings from previous beef finishing studies, where only a few effects on LWG and carcass traits were noted from supplementation of full-fat hempseed (Gibb et al., 2005) or of other protein feeds to diets (Huhtanen et al., 1989; Aronen, 1990; Comerford et al., 1992; Huuskonen et al., 2007). When discussing effects of protein supplementation, the digestibility and protein content of the forage fed are of major importance. When finishing beef cattle are fed high-quality grass/clover silage and barley, the animals receive enough protein from the forage and grain (Aronen, 1990; Huuskonen et al., 2007). However, in the present study, protein concentration of the silage was low and protein supplementation was needed.

The increased feed intake in Exp. 1 may have been caused by improved rumen functions in terms of selective retention of feed particles, adequate rumination and/or rumen motility, extensive ruminal digestion of carbohydrates and a normal ruminal pH (Sniffen & Robinson, 1984; Hall, 2002). The higher fibre content in the hempseed diet compared to the soybean meal diet resulted in 31 and 13% higher NDF intakes for hemp-fed calves and steers, respectively. The higher fibre intakes in animals fed hempseed cake were accompanied by fewer long particles in faeces and, for the steers, also by higher DM content and firmer consistency of the faeces indicating a more balanced rumen fermentation (Poppi & Norton, 1980). The larger number of long particles in faeces from calves and steers and the lower consistency score from steers fed soybean meal indicate an insufficient rumen retention time for satisfactory mastication and microbial fermentation to occur before passage (Mertens, 1997). Nørgaard et al. (2007) concluded from a number of faecal samples from high-producing dairy cows that, more than 40 long particles per 100 g faeces indicates a poor capacity of the animal for selective retention of large particles in rumen. Therefore, a high number of long particles in faeces can be a sign of poor rumen function in terms of low rumen pH and decreased fibre digestibility. In the present study, there were 65 to 89 long particles per 100 g faeces in animals fed soybean meal, which clearly is above the upper limit of 40 particles per 100 g faeces (Nørgaard et al., 2007).

Starch concentration of the diets containing soybean meal was higher than the diet containing hempseed cake. Starch is rapidly broken down in the rumen, which results in a large production of ruminal short chain fatty acids and a reduced pH (Krause et al., 2003). An acidic rumen environment is contributing to a decreased fibre digestion because, ruminal acids kill or destroy the fibre digesting micro organisms and thereby interrupting the mechanism involved in fibre digestion (Russell & Wilson, 1996). Reduced fibre digestion and starch-rich diets result in faster rumen passage rates leading to increased numbers of long particles in faeces (Mould et al., 1983; Hall, 2002; Mgbeahurike, 2007). The higher proportion of kernels in faeces from calves fed soybean meal compared to calves fed hempseed cake can depend on either the higher number of dietary kernels, the higher starch content in the diet or on inefficient mastication and nutrient utilization (Varga & Kolver, 1997).

Despite greater differences in NDF and starch concentrations in diets fed to young calves compared to diets fed to finishing steers, differences in faecal parameters were somewhat more obvious in the steers. Numerical differences in average faecal DM content were greater for the calves than for the steers, but larger individual variations may have decreased the possibilities to show differences. The individual variations could have been caused by higher stress levels of the newly weaned calves due to their new environment and diets, when the faecal sampling was undertaken.

Concentrations of rumen degradable protein in hempseed cake used in the present study were on the same level as reported by Martinsson (2008), but higher than in hempseed meal analyzed by Mustafa et al. (1999). In the latter, however, processing of the feed was not reported but, considering the composition, it probably was not cold-pressed. Concentrations of rumen degradable protein differed by 18 g kg^{-1} DM between the two batches of hempseed cake used in the study, despite use of the same variety and extraction method. The difference may be related to differences in seed maturity at harvest as the protein in seeds becomes less degradable in rumen with advanced maturity of the plant (Åman & Graham, 1987).

Conclusions

Cold-pressed hempseed cake as a protein feed for growing cattle compared to soybean meal results in similar weight gains and carcass traits and, due to a higher fibre content and/or a lower starch content, leading to an improved rumen function. Therefore, cold-pressed hempseed cake is a viable alternative as a protein feed for intensively fed growing cattle.

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