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Effect of starch level and straw intake on animal performance, rumen wall characteristics and liver abscesses in intensively fed Friesian bulls

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The objective was to reduce the incidence of liver abscesses (LAs) in young bulls by reducing the starch content of the concentrate and increasing the straw intake by adding molasses without reducing performance. Eighty-five Danish Friesian bulls (146 ± 2.6 kg live weight (LW)) were allocated to four treatment groups in a 2 × 2 factorial design and were ad libitum *fed either a high (H) (43%) or a low (L) (25%) starch concentrate, and either chopped barley straw (S) or a mixture (Sm) of chopped barley straw and sugar-beet molasses (75:25). The bulls were slaughtered at 440 (±4.2) kg LW (11.3 months of age) on average. The concentrate dry-matter intake (DMI) was 7.5% higher (*$P < 0.001$*), the roughage DMI was 12% higher (*$P < 0.01$*), whereas the total net energy intake was 7% lower (*$P < 0.001$*) for the L compared with the H concentrate. By adding molasses to the straw, roughage DMI increased from 0.50 to 0.96 kg/day (*$P < 0.001$*). Average daily gain (ADG) was not affected by treatment. Feed conversion efficiency (FCE) for dry matter (*FCE_{DM}*) was decreased (*$P < 0.001$*), whereas FCE for net energy (*FCE_{NE}*) was increased with the L concentrate (*$P < 0.01$*), suggesting a lower utilisation of the cell wall fraction with the H starch concentrate. There were no major effects of treatment on carcass characteristics. The higher roughage intake with Sm prevented rumen wall damage, but did not reduce the number of animals with LAs. The L concentrate did not affect the rumen wall but reduced the level of LA (2* v. *9 animals,* $P < 0.02$*). There was a higher level of respiratory diseases in animals fed the H concentrate (*$P < 0.05$*). The experiment showed that it was possible to maintain performance and reduce LA by using a lower starch content of the concentrate.*

Keywords: bulls, feed intake, live-weight gain, liver abscesses, rumen wall

Introduction

In Denmark, dairy breed bulls are raised for beef production by feeding pelleted grain-based concentrates *ad libitum* supplemented with straw. A growth rate above 1100 g/day is required to fulfil the slaughter standards and to achieve the maximal pay-off. However, this traditional feeding regimen leads to a risk of rumen acidosis due to a high starch load (Krause and Oetzel, 2006). In addition, feeding concentrates *ad libitum* often results in a concomitant low roughage intake (Thomas and Hinks, 1982; Drennan and Keane, 1987) and straw in itself does not favour a high intake (Jorgensen *et al*., 1971). Rumen acidosis is known to be related to diseases such as ruminitis, rumen parakeratosis, liver abscesses (LAs), laminitis and bloat (Nocek, 1997; Galyean and Rivera, 2003; Krause and Oetzel, 2006). The development of LAs is mainly feed related and the pathology of the ruminitis – LA complex is described in detail by Scanlan and Hathcock (1983) and Nagaraja and Chengappa (1998). The high frequency (11%) of LAs in Danish bulls clearly indicates that there is a high incidence of rumen acidosis in this intensive production system (Kjeldsen *et al*., 2002).

Animals having a high incidence of LAs or large abscesses have reduced dry-matter intake (DMI), growth rate and feed efficiency and can show dullness and depression (Brown *et al*., 1975; Brink *et al*., 1990; West, 1997). Foster and Woods (1970) found that average daily gain (ADG) was reduced by 5.9% for cattle having LAs, whereas Brown *et al*. (1975) found that severely abscessed livers reduced ADG by 12.7%, when compared with cattle with no abscessed livers.

Adjusting the ration by increasing the cell wall fraction of the concentrate (Utley *et al*., 1974) or by increasing the overall roughage intake (Kreikemeier *et al*., 1990; Zinn and Plascencia, 1996) can reduce the risk of LAs and thereby

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increase the health and welfare of the animals. However, there is a possibility of a reduction of the growth rate when the cell wall or roughage fraction exceeds a certain level and this level is highly dependent on the feed sources used (Utley *et al*., 1974; Kreikemeier *et al*., 1990; Zinn and Plascencia, 1996).

We hypothesise that it would be possible to formulate a low starch concentrate with a high cell-wall content, which would improve ruminal conditions and thereby decrease LA formation without jeopardising performance. The objective of this study was to investigate the effect of replacing some of the starch content by cell-wall-rich compounds in the concentrate ration and the effect of increasing intake of straw, by adding molasses, on feed intake, animal performance, damage to the rumen wall and incidence of LAs in intensively fattened young bulls.

Materials and methods

Health, care and use of experimental animals

Housing, rearing, feeding, transportation and slaughtering of the animals were in compliance with the Danish Ministry of Justice Law No. 382 (10 June 1987), Act No. 726 (9 September 1993) concerning experiments with animals and care of experimental animals. Furthermore, the Danish Animal Experimentation Inspectorate approved the study protocols and supervised the experiment. The health of the animals was monitored and sick animals treated by a veterinarian. Veterinary treatments were unrelated to the experimental treatments. In total, 11 animals (seven in year 1 and four in year 2) were culled or they died during the experimental period, primarily due to severe respiratory disease (pneumonia or BRS virus) (7), bloat (2) or accidental reasons (2).

Animals and feeding

A 30-week trial with 48 Danish Friesian bull calves allocated to four treatment groups in a 2×2 factorial design was repeated in two consecutive years. Each year, the bulls were blocked according to sire and date of birth and randomly allocated with 12 animals per treatment group. The bulls entered the experiment at 4.4 ($\pm$0.5) months of age weighing 146 ($\pm$2.6) kg live weight (LW) and were weighed every 2nd week during the experiment.

The bulls were fed one of two concentrates: a high (H) starch (43% of DM) or a low (L) starch (25% of DM) concentrate (Table 1), and one of two roughages; chopped barley straw (S) or chopped barley straw containing 25% (wt:wt) sugar-beet molasses (Sm).

The L concentrate was formulated by replacing 25% of the wheat (DM) in the H concentrate by dried sugar-beet pulp and high-quality grass pellets. Digestible protein, mineral and vitamin contents were equal in both rations. For both concentrate rations, the ingredients were coarsely ground and pelleted in 3-mm pellets.

The animals were housed indoors in the treatment groups with 12 animals/pen. The pen had one automatic feed bin containing concentrate pellets and one automatic feed bin containing roughage. Concentrates and roughage were available *ad libitum* and were fed twice daily. Orts were removed once daily. Individual feed intake was recorded continuously by Insentec® RIC Feed System (Insentec BV, The Netherlands). The pens were bedded with wheat straw and water was available from open drinking troughs.

Table 1 *Composition and nutrient content of the low (L) and high (H) concentrate ration*

	L	H
Ingredients (% dry matter)		
Wheat	19.5	44.8
Barley	22.3	22.5
Soya-bean meal	18.1	20.4
Dried sugar-beet pulp	20.2	
Grass pellets[†]	8.5	
Sugar-beet molasses	4.3	4.4
Rapeseed oil	3.4	3.4
Mineral-vitamin mix[‡]	3.5	3.5
Limestone	0.2	1.0
Nutrient content		
Dry matter (DM %)	88.1	87.3
Net energy (MJ/kg DM)[§]	9.78	10.26
Starch (% DM)	24.8	42.7
NDF (% DM)	20.2	11.0
Digestible protein (% DM)	13.4	14.3

[†] Dangroent A/S Quality plus.
[‡] Content per kg DM: Ca 220 g, P 55 g, Mg 40 g, Na 50 g, Cl 80 g, S 0.5 g, Mn 4000 mg, Zn 4500 mg, Cu 900 mg, Co 25 mg, Se 20 mg.
[§] Net energy, MJ/kg DM = $7.89 \times [-0.369 + 0.0989 \times ((24.237 \times$ digestible crude protein) + $(34.116 \times$ digestible crude fat) + $(17.300 \times$ digestible carbohydrate) − $(0.347 \times$ crude fibre)] Weisbjerg and Hvelplund (1993).

Sampling

Feed samples were collected weekly and pooled for chemical analysis after the experiment. The animals were stunned and killed by exsanguination. At slaughter, the reticulorumen was removed immediately from the abdominal cavity and a $10 \times 10\,cm^2$ area of the rumen wall was taken from the bottom of the atrium ruminis. The rumen wall samples were cleaned in 37°C 0.9% NaCl solution and were kept in the solution until stripping of the muscular layer from the epithelium. A circular piece of epithelium (diameter 6.6 cm) was cut out, oven dried at 90°C for 24 h and moved to a desiccator for 24 h before weighing in order to determine the density of the papillae.

The reticulorumen was emptied and rinsed in cold water and weighed after dripping off. A macroscopic evaluation was made of the rumen wall in the atrium ruminis and the ventral sac. The rumen wall condition was scored using a scale from 0 (normal) to 4 (very severe clotting, hyperaemia, etc.) (Mgasa, 1991). The papillary colour and shape was examined at the bottom of the atrium ruminis. The colour of the papillae were scored as 1, pale; 2, medium; and 3, dark. The papillae shape was scored according to Mgasa (1991): 1, short and slender; 2, short and leaf-like; 3, long and slender; and 4, long and leaf like.

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At slaughter, the weight of the liver, heart, kidneys, kidney fat and hot carcass were measured. Carcass length was measured from the posterior edge of the first rib to the symphysis pubis. Carcasses were scored according to the EUROP system for conformation (1–15) and fatness (1–5) and for lean/fat colour (1–5).

Lungs were examined for acute or chronic signs of pneumonia and pleuritis. All organs were examined for abnormalities. The liver was frozen at –18°C for later dissection. Livers were dissected by slicing up the semi-thawed liver in 1–2 cm slices. The numbers, positions and size of LAs and their capsule thickness were recorded.

The LAs were being categorized as follows: 0, no abscess; 1, one abscess or more small abscesses less than 2.5 cm in diameter; 2, two to four abscesses, more than one of them larger than 2.5 cm in diameter; 3, more than four abscesses, more than one larger than 2.5 cm in diameter (modified after Brink *et al*. (1990)).

Feed analysis

For DM determination, feed samples were dried in a forced air oven for 20 h at 103°C. Samples for chemical analysis were ground through a 1.0-mm screen. Ash was determined by combustion at 525°C for 6 h. Total nitrogen content was determined according to Dumas principle (Hansen, 1989). Crude fibre was determined using FiberTec system (Foss Tecator, Hillerød, Denmark) according to Weende's method. Ash-free NDF was determined using FiberTec system, according to Van Soest *et al*. (1991), applying an overnight pretreatment with α-amylase (A6380, Sigma) at 38°C in accordance with Ferreira *et al*. (1983), and followed by addition of sodium sulphite and a thermostable α-amylase (Termamyl, Novo Nordisk, Bagsværd, Denmark) during neutral-detergent boiling. Starch was determined based on gelatinisation of starch and simultaneous partial hydrolysis at 100°C using thermostable α-amylase (Termamyl) followed by complete hydrolysis at 60°C using amyloglucosidase as described by Åman and Hesselman (1984). Sugar was determined by spectrophotometry after extraction with sodium acetate buffer and precipitation with zinc sulphate (Jacobsen, 1981). Fat was determined by a Soxhlet extraction with petroleum ether after HCl hydrolysis according to Stoldt (1952). Organic matter digestibility was determined enzymatically, and the net energy content was calculated by multiplying the content of Scandinavian feed units by 7.89 MJ as described by Weisbjerg and Hvelplund (1993).

Calculations

ADG and the increase in roughage DMI as a percentage of the total DMI were estimated by linear regression procedure of Statistical Analysis Systems Institute (SAS, 1997) for each individual. Estimating the ADG by linear regression resulted in R^2 of at least 0.95. Feed conversion efficiency (FCE) was calculated for DMI (FCE_{DM}) and for net energy intake (NEI) (FCE_{NE}) by dividing the total weight gain (g) estimated from the linear regressions, by either the total DMI (kg) or NEI (MJ). The standard error of the mean of daily DMI of either concentrate or roughage was estimated as a percentage of the average daily DMI for each individual in order to express the day-to-day variation in DMI.

Statistical analysis

Statistical ANOVA was performed by using the GLM procedure of SAS (1997). Data were analysed using concentrate type, roughage type and their interaction, year of experiment and block within year as class variables and initial LW of the animal as a co-variable.

In the analysis concerning the weight of organs (liver, kidney and heart), animals with LAs were excluded from the analysis. The effect of treatment on rumen score, papillae colour, density and the day-to-day variation (%) in DMI was analysed without block and initial LW in the model. When analysing the effect of different LA categories or lung remarks, either the LA categories or lung remarks were included in the model as a class variable and without initial LW as a co-variable. The incidence of LAs, lung remarks and the score for papillae shape were analysed by using the χ^2 method in SAS (1997). Results are presented as least-squares means. Standard errors presented in the tables correspond to the maximum s.e. of the treatment group with the lowest number of observations. Differences with $P < 0.05$ were considered to be significant. Few interactions were found between treatments and these will be described in the text.

Results

In the first year 41 bulls and in the second year 44 bulls completed the experiment. The bulls were slaughtered at 11.3 ± 0.3 months of age weighing 440 ± 4.2 kg LW.

The average daily concentrate consumption was 0.4 kg DM (7.5%) higher ($P < 0.001$) but 7% lower ($P < 0.001$) in NEI for the L groups than for the H groups (Table 2). The total NEI was significantly higher in the H groups compared to L groups ($P < 0.001$).

The L concentrate had a positive effect ($P < 0.01$) on the roughage DMI (Table 2). Adding molasses to the straw increased the daily intake of roughage from 0.50 to 0.96 kg DM per day. On a DM basis, the roughage intake amounted to 7.8% and 14.3% of total DMI for S and Sm, respectively. Considering the molasses from the Sm roughage as a part of the concentrate, the straw DMI was 0.8 kg and amounted to 12% of the total DMI for the Sm groups.

Both concentrate and roughage DMI increased as expected during the experiment. Furthermore, the percentage to which the roughage DMI amounted of the total DMI also increased, as shown in Figure 1. This increase in roughage percentage was significantly higher for the L-Sm group compared with the other treatment groups. The NEI from roughage was three-fold higher in the Sm groups than in the S groups. Inspite of a tendency to a negative effect on the concentrate DMI in the Sm-fed groups, the total DMI was significantly higher in the Sm compared with the

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Table 2 *Effect of concentrate (low starch (L), high starch (H)) and roughage (S, Sm) on dry-matter intake (DMI) of concentrate (CONC) and roughage (ROUG), net energy intake (NEI), average daily gain (ADG), feed conversion efficiency of dry matter (FCE_{DM} g gain per kg DM) and net energy (FCE_{NE} g gain per MJ) and frequencies of liver abscesses (LAs) and lung remarks*

	L		H			Significance	
	S	Sm	S	Sm	s.e.[†]	CONC	ROUG
No. of animals	21	22	20	22			
DMI CONC (kg/day)	6.23	5.88	5.65	5.63	±0.12	***	‖
DMI ROUG (kg/day)	0.55	0.99	0.45	0.93	±0.03	**	***
Total DMI (kg/day)	6.76	6.87	6.10	6.56	±0.13	***	*
NEI CONC (MJ/day)	55.4	52.4	58.2	57.9	±1.14	***	
NEI ROUG (MJ/day)	0.78	3.32	0.65	3.11	±0.08	*	***
Total NEI (MJ/day)	56.2	55.7	58.8	61.0	±1.16	***	
Final live weight (kg)	446	431	433	450	±52		
ADG[‡] (g/day)	1441	1364	1417	1444	±32.1		
FCE_{DM}[‡]	209.5	199.9	232.5	220.2	±3.2	***	***
FCE_{NE}[‡]	25.2	24.7	24.1	23.7	±0.36	**	
No. of animals with							
LAs	2	0	4	5		*	
Lung remarks[§]	7	9	15	10		*	

[†] For the H-S group.
[‡] Significant effects of year: (ADG $P<0.01$), (FCE_{DM} and FCE_{NE} $P<0.05$).
[§] Signs of chronic/acute pneumonia and/or pleuritis at slaughter.
[‖] Approaching significance ($P<0.1$).

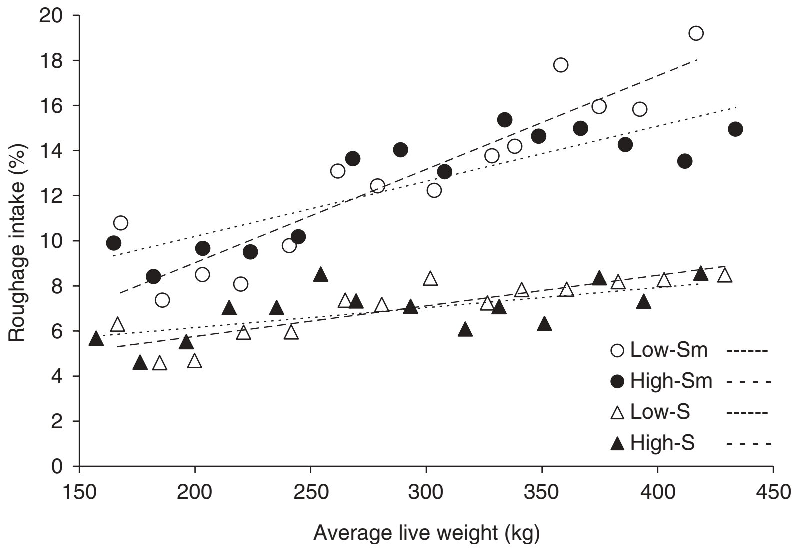

Figure 1 Average roughage dry-matter intake in percentage of the total dry-matter intake as a function of live weight for the four treatment groups (L-Sm: $y=0.042x+0.70$, $R^2=0.84$; H-Sm: $y=0.025x+5.29$, $R^2=0.74$; L-S: $y=0.0014x+3.04$, $R^2=0.75$; H-S: $y=0.0089x+4.37$, $R^2=0.40$).

S groups ($P<0.05$). However, the total NEI was not affected by roughage treatment.

The ADG was 1409 g/day and there was no significant treatment effect even though ADG was numerically higher ($P=0.13$) for the H groups (Table 2). The H groups had a better ($P<0.001$) FCE_{DM} (226 *v.* 205 g gain/kg DM); however, in terms of net energy the FCE_{NE} was lower (23.9 *v.* 24.9 g gain/MJ; $P<0.01$) compared with the L groups. The FCE_{DM} was lower (210 *v.* 221 g/kg DM; $P<0.01$) for Sm compared with S, whereas the FCE_{NE} was unaffected.

There was a significant difference in the frequency of LAs between years ($P<0.01$). In the first year, 10 animals had LAs and, in the second year, only one animal had LAs. The type of concentrate affected the frequency of LAs ($P<0.05$) with H groups having a higher frequency than L (9 *v.* 2) (Table 2). The roughage did not have any effect on the frequency of LAs.

Animals were categorised into four LA categories as follows: score 0: 74 animals, score 1: seven animals, score 2: two animals, and score 3: two animals. ADG was only significantly reduced for animals having severe abscessation (score 3) ($P<0.05$). In general, animals with LAs had an 8% higher ($P<0.05$) day-to-day variation in their roughage DMI than animals without LAs, whereas day-to-day variation in concentrate DMI was unaffected.

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There was a tendency ($P = 0.08$) to a higher incidence of animals having LAs in the group of animal with pleuritis and/or pneumonia findings at slaughter. The number of animals with LAs was eight in the group of animals having lung remarks (41 animals) compared with only three in the group without lung remarks (44 animals) (Table 2). As for the frequency of LAs, the number of animals with lung remarks was higher the first year compared with the second year (26 *v.* 15 animals; $P < 0.01$), indicating that the general health level of the animals was better the second year. More animals had lung remarks on H, compared with L concentrate ($P < 0.05$), whereas no difference was found for roughage treatment ($P > 0.1$) (Table 2). Animals having lung remarks tended to gain less ($P = 0.08$) and had a significant lower DMI of concentrate ($P < 0.01$). Furthermore, animals with lung remarks had a 7% larger day-to-day variation in their concentrate DMI than animals with no lung remarks ($P \leqslant 0.004$). No difference was found in roughage DMI day-to-day variation.

Hot carcass weight and carcass length were not different between the treatment groups (Table 3). The dressing percentage was significantly higher in the Sm compared with S groups ($P < 0.05$). There was an interaction between the treatment groups ($P < 0.05$) on the EUROP conformation score. The L groups had a higher conformation score when fed S compared with Sm (5.2 *v.* 4.9) whereas the H groups had a higher conformation score when fed Sm compared with S (5.7 *v.* 4.9). There was no effect of treatment on EUROP fatness ($P = 0.11$). The L groups showed a tendency to have a darker lean/fat colour score compared with H group ($P < 0.08$).

The average weight of the liver with no abscesses was 6.71 ± 0.7 kg and with abscesses 8.54 ± 3.3 kg. In one case with severe abscessation, the liver weighed 17.7 kg. The average weight of the liver and the heart was 0.4 kg ($P < 0.05$) and 60 g ($P < 0.05$) higher, respectively, in the H compared with L groups, when the animals with LAs were excluded from the data set. The roughage did not affect the size of liver or heart. The amount of kidney fat tended to be higher for H compared with L groups ($P < 0.07$). There was no effect of concentrate type on the size of the kidneys, but the animals fed S had larger kidneys than the animals fed Sm (1.31 *v.* 1.24 kg; $P < 0.05$).

The weight of the reticulorumen was significantly higher in the groups fed S compared with Sm ($P < 0.001$) (Table 4). Macroscopic evaluation of the rumen wall at slaughter showed that the bulls with a higher straw intake (Sm groups) had a lower rumen score (less clotting,

Table 3 *Effect of concentrate (CONC: low starch (L), high starch (H)) and roughage (ROUG: S, Sm) on carcass characteristics and organ weight*

	L		H			Significance	
	S	Sm	S	Sm	s.e.[†]	CONC	ROUG
Hot carcass weight (kg)	236.8	233.4	234.2	243.8	±4.20		
Dressing percentage	53.9	54.1	53.0	54.4	±0.37		*
EUROP conformation (1–15)	5.21	4.85	4.90	5.65	±0.26		
EUROP fatness (1–5)	2.46	2.44	2.51	2.67	±0.09		
Lean/fat colour (1–5)	3.07	3.06	2.95	2.89	±0.08	§	
Liver weight[‡] (kg)	6.70	6.37	6.89	6.92	±0.17	*	
Kidney weight[‡] (kg)	1.29	1.23	1.33	1.25	±0.03		*
Kidney fat (kg)	1.78	1.76	1.84	1.83	±0.03	§	
Heart weight[‡] (kg)	1.80	1.76	1.82	1.87	±0.03	*	

[†] For the H-S group.
[‡] Data from 11 animals with abscessed livers are excluded.
[§] Approaching significance ($P < 0.1$).

Table 4 *Effect of concentrate (CONC: low starch (L), high starch (H)) and roughage (ROUG: S, Sm) on the weight of the reticulorumen, the macroscopic evaluation of the rumen wall, papillae colour and density*

	L		H			Significance	
	S	Sm	S	Sm	s.e.[†]	CONC	ROUG
Reticulorumen weight (kg)	9.13	8.44	9.53	8.45	±0.24		***
Score1[‡]	0.96	0.44	1.48	0.50	±***0.19***		***
Score 2[‡]	1.04	0.49	1.41	0.64	±0.19		***
Papillae							
Colour	1.98	2.20	2.21	2.63	±0.12	**	**
Density (mg/cm^2)	43.9	39.8	43.8	41.1	±2.14		§

[†] For the H-S group.
[‡] Score 1: atrium ruminis. Score 2: ventral sac.
[§] Approaching significance ($P < 0.1$).

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hyperaemia and/or necrosis) for both sample sites of the rumen ($P < 0.001$) than did the S groups. For concentrate type, the rumen score was numerically higher for H-fed animals ($P = 0.16$).

The animals fed H concentrate and the animals fed Sm had a significant darker colour of the ruminal papillae. The papillae density was not affected by concentrate type, but there was a tendency to a larger papillary density of animals fed S compared with Sm ($P < 0.10$). There was no effect of treatment on the shape of the papillae (data not shown). The majority had a score of 3 or 4.

Discussion

In general, the growth rate and the carcass classifications were satisfactory compared with Danish results for intensively fed young bulls of the Friesian breed (Therkildsen *et al*., 1995). Substitution of dietary starch by fibre in the L concentrate resulted in an increased total DMI, which compensated for the reduced energy content, and the animals were able to attain the same ADG as on H. This resulted in a lower FCE_{DM} for the L groups as found by Utley *et al*. (1974) when increasing the level of peanut hulls from 10 to 30% in an all-concentrate ration. However, in the present experiment the FCE_{NE} was improved in groups fed the L concentrate, which could be caused by a more efficient utilisation of the cell wall fraction in the rumen, due to a more favourable ruminal environment with the lower level of dietary starch. Results by Kreikemeier *et al*. (1990) show that the cellulolytic bacteria in the rumen of steers fed high-grain diets only represented relatively small numbers ($\sim 1\%$) of the total bacterial population, and DeGregorio *et al*. (1982) found that the digestion of ADF in the rumen was reduced from 48% to 8% when the amount of grain in the diet was increased from 40% to 80% of the diet DM. Similarly, Brink and Steele (1985) found that NDF digestion declined from 69% to 35% when the amount of grain was increased from 70% to 90% of the diet (kg). With a grain level of 68% and 42% of DM in the H and L ration, respectively, the number of cellulolytic bacteria could have been reduced when feeding the H concentrate. In our study, feeding the L concentrate stimulated the animals to eat more roughage, indicating that either passage and/or fermentation efficiency has been enhanced. Another possible reason for the lower FCE_{NE} in the H groups could be a metabolic disturbance leading to reduced efficiency of utilisation of the metabolisable energy.

Similar to our results, the total DMI was found to increase with increasing roughage levels in a high-grain ration fed to steers (Kreikemeier *et al*., 1990; Stock *et al*., 1990; Shain *et al*., 1999) but these studies show no consistency in the way gain or feed efficiency was influenced. In the present experiment, the positive effect of the Sm treatment on straw intake was too small to affect total NEI, ADG or feed efficiency. The low intake of the straw in the S groups supports earlier Danish studies showing that the average daily intake of straw rarely exceeded 0.5–0.7 kg/day in an *ad libitum* feed situation (Jorgensen *et al*., 1971; Andersen, 2000) and that such a low amount of straw was insufficient to avoid pathological changes in the rumen (Jorgensen *et al*., 1971).

In the Sm groups with the higher roughage intake, the average rumen and atrium score was improved, which agrees with Tamate *et al*. (1976). Sugar-beet molasses are known to elevate the proportion of butyric acid in the ruminal content of short-chain fatty acids (Shen *et al*., 2004). Results by Shen *et al*. (2004) with goats, Shen *et al*. (2005) with steers and Mentschel *et al*. (2001) with calves, show that an increase of butyric acid content in the rumen, enhances the cell proliferation of the papillae, thus enhances the papillae length, shape and density. In the present study, we found no effect on the papillae shape or density of the papillae in atrium ruminis. On the contrary, there was a tendency to a higher papillae density in the S groups.

Several experiments show that increasing the proportion of roughage in a concentrate diet lowers the incidence of LAs (Foster and Woods, 1970; Utley *et al*., 1974; Zinn and Plascencia, 1996). However, except for Foster and Woods (1970) the severity of LAs is usually not changed when increasing the roughage level from 0% to a maximum of 15% of DMI (Kreikemeier *et al*., 1990; Shain *et al*., 1999). Utley *et al*. (1974) also found that a level of peanut hulls less than 20–30% of DM was inadequate to reduce the severity of LAs. These findings agree with our results concerning the LA finding in L and H groups. However, unlike Tamate *et al*. (1973), we found no difference in the rumen scores between the H and L groups.

With the exception of animals with a severe number of LAs, growth rate and feed efficiency were generally not reduced by the presence of LA, which is in accordance with results found by Brink *et al*. (1990). In agreement with our findings, Kjeldsen *et al*. (2002) reported that having lung remarks at slaughter was associated with a doubling in the incidence of LAs and that animals fed high grain concentrate had a significantly higher level of lung remarks. Lofgren (1983) also reported an increased rate and severity of bovine respiratory disease complex when the amount of concentrate in the diet fed to calves was increased. Results by Donovan *et al*. (2003) show that the immune response of calves fed an acidogenic diet is weakened, which could be a possible factor contributing to the higher level of respiratory diseases and LAs among animals fed the H concentrate. Another explanation of the higher risk of LAs could be that animals with respiratory diseases might have a different eating pattern with reduced feed intake during periods of illness followed by a period with compensatory growth and feed intake. Our result indicate that the day-to-day variation in DMI was more variable in animals suffering from either respiratory diseases or LAs compared with healthy animals.

The results showed that when reducing the starch content of the concentrate ration, the young bulls were able to maintain the performance level and slaughter quality. There was a better effect of reducing the starch content of the concentrate than increasing the straw intake by adding

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molasses, on the incidences of LAs. However, in terms of improving the condition of the ruminal wall, the results indicated that the roughage intake is of importance.

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References

Andersen HR. 2000. How ruminal acidosis, liver abscesses, etc. can be prevented in intensive feeding of slaughter calves, young bulls and bullocks. The National Institute of Animal Science, Research Center Foulum, Denmark, Research Report No. 16.

Åman P and Hesselman K 1984. Analysis of starch and other main constituents of cereal grains. Swedish Journal of Agricultural Research 14, 135–139.

Brink DR and Steele RT 1985. Site and extent of starch and neutral detergent fiber digestion as affected by source of calcium and level of corn. Journal of Animal Science 60, 1330–1337.

Brink DR, Lowry SR, Stock RA and Parrott JC 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. Journal of Animal Science 68, 1201–1207.

Brown H, Bing RF, Grueter HP, McAskill JW, Cooley CO and Rathmacher RP 1975. Tylosin and chlortetracycline for the prevention of liver abscesses improved weight gains and feed efficiency in feedlot cattle. Journal of Animal Science 40, 207–213.

DeGregorio RM, Tucker RE, Mitchell GE and Gill WW 1982. Carbohydrate fermentation in the large intestine of lambs. Journal of Animal Science 54, 855–862.

Donovan DC, Hippen AR, Hurley DJ and Chase CCL 2003. The role of acidogenic diets and β-hydroxybutyate on lymphocyte proliferation and serum antibody response against bovine respiratory viruses in Holstein steers. Journal of Animal Science 81, 3088–3094.

Drennan MJ and Keane MG 1987. Responses to supplementary concentrates for finishing steers fed silages. Irish Journal of Agricultural Research 26, 115–127.

Ferreira AM, Kerstens J and Gast CH 1983. The study of several modifications of the neutral detergent fibre procedure. Animal Feed Science and Technology 9, 19–28.

Foster L and Woods W 1970. Influence of liver abscesses on animal performance. Journal of Animal Science 31, 241.

Galyean ML and Rivera JD 2003. Nutritionally related disorders affecting feedlot cattle. Canadian Journal of Animal Science 83, 13–20.

Hansen B 1989. Determination of nitrogen as elementary N an alternative to Kjeldahl. Acta Agriculturae Scandinavica 39, 113–118.

Jacobsen EE 1981. Sukker og stivelse (LHK). Ny analysemetode. Meddelelse Fra Bioteknisk Institut ATV 98, 39–54.

Jorgensen JG, Lykkeaa J, Krohn C, Sørensen M and Bille N 1971. Fuldfoder til ungtyre og fedekalve. Landøkonomisk Forsøgslaboratoriums Efterårsmøde, 27–29 Oktober 1971, Denmark, pp. 406–419.

Kjeldsen AM, Bossen D and Fisker I 2002. Liver abscesses in veal calves. Danish Cattle, Danish Agricultural Advisory Service, Skejby, Report No. 96.

Krause KM and Oetzel GR 2006. Understanding and preventing subacute ruminal acidosis in dairy herds: a review. Animal Feed Science and Technology 126, 215–236.

Kreikemeier KK, Harmon DL, Brandt Jr RT, Nagaraja TG and Cochran RC 1990. Steam-rolled wheat diets for finishing cattle: effects of dietary roughage and feed intake on finishing steer performance and ruminal metabolism. Journal of Animal Science 68, 2130–2141.

Lofgren GP 1983. Nutrition and management of stressed beef calves. The Veterinary Clinics of North America Large Animal Practice 5, 87–101.

Mentschel J, Leiser R, Mülling C, Pfarrer C and Claus R 2001. Butyric acid stimulates rumen mucosa development in the calf mainly by a reduction of apoptosis. Archives of Animal Nutrition 55, 85–102.

Mgasa MN 1991. Orthopaedic diseases related to nutrititon and forestomach pathology in ruminantsDepartment of Clinical Studies, PhD, The Royal Veterinay and Agricultural University, Copenhagen.

Nagaraja TG and Chengappa MM 1998. Liver abscesses in feedlot cattle: a review. Journal of Animal Science 76, 287–298.

Nocek JE 1997. Bovine acidosis: implications on laminitis. Journal of Dairy Science 80, 1005–1028.

Scanlan CM and Hathcock TL 1983. Bovine rumenitis–liver abscess complex: a bacteriological review. The Cornell Veterinarian 73, 288–297.

Shain DH, Stock RA, Klopfenstein TJ and Herold DW 1999. The effect of forage source and particle size on finishing yearling steer performance and ruminal metabolism. Journal of Animal Science 77, 1082–1092.

Shen Z, Seyfert HM, Lohrke B, Schneider F, Zitnan R, Chudy A, Kuhla S, Hammon HM, Blum JW, Martens H, Hagemeister H and Voigt J 2004. An energy-rich diet causes rumen papillae proliferation associated with more IGF type 1 receptors and increased plasma IGF-1 concentrations in young goats. The Journal of Nutrition 134, 11–17.

Shen Z, Kuhlam S, Zitnan R, Seyfert HM, Schneider F, Hagemeister H, Chudy A, Lohrke B, Blum JW, Hammon HM and Voigt J 2005. Intraruminal infusion of *n*-butyric acid induces an increase of ruminal papillae size independent of IGF-1 system in castrated bulls. Archives of Animal Nutrition 59, 213–225.

Statistical Analysis Systems Institute 1997. Windows software version 8.1. SAS Institute, Cary, NC, USA.

Stock RA, Sindt MH, Parrott JC and Goedeken FK 1990. Effects of grain type roughage level and monensin level on finishing cattle performance. Journal of Animal Science 68, 3441–3455.

Stoldt W 1952. Vorschlag zur Vereinheitlichung der Fettbestimmung in Lebensmitteln. Fette und Seifen 54, 206–207.

Tamate H, Nagatani T, Yoneya S, Sakata T and Miura J 1973. High incidence of ruminal lesions and liver abscess in the beef associated with intensive fattening in Miyagi prefecture. Tohoku Journal of Agricultural Research 23, 184–195.

Tamate H, Ishihara T, Yoneya S and Miura J 1976. A further study on the incidence of ruminal lesions and liver abscess in the beef cattle in Miyagi prefecture. Tohoku Journal of Agricultural Research 27, 139–144.

Therkildsen M, Vestergaard M, Jensen LR and Andersen HR 1995. Effect of feeding level, grazing and finishing on growth and carcass quality of young Friesian bulls. The National Institute of Animal Science, Research Center Foulum, Denmark, Research Report No. 35.

Thomas DB and Hinks CE 1982. The effect of changing the physical form of roughage on the performance of the early-weaned calf. Animal Production 35, 375–384.

Utley PR, Lowrey RS and McCormick WC 1974. Peanut hulls as a source of roughage in cattle finishing diets. In Research bulletin (ed. SL Burgess and NJ Bunker) Department of Animal Science, Georgia Coastal Plain Agricultural Experiment Station, Georgia USA, 154, pp.1–23.

Van Soest PJ, Robertson JB and Lewis BA 1991. Methods for dietary fibre neutral detergent fibre, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74, 3583–3597.

Weisbjerg MR and Hvelplund T. 1993. Estimation of net energy content (FU) in feeds for cattle. The National Institute of Animal Science, Research Center Foulum, Denmark, Research Report No. 3.

West HJ 1997. Clinical and pathological studies in cattle with hepatic disease. Veterinary Research Communications 21, 169–185.

Zinn RA and Plascencia A 1996. Effects of forage level on the comparative feeding value of supplemental fat in growing-finishing diets for feedlot cattle. Journal of Animal Science 74, 1194–1201.

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