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Effect of processed cereal grains as a supplement on grass intake, rumen pool sizes, ruminal kinetics and the performance of grazing lactating dairy cows

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ABSTRACT

Five multiparous lactating Holstein-Friesian dairy cows fitted with rumen cannula were allowed to graze perennial ryegrass swards. Next to a control treatment of grazing only, pelleted barley (PB), pelleted maize (PM), toasted and subsequently pelleted barley (TPB), and toasted and subsequently pelleted maize (TPM) were fed as a supplement in two equal portions. Before and after 3 h of grazing the rumen content was evacuated, weighed, sampled and returned to the animals. Then the cows were kept inside the barn and starved for 6 h, after which rumen evacuations were repeated. The estimated clearance rates of starch showed significant differences ($P<0.001$) between grain types and compared to unsupplemented animals the apparent ruminal clearance of nitrogen was significantly ($P<0.001$) reduced. Supplementation with processed grains significantly increased ($P<0.05$) the milk production and significantly ($P<0.001$) decreased milk fat percentage. It is concluded that supplementing grass with high-energy low protein feeds, such as grains, substantially improves the N utilization and reduces the urea output in milk.

KEY WORDS: dairy, rumen, grazing, supplementation, barley, maize

INTRODUCTION

In high-producing Holstein Friesian dairy cows, even an optimal rumen fermentation results in insufficient microbial protein to maintain milk productions of over 25 kg/cow/day. Crude protein content of highly fertilized fresh grass is frequently high and this protein is easily degradable and to a large extent fermented in the reticulorumen. As a result recovery of grass N in milk is low, and N losses in urine are high (Tamminga, 1992). Hence, dairy cow nutrition based on grazed pasture, gives little scope to change milk production and composition in order to achieve maximum expression of the genetic potential of modern dairy cows. Consequently, when dairy cow nutrition is based on fresh grass, supplementation is needed. Partial replacement of grass by low protein, high carbohydrate concentrates maybe an adequate method to improve protein utilization by grazing cows and to reduce N excretion. For an optimal synchronization of energy supply and microbial growth, supplements should have a rate of carbohydrate fermentation close to that of fresh grass crude protein. Cereal grains meet the requirement of a low protein and high carbohydrate content, but their rate of degradation may not always match with that of fresh grass. A variety of feed processing methods can be applied to alter the degradation characteristics of cereal grains and make them more effective as a supplement to fresh grass.

Under grazing conditions, periods of herbage eating and fasting alternate. For lactating dairy cows, two major grazing bouts have been observed, one in the morning, the other one in the afternoon (Rook et al., 1994). The experiments described in this paper focused on the morning grazing. This space of time after milking is characterized by a grazing bout between 1 and 3 h. During this period intake rate is high and intake varies between 1 and 5 kg of dry matter during the first hour (Chilibroste, 1999). In some experiments it was shown that feeding easily fermentable carbohydrates resulted in a reduced roughage intake (Meijs, 1986) but not in others (Visser et al., 1990). The present study was designed to compare the effect of two different treatments (pelleting and pressure toasting followed by pelleting) of two cereal grains differing in their starch content and starch structure (maize and barley) on the dry matter intake (DMI), rumen fill and ruminal kinetics of nutrients in dairy cows. A second objective of this experiment was to investigate the effect of processed grains on the performance of grazing high yielding Holstein-Friesian dairy cows.

MATERIAL AND METHODS

Animals and management

The experiment was carried at the experimental farm 'De Ossekampen' of Wageningen University (The Netherlands). Five multiparous lactating Holstein-Friesian dairy cows fitted with a large rumen cannula (10 cm id., Bar-Diamond Inc., Parma, Idaho, USA) were used. Two cows were in their 7^{th} and the others were in 2^{nd}, 4^{th} and 6^{th} lactation, respectively. At the beginning of the experiment the cows produced 28.6 ± 4.6 kg/day milk and averaged 173 days post partum. The animals were milked twice daily at 6.30 and 17.00 h.

Experimental design

The experiment was based on a 5 x 5 Latin square design with five cows, five treatments and five periods. Each experimental period consisted of 14 days. Days 1-9 were used for adaptation and days 10-14 for sample collection.

Treatments and feed processing

The five treatments were control (grass with no supplement, NS), grass supplemented with pelleted barley (PB), grass supplemented with pelleted maize (PM), grass supplemented with toasted and subsequently pelleted barley (TPB), grass supplemented with toasted and subsequently pelleted maize (TPM). Grain processing was carried out at the Wageningen Feed Processing Centre (WFPC). A laboratory scale pressurised toaster was used for pressure toasting the grains for 1.5 min at 135ºC. After toasting, the grains were dried in a forced air oven for 16 h at 35ºC, and subsequently pelleted. Pelleting (80^{o}C, 10 s) was carried out with a 5 x 65 mm (bore x hole) die, using a V2-30 pelleting press (Robinson mill system B.V., Boxtel, The Netherlands).

Sward management, measurements and grass analysis

An experimental pasture divided in five experimental plots (5 x 880 m^2) of predominantly perennial ryegrass (*Lolium perenne*) was available during the experiments. The grass in the plots was mowed with a cutter bar every second week (from 25 May to 21 July). Before the 3rd period manure was applied to the experimental pasture as fertilizer (approximately 7 m^3 manure per ha). On day 10 and day 14 of each collection period 5 measuring points were selected in the whole experimental pasture (138 m x 32 m). At each point the sward height was measured with a plate meter (weight 9.47 g, diameter 0.1 m) and the grass mass was cut (50 x 25 cm square) at 2.5 cm with a garden shears at 13.00 h.

After being weighed fresh, the samples were oven dried (80ºC, 48 h) and weighed again, and the dry matter content of the grass was calculated. On each experimental day the sward height was measured with the plate meter in each experimental plot (27.6 m x 32 m) before grazing (31 measurements/day). The whole experimental pasture was measured before (76 measurements) and after grazing (76 measurements). Grass samples from the plots were taken each experimental day at around 10.00 h (when the grass was not dewy) and analysed for dry matter (DM), ash, nitrogen (N), acid detergent lignin (ADL) and neutral detergent fibre (NDF).

Concentrate feeding and rumen evacuations

Next to a control treatment of grazing only, the four forms of processed grains were fed as a supplement in two equal portions of 3 kg each in the milking parlour during the morning (6.30 h) and evening milking. In the 10 days long adaptation period the cows were allowed to graze freely with the herd in a pasture of perennial ryegrass. On days 11 and 13 (also days 12 and 14), rumen evacuations were conducted after milking (7.00 h) for 3 (the other days 2) cows, in the same sequence with a time interval of 30 min. After rumen evacuation, at 8.00 h, cows were allowed to graze individually, tethered within a circular plot of a fixed area with a radius of six meters. This method was used earlier by different researchers (Forbes, 1988; Dougherty et al., 1992) and the procedure was further developed by Chilibroste (1999). After 3 h each cow was removed from the experimental plot and brought to the barn and rumen evacuations were repeated at 11.00 h. Then the animals were kept inside the barn and starved until 17.00 h, at which time rumen evacuations were repeated in order to determine the clearance rate of the rumen contents. After the last rumen evacuations the cows were allowed to graze freely in experimental pasture of perennial ryegrass until the next morning. During the starvation period the animals had free access to water and mineral blocks (KNZ Liksteen). Manual emptying of the rumen contents was performed according to the procedure described by Børsting and Weisbjerg (1989), but the mat fraction and the rumen liquid was not separated. Solid rumen contents were removed through the rumen cannulae by hand into plastic containers. Liquid not removable by hand was collected with a soft plastic beaker, sampled and returned to the rumen immediately. The evacuated solid material was weighed and thoroughly mixed by hand and then samples (400 g) were taken and kept at -20ºC until analysis.

Chemical analysis

Processed cereal grains, grass and rumen content samples were analysed for dry matter (DM), starch (except the grass samples), nitrogen (N), neutral detergent fibre (NDF) and acid detergent lignin (ADL) and ash. DM was determined by drying at 103ºC to a constant weight according to ISO-standard 6496, ash by combustion at 550ºC following ISO-standard 5984. Nitrogen was determined with the Kjeldahl method with $CuSO_4$ as the catalyst, according to ISO standard 5983. ADL was analysed by the method of Goering and Van Soest (1970). NDF was determined by the VVR/protocol NSP analyses (Anonymus, 1992). This method is similar to the method of Van Soest and Mason (1991), but includes an incubation step with 1 ml heat stable amylase (Sigma 6814, 1350 U/ml) and 0.25 ml protease (Alcalase, 2.4 L NOVO, 2.4 AU/g) in 60 ml phosphate buffer (pH 7). This incubation is carried out for 15 min at 40°C after boiling and removal of the neutral detergent. Starch was analysed according to the NIKO method (Brunt, 1992). Total starch was analysed by extracting soluble sugars with a 40% ethanol solution, followed by autoclaving for 3 h at 130°C followed by enzymatic breakdown for 1 h (at 60°C, pH 5) to glucose, using an enzyme cocktail containing amyloglucosidase, alpha-amylase and pullulanase. After cooling in ice-water 2 ml Carrez 1 (potassium- hexacyanoferrate (II) 0.25 M: 10.6 g: 21.95 g. $K_4Fe(Cn)_6 \cdot 3H_2O$ p.a. per 100 ml) and 2 ml Carrez 2 (Zinkacetate solution 1 M in 0.5 M acetic acid: 21.95g $Zn(C_2H_3O_2)_2 \cdot 2H_2O$ p.a. and 3.0 g acetic acid per 100 ml) were added. Glucose was converted to glucose-6-phosphate (G6P) by the enzyme hexokinase and ATP, then G6P was oxidized by $NADP^+$ in the presence of G6P-DH. The amount of NADPH formed was proportional to the concentration of G6P in the samples and measured spectrophotometrically at 340 nm.

Performance measurements

During the experimental periods cows were milked twice daily. Milk yield was measured and recorded using milk meters. Milk samples, taken during two consecutive morning and evening milkings in each experimental period, were analysed for fat, protein, lactose and urea using an automated infrared milk analyser (Melkcontrole Station West-Veluwe, Ede, The Netherlands). The milk samples were frozen until analysis.

Calculations

Grass dry matter intake (DMI_R) was estimated according to Chilibroste (1999) from changes in the DM rumen pools before and after the grazing period and clearance of DM during the grazing sessions. The calculations for DMI were based on NDF analysis of rumen content, because NDF in the feed has been suggested as the best predictor of rumen fill (Van Soest and Mason, 1991; Mertens, 1994). NDF clearance rate was estimated for the starvation period assuming first order kinetics (Robinson et al., 1986). Dry matter intake was calculated as follows:

$$DMI_R = (RP_{AG} - RP_{BG}) + RP_{BG}\ (1\text{-}\exp^{(-kcl*GT)}) + CNGI$$

$$CNGI = (RP_{AG} - RP_{BG}) + RP_{BG}\ (1\text{-}\exp^{(-kcl*GT)})\ ^{x}\ (1\text{-}\exp^{(-kcl*2.5)})$$

where RP_{AG} is the size of the estimated DM rumen pool after grazing (kg), RP_{BG} is the size of the estimated DM rumen pool before grazing, corrected by clearance of DM rumen content in the time elapsed between emptying the rumen and the start of grazing, k_{cl} is DM clearance rate (h^{-1}) during starvation, GT is grazing time (h) and CNGI is clearance of the newly ingested grass (kg). To calculate CNGI the following assumptions were made: a uniform pattern of ingestion through the grazing bout and a mean residence time of the particles ingested (2.5 h).

Grass characterization

For the available grass characterization before and after grazing a regression line calculated from the relationship between sward mass and sward height, and based on the measuring points of day 10 and day 14 was used.

The regression line calculated and used was the following:

$$y = 14.43\ (4.02) + 1.089\ (0.26)\ x$$

where: y = grass sample weight (g/1250 cm^2), x = sward height (mm), standard deviation in brackets.

Statistical analysis

Experimental data were analysed using the PROC GLM procedure of SAS (1995). Cow, period and treatment (i.e. supplementation, grain, heat and the interaction between heat and grain) were the class variables in the model. Results are reported as least squares means and standard error of least square means. P values were according to the SS2 procedure of PROC GLM in SAS 6.12 (SAS, 1995). Treatment effect within feed type was judged using PDIFF in SAS 6.12 (SAS, 1995). Significance was declared when $P \leq 0.05$.

RESULTS AND DISCUSSION

Chemical composition of supplements

The chemical composition of the processed grains is shown in Table 1. The values show good agreement with tabular values (CVB, 1994). As expected, maize contained the highest amount of starch and barley had the highest crude protein and neutral detergent fibre content. Barley is usually higher in fibre than maize, wheat or sorghum. Variation in fibre content may indicate separation of the grain kernel into its components, particularly toasted grains containing greater quantities of pericarp. Also, artefact lignin may be formed when grains are processed at temperatures above 65°C. Heat treatments increase lignin-like components that can analytically be determined as insoluble fibre (Van Soest and Mason, 1991). Total starch content of barley and maize increased after toasting. These results agree with those obtained by Malcom and Kiesling (1993), but are in contrast with what Goelema (1999) found in legume seeds, where total starch content in peas and faba beans decreased after toasting. Maybe the effect of steam treatment on the protein matrix embedding the starch (Holm et al., 1995) have rendered the starch accessible for hydrolysing enzymes during analysis.

TABLE 1

Chemical composition of processed grains

Supplements	Barley		Maize	
	PB[1]	TPB[1]	PM[1]	TPM[1]
Dry matter, g/kg	972.2	972.9	970.9	971.8
In dry matter, g/kg DM				
organic matter	977.7	978.9	986.6	986.1
crude protein	114.9	113.7	92.0	92.9
starch	571.9	596.7	682.9	710.1
NDF	139.0	134.0	80.1	84.0
ADL	7.8	11.3	4.3	8.5

PB: pelleted barley, TPB: toasted and pelleted barley, PM: pelleted maize, TPM: toasted and pelleted maize

[1] values represents duplicate assays of pooled grab samples taken from each 50 kg bags after processing

Weather conditions, sward measurements, characterization

Weather conditions during the experiment are presented in Table 2. The information was collected from a meteorological station (Haarweg Station Wageningen, Meteorology and Air Quality Group) located approximately 400 m from the experimental pasture. In the first three hours of the experimental days (grazing period) the weather conditions were stable. The air conditions (temperature, relative humidity, windspeed) were higher than in former years and the low rainfall which is also quite unusual in this season may have effected the grazing behaviour of the experimental animals. The sward characteristics before and after grazing are given in Table 3. For the available grass characterization we used the calibration line on day 10 and day 14 to calibrate the relationship between sward mass and sward height. A comparison of the slopes of day 10 and day 14 revealed no differences from which it was concluded that between day 14 and day 10 the condition of the offered grass remained the same in the five days period.

Growing conditions like radiation, rainfall and temperature affected the chemical composition and nutrient content of the grass, as can be seen in Table 4. Results showed a high but somewhat variable N content throughout the grazing season. Pasture N content was highest in Period 3, which may have resulted from N fertilization with manure application immediately before Period 3 started. An increase in crude protein content after Period 1 may have resulted from an increase of the proportion of leaves, then the dry July resulted in an increase in the proportion of stem which has lower crude protein content than leaves. NDF increased during the warm summer months, but no significant differences were observed between the periods. The residual fraction (OM-NDF-CP) was high in Period 1 compared with the other periods, which is assumed to be the result of a high content of soluble sugars.

TABLE 2

Weather conditions during the experiments

Per.	Date	Air temperature, °C	Relative humidity, %	Wind m s^{-1}	Rainfall		Grazing time 8.00 to 11.00 h		
							Air temperature, °C	Rain	
					mm	min		mm	min
1	02 to 06 June	18.6	46.6	3.6	0	0	20.1	0	0
2	16 to 20 June	14.2	61.4	2.9	0.4	36	20.8	0	0
3	30 June to 04 July	15.0	77.8	3.5	0.5	36	20.8	0	0
4	14 to 18 July	17.3	81.2	2.4	1.8	96	20.8	0.4	11
5	28 July to 01 August	17.3	75.0	3.1	1.3	84	20.8	0.1	4

Data source: Haarweg Station Wageningen, Meteorology and Air Quality Group

TABLE 3

Mean sward height and sward mass before and after grazing in each experimental period

Variable	Period					Average
	1	2	3	4	5	
	02 to 06 June	16 to 20 June	30 June to 04 July	14 to 18 July	28 July to 01 August	
Sward height, mm						
before grazing[a]	193.5	130.8	103.7	153.4	126.3	141.5
after grazing[b]	111.9	83.5	70.5	98.3	94.1	93.1
Sward mass, kg DM/ha						
before grazing[a]	2841	2294	2058	2490	2255	2387
after grazing[b]	2446	1882	1769	2111	1974	2036

[a] before grazing: measurements of the first experimental day

[b] after grazing: measurement of the last (after the fifth) experimental day

In fresh perennial ryegrass (*Lolium perenne)* 70% of the water soluble carbohydrates are normally present as fructosans (McGrath, 1988), the rest is other mono-, di-, oligo- and polysaccharides. Free sugars usually occur at low concentrations. With increasing maturity fructosans increase until a peak, and after this peak they are either translocated or synthesised into structural carbohydrates (Blaster, 1964).

The OM intake of fresh grass is limited. For cows from 550-700 kg liveweight, maximum daily grass intake varies between 15 and 20 kg OM (Meijs, 1982). In this experiment the calculated OM intake based on pasture measurements was approximately 13.1 kg for NS (control) animals, this means that the grass in the pasture was sufficient for the cows to reach maximum OM intake.

TABLE 4

Chemical composition of the grass from different experimental periods

Item	Period				
	1	2	3	4	5
Sampling time	02 to 06 June	16 to 20 June	30 June to 04 July	14 to 8 July	28 to 31 July
Dry matter, g/kg	238.2	228.2	170.4	163.9	217.8
In dry matter, g/kg DM					
organic matter	912.2	908.2	894.3	899.8	902.4
crude protein	156.5	210.7	247.9	236.8	204.1
NDF	360.9	382.9	371.0	382.0	378.6
ADL	21.7	21.5	18.8	20.2	22.6
residue[1]	394.8	314.6	275.4	281.0	319.7
ash	87.8	91.8	105.7	100.2	97.6
ADL/NDF, g/kg	60	56	50	53	60

[1] residue = 1000 – (ash+CP+NDF)

DM intake, rumen pool kinetics and rumen pool sizes

DM intakes and evacuated rumen contents of the experimental animals are shown in Table 5. The total rumen DM content before grazing was significantly higher in the supplemented animals, than in the control animals, because of the supplementation. The weight of total rumen content was not significantly ($P>0.05$) affected by supplementation after grazing and after starvation. Cows consuming only grass tended to have greater weights and volumes of rumen contents after grazing, but lower rumen DM content than cows offered a processed cereal grain supplement. The estimations of DMI_R derived from rumen pool sizes before and after grazing shows, that there are neither significant differences in DM intake between the unsupplemented control and the supplemented animals nor between the treatments. Numerically as could be expected, the intake of grazing only animals was higher, than that of the supplemented cows. The variation of estimated values is high, which would affect the reliability of calculations of DMI from rumen pool sizes. Under grazing conditions daily feed intake would probably vary substantially more between days than under the more controlled feeding conditions. Higher level of supplementation, more animals and longer observation period than five days may be required to average out the effects of daily fluctuations in grass intake.

According to Hodgson (1985) the dry matter intake under grazing is the product of grazing time, rate of biting and weight of pasture per bite. The allowed grazing time

TABLE 5

Dry matter intake (DMI_R, kg) during 3 h grazing, total and dry matter (DM) rumen pools of cows grazing grass pasture, and supplemented with processed cereal grains

Item	NS	Barley grain		Maize grain		SEM	P		
		PB	TPB	PM	TPM		G	H	G x H
DMI_R	3.41	2.79	3.17	2.00	2.54	0.61	0.2	0.3	0.9
Rumen pools size, before grazing									
total, kg	83.8	84.0	83.4	81.0	81.6	2.81	0.5	0.9	0.7
DM, kg	10.1^S	12.5	11.9	11.6	11.6	0.43	0.2	0.5	0.5
Rumen pools size, after grazing									
total, kg	89.5	86.7	88.1	83.3	85.4	4.22	0.5	0.7	0.9
DM, kg	10.2	10.5	11.4	10.5	10.3	0.50	0.3	0.5	0.1
Rumen pools size, after starvation									
total, kg	60.5	58.3	61.8	60.5	63.4	2.62	0.5	0.2	0.9
DM, kg	6.66	5.95	6.31	6.02	6.42	0.35	0.8	0.3	0.9

NS: no supplement addition, PB: pelleted barley, TPB: toasted and pelleted barley, PM: pelleted maize, TPM: toasted and pelleted maize, G: effect of grain type, H: effect of type of heat treatment, GxH; effect of grain type and heat interaction

^{S} figure with superscript is significantly ($P<0.05$) different from others

in this experiment was 3 h for the animals, and the grazing sessions were followed by a long period of starvation. In the first hour of grazing we observed an active eating, probably because of the effect of feeling hunger after starvation during milking and rumen evacuations. But in our observation the total lenght of the grazing bout was much shorter than 3 h. We normally observed that the cows after 1-1.5 h grazing laid down and started rumination, instead of actively biting. A reduction in grazing time has been reported when cows have been exposed to short swards, and this sward condition is not preferred by cattle (Rook et al., 1994). But based on measurements of sward height this was not the reason to stop grazing. Temporal pattern of grazing may be altered due to poor weather conditions, mainly high temperatures (relatively hot summer days) and some rainy mornings (Chilibroste, 1999). In this experiment maybe because of the warm air temperature in grazing hours and because of the continuously high daily temperature, active grazing was predominantly observed in the early hours before milking in the morning (from 5.00 to 6.00 h.). The resulting high rumen fill could have limited grazing time and also the intake of the experimental animals in the grazing session after milking.

Rumen clearance by degradation and by outflow is considered to follow first order kinetics (Robinson et al., 1986) which means that per unit of time a rather constant fraction of what is present is cleared from the rumen of dairy cows by degradation and passage to the lower gut. Therefore we estimated clearance rate

(k_{cl}) for NDF, ADL, N and starch from the changes in rumen pool sizes after grazing, during the 6 h of starvation (Table 6). The estimated clearance rates of starch show significant differences (P<0.001) between grain types in agreement with Tóthi et al. (2003). The combination of pressure toasting and pelleting resulted in a 15% units per hour slower clearance rate for barley and a numerical but not significantly elevated clearance rate of maize as compared to pelleting alone. The N clearances were also influenced by grain type, but there was no statistically significant difference between the heat treatments. The supplementation caused a significant reduction in the apparent clearance rate of N, most likely resulting from more N being captured by the rumen microbes. In 3 of the 4 supplemented diets the clearance rate of lignin was significantly reduced as compared to no supplementation. This could indicate a slowing down of the degradation of organic matter, resulting in an increased retention time in the rumen, but this was not clearly reflected in a reduced clearance rate of NDF.

Table 7 shows the results of the rumen pools analysis. The interaction between grain type and heat treatment was not significant for any of the measured variables. Starch pools before grazing (BG) were significantly higher because of the supplementation of starchy grains. After grazing (AG) the changes, that is the disappearance of starch for PB, TPB, TM and TPM were 83.2, 75.8, 59.7, and 64.6%, respectively. After the starvation period 97.4 and 96.4% of starch in PB and TPB had disappeared, while after treatments PM and TPM 85.8 and 92.5% had disappeared. The highest rumen starch pools with maize supplementation (PM and TPM) can be explained by the lower k_{cl} of maize starch as compared

TABLE 6

Rumen pool kinetics of starch, nitrogen (N), neutral detergent fibre (NDF) and acid detergent lignin (ADL) of cows grazing grass pastures, and supplemented with processed cereal grains, values calculated from rumen evacuation data (rates in % h^{-1})

Item	NS	Barley grain		Maize grain		SEM	P		
		PB	TPB	PM	TPM		G	H	GxH
Starch rates									
k_{cl}	-	67.4^a	52.4^b	32.1^c	35.9^c	0.51	<0.001	0.3	0.07
N rates									
k_{cl}	7.77^S	3.94	4.17	4.49	4.18	0.40	0.5	0.9	0.6
NDF rates									
k_{cl}	7.38	6.27	6.73	6.26	6.22	0.67	0.2	0.6	0.2
ADL rates									
k_{cl}	5.39^S	3.81	3.34	4.60	3.42	0.48	0.4	0.1	0.4

NS: no supplement addition, PB: pelleted barley, TPB: toasted and pelleted barley, PM: pelleted maize, TPM: toasted and pelleted maize

G: effect of type of grain, H: effect of type of heat, GxH; effect of grain type and heat interaction

[a,b,c] figures with different superscript are significantly different

[S] figure with superscript is significantly (P<0.05) different from others to starch originating from barley, which agrees with other observations by Visser (1993), Tóthi et al. (2003) and reviewed by Nocek and Tamminga (1991) comparing the digestion of starches in the gastrointestinal tract of dairy cows. Pressure toasting decreased the starch degradation of barley starch and elevated the degradation of maize starch. Surprisingly a starch pool was also observed in

TABLE 7

Rumen pool sizes of organic matter (OM), nitrogen (N), starch, neutral detergent fibre (NDF), acid detergent lignin (ADL) and ash of cows grazing grass pasture, and supplemented with processed cereal grains, before and after grazing and after the starvation period

Item	NS	Barley		Maize		S.E.M.	P		
		PB	TPB	PM	TPM		G	H	G x H
OM pool, kg									
BG	8.95^{S}	11.41	10.85	10.60	10.62	0.40	0.2	0.5	0.4
AG	9.11	9.54	10.36	9.52	9.36	0.47	0.3	0.5	0.3
AS	5.87	5.26	5.56	5.31	5.70	0.32	0.7	0.3	0.9
N pool, kg									
BG	0.37	0.37	0.38	0.37	0.36	0.01	0.6	0.3	0.5
AG	0.39	0.34	0.39	0.37	0.35	0.01	0.9	0.3	0.3
AS	0.25	0.22	0.25	0.25	0.25	0.01	0.3	0.3	0.2
Starch pool, kg									
BG	0.27^{S}	1.13^{a}	1.20^{ab}	1.34^{ab}	1.47^{b}	0.09	0.01	0.3	0.7
AG	0.27^{M}	0.19^{a}	0.29^{a}	0.54^{b}	0.52^{b}	0.06	0.001	0.5	0.3
AS	0.07^{M}	0.03^{a}	0.04^{a}	0.19^{b}	0.11^{b}	0.04	0.007	0.7	0.2
NDF pool, kg									
BG	4.54^{PB}	5.76^{a}	5.13^{ab}	4.74^{b}	4.78^{b}	0.23	0.07	0.2	0.1
AG	4.51^{B}	5.19^{ab}	5.42^{a}	4.77^{ab}	4.58^{b}	0.22	0.01	0.9	0.3
AS	3.04^{TPB}	3.58	3.60	3.27	3.44	0.19	0.2	0.6	0.7
ADL pool, kg									
BG	0.49^{PM}	0.49^{ac}	0.52^{a}	0.43^{b}	0.47^{bc}	0.01	0.03	0.08	0.8
AG	0.50^{M}	0.47^{ab}	0.53^{a}	0.44^{b}	0.45^{b}	0.02	0.02	0.2	0.2
AS	0.38	0.35^{a}	0.40^{b}	0.33^{a}	0.36^{ab}	0.02	0.10	0.02	0.6
Ash pool, kg									
BG	1.11	1.07	1.03	1.00	0.98	0.04	0.2	0.5	0.8
AG	1.15	0.99	1.08	0.99	0.97	0.04	0.2	0.4	0.2
AS	0.79	0.70	0.76	0.71	0.73	0.03	0.8	0.2	0.5

NS: no supplement addition, BG: before grazing (8 h), AG: after grazing (11 h), AS: after starvation (17 h) PB: pelleted barley, TPB: toasted and pelleted barley, PM: pelleted maize, TPM: toasted and pelleted maize

G: effect of type of grain, H: effect of type of heat, GxH; effect of grain type and heat interaction

^{a,b,c} figures with different superscript are significantly different

$^{S,B,PB,\ TPB,M,PM}$ figure with superscript is significantly different ($P<0.05$), from all other treatments (^{S}), from all maize supplementation (^{M}), from all barley supplementation (^{B}), from PM, PB, or TPB supplementation ($^{PM,\ PB,\ TPB}$)

the control treatment (only grazing). Because the starch content of grasses in a vegetative status is low, being usually less than 10 g/kg DM, this was presumably starch of microbial origin. This starch of microbial origin was taken into account when we calculated the starch pool of supplemented animals. The NDF pool measured in supplemented animals was below the threshold level of 1.1-1.2% of body weight described by Mertens (1994) as the average NDF holding capacity of dairy cows on a daily basis. Therefore the NDF pool was not considered the main signal received by the cows to stop the grazing session, rather the environmental factors and rumen fill. The numerically decreased ruminal turnover of NDF on supplemented animals compared with only grazing cows is in agreement with results of Robinson et al. (1987), who observed a linear decrease in turnover of NDF when the starch content in the diet increased.

Performance measurements

Feeding heat treated grains increased the average daily milk yield for PB, TPB, PM and TPM with 2.7, 2.4, 2.3 and 1.8 kg/d, respectively, compared to the performance of the animals that had not received supplementation (Table 8). This may have resulted from an increased energy supply, because supplementation did not result in a significantly decreased grass intake. The increase in milk yield with supplementation was usually accompanied by an increase in the milk protein content. Delaby et al. (2001) showed that the increase in milk protein content averaged 0.02% per kg of concentrate DM and was linear up to 6 kg of concentrate. In this experiment milk protein output was increased by on average 114 g/day, which may be the result of an improved protein supply, probably because of the synthesis of more microbial protein. Rooke et al. (1986) showed an increase in microbial protein synthesis in the rumen, when the rate of degradation of the protein and the carbohydrates was in balance. Under these more balanced conditions the supply of aminogenic nutrients to the mammary gland may have been improved, and have resulted in a higher protein yield. The milk fat concentration for PB, TPB, PM and TPM decreased with 0.44, 0.62, 0.71 and 0.75 percentage units, respectively, whereas milk protein content for PB, TPB, PM and TPM, increased with 0.27, 0.16, 0.21 and 0.21 percentage units, respectively. This was probably because of the supposedly increased supply of glycogenic nutrients with intestinal digestible starch, propionic acid and aminogenic nutrients with (microbial) protein. It seems that pressure toasting had an appreciable effect on decreasing milk fat yield for barley fed cows but this could statistically not be proven. The decreased fat concentration of on average 85 g/day can partly be explained by a dilution effect, which is related to the limited amount of available lipogenic energy for milk synthesis. In the study of Delaby et al. (2001), the reduction in milk fat content was consistent and averaged

TABLE 8

Milk production and milk composition of cows grazing grass pasture and supplemented with processed cereal grains

Item	NS	Barley grain		Maize grain		SEM	P		
		PB	TPB	PM	TPM		G	H	G x H
Milk, kg/d	22.65[T]	25.37[a]	25.10[b]	24.95[b]	24.44[ab]	0.50	0.4	0.2	0.03
Protein, %	3.41	3.68	3.57	3.62	3.62	0.07	0.9	0.5	0.5
Fat, %	3.99[S]	3.55	3.37	3.28	3.24	0.12	0.2	0.5	0.7
Lactose, %	4.33	4.35	4.45	4.32	4.44	0.07	0.8	0.2	0.9
MUN[d]	18.64[S]	12.57[ab]	13.57[a]	10.83[b]	10.77[b]	0.80	0.03	0.6	0.5

NS: no supplement addition, PB: pelleted barley, TPB: toasted and pelleted barley, PM: pelleted maize, TPM: toasted and pelleted maize

G: effect of type of grain, H: effect of type of heat, GxH; effect of grain type and heat interaction

[a,b,c] figures with different superscript are significantly different

[d] MUN milk urea nitrogen, mg per 100 ml milk

[S] figure with superscript is significantly ($P<0.001$) different from others

[T] figure with superscript is significantly ($P<0.05$) different from others

-0.6 g/kg per kg DM of concentrate between 0 and 5.4 kg of concentrate DM. This also might be a consequence of the ruminal fermentation pattern because the acetic to propionic ratio in the rumen might have decreased in supplemented cows. The lactose content of milk was not influenced by nutritional factors. Consequently this observed production response with feeding heat-treated grains is probably related to optimization of the fermentation process in the rumen, as well as to the increased supply of intestinal digestible starch and protein.

Milk urea nitrogen (MUN) concentration decreased when the animals received heat treated grains as a supplement, if we compare it to the grazing only status. Supplementation of maize resulted in a stronger decrease than barley did because maize lower in CP and has lower rumen degradability. But we found no differences between the heat treatments. Generally milk urea concentration in milk is a valuable tool to monitor the rumen degraded protein balance in the ration and the N losses (Hof et al., 1997). Milk urea nitrogen concentrations of cows grazing ryegrass pastures is around 18 mg MUN per 100 ml milk which can vary due the maturity and protein content of the grass and the selection by the grazing cows (Trevaskis and Fulkerson, 1999; Merwe et al., 2001). Visser et al. (1997) showed that the concentration of ammonia in rumen fluid, ammonia release in portal-drained viscera, urea synthesis in the liver, urea release from the liver and milk urea highly correlate. Therefore in this experiments the higher MUN values found in unsupplemented than in supplemented animals indicates that the protein and carbohydrates were not properly combined which resulted in an excess of ruminal ammonia.

CONCLUSIONS

Supplementation of grazing dairy cows with 3 kg pelleted and pressure toasted grains probably not influence the DMI of grass in the first grazing bout in the morning after milking, but it did affect the ruminal clearance of nitrogen. The estimated clearance rates of starch significantly differ between grain types, but the effect of toasting more pronounced on barley. Pelleting as well as toasting followed by pelleting did affect production responses in dairy cows, by elevating milk protein and decreasing milk fat production, but no significant differences between these two treatments were found in this experiment.

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STRESZCZENIE

Wpływ dodatku różnie preparowanego ziarna zbóż na pobranie runi, pojemność i kinetykę żwacza oraz wyniki produkcyjne wypasanych krów mlecznych

Pięć wieloródek krów holsztyno-fryzów, produkujących mleko, z przetokami żwaczowymi, wypasano na pastwisku porośniętym życicą trwałą. Kontrolę stanowił wypas pastwiskowy, a w grupach doświadczalnych jako dodatek zastosowano: granulowany jęczmień (PB), granulowaną kukurydzę (PM), tostowany i następnie granulowany jęczmień (TPB) oraz tostowaną, a następnie granulowaną kukurydzę (TPM), które podawano w dwóch jednakowych porcjach. Przed i po 3 godz. wypasu ewakuowano treść żwacza, ważono, pobierano próby i pozostałość wkładano na powrót do żwacza. Następnie krowy przetrzymywano w oborze i głodzono (bez paszy) przez 6 godz., po czym ponownie opróżniano żwacz. Tempo ubytku skrobi różniło się istotnie ($P<0,001$) w zależności od gatunku ziarna, a pozorny ubytek azotu przy dodatku ziarna był istotnie mniejszy ($P<0,001$) niż w grupie kontrolnej.

Dodatek preparowanego ziarna istotnie zwiększył ($P<0,05$) produkcję mleka i istotnie obniżył ($P<0,001$) procent tłuszczu w mleku.

W podsumowaniu stwierdzono, że uzupełnienie dawki złożonej z trawy wysokoenergetycznej niskobiałkową paszą, taką jak ziarno zbóż, znacznie poprawia wykorzystanie azotu i obniża zawartość mocznika w mleku.