Irish Journal of Agricultural and Food Research **45:** 135–147, 2006

The effect of cereal type and feeding frequency on intake, rumen fermentation, digestibility, growth and carcass traits of finishing steers offered a grass silage-based diet

M.J. Drennan†, M. McGee and A.P. Moloney
Teagasc, Grange Beef Research Centre, Dunsany, Co. Meath, Ireland

The effect of concentrate cereal type (rolled barley-based v. rolled wheat-based) and concentrate feeding frequency (one 6 kg feed v. two 3 kg feeds per day) on intake, rumen fermentation, diet digestibility and performance of finishing steers offered grass silage to appetite was evaluated over four experiments using a total of 154 animals. Not all four feeding treatments were used in each of the four experiments. The duration of the growth measurement period was 152, 112, 111 and 113 days for experiments 1 to 4, respectively, after which all animals were slaughtered. Dietary dry matter (DM) intake and *in vivo* digestibility, final live weight, kill-out proportion, carcass weight, carcass conformation score, carcass fat score and daily live-weight and estimated carcass gain were not affected ($P > 0.05$) by cereal type or feeding frequency. Cereal type or feeding frequency had no effect ($P > 0.05$) on feed conversion efficiency (FCE) expressed as either live-weight or carcass gain per unit DM intake. Neither mean rumen fluid pH or concentrations of ammonia or L-lactate were influenced by cereal type or feeding frequency. The mean molar proportion of propionate was higher and that of butyrate lower ($P < 0.05$) with wheat than with barley. Estimated carcass weight gain and FCE to carcass were similar for wheat-based and barley-based concentrate as a supplement to grass silage offered either as one feed or two equal feeds daily.

Keywords: barley; beef cattle; feeding frequency; wheat

†Corresponding author: michael.drennan@teagasc.ie

Introduction

Cereals make up a substantial proportion of animal feedingstuffs used in Ireland. Of the 2.1 million tonnes (mt) of cereals produced and 0.8 mt imported, over 1.8 mt was used in animal feedingstuffs in the crop year 2003/04 (CSO, 2005). Depending on dry matter digestibility, to achieve target growth rates with finishing cattle offered grass silage-based diets, supplementary concentrates should account for at least 0.3 to 0.5 of the total dry matter (DM) intake (Drennan and Keane, 1987).

Traditionally, winter-finishing diets for cattle in Ireland were largely based on grass silage plus a rolled-barley supplement typically given in two feeds daily to reduce the likelihood of digestive problems. As a result of higher yields, feed wheat has become an economically attractive alternative to barley in cattle rations. However, there is a paucity of published information on the relative performance of cattle offered wheat compared to barley as a supplement to grass silage. Steen (1993) reported that wheat and barley had similar nutritive values as supplements to grass silage but the concentrate levels used in that study were comparatively low (2.5 and 4.0 kg of barley per day and 3.25 kg of wheat per day). Higher levels of concentrate feeding to beef cattle may be desirable because of the increasing cost of grass silage relative to concentrate feeds, as well as changing beef production systems (McGee, 2005).

A particular concern with feeding high-grain diets however, is the excessively rapid fermentation of the high levels of starch to organic acids possibly resulting in acidosis (Huntington, 1997; Owens *et al.*, 1998). Wheat grain has more starch and less fibre per unit weight than barley grain (INRA, 1989; MAFF, 1990; CVB, 1998) and the proportion of soluble starch is greater in wheat than barley (Offner, Back and Sauvant, 2003). However the literature is inconsistent regarding the rate of degradation of non-soluble starch in both cereals (Herrera-Saldana, Huber and Poore, 1990; Offner *et al.*, 2003). Using *in vitro* methodology, De Smet *et al.* (1995) reported that the decline in ruminal fluid pH was greater for wheat than barley. One way to overcome the risk of acidosis is to reduce meal size (Owens *et al.*, 1998).

With increasing emphasis on labour efficiency in beef production systems, once as opposed to twice daily feeding of the concentrate allowance has become an important labour saving issue. In a recent survey of suckler herds in Ireland, the feeding of concentrate accounted for 0.28 of total time spent feeding during the indoor period (H. Leahy, personal communication).

The overall objective of the experiments outlined here was to examine the effect of offering rolled barley or rolled wheat either in one or two equal feeds daily as a supplement to grass silage, on silage intake, rumen fermentation, diet digestibility, growth performance and carcass characteristics of finishing steers.

Materials and Methods

Four feeding experiments were carried out over four consecutive years using a total of 154 finishing Friesian or Friesian-cross steers accommodated in conventional slatted-floor sheds. Animals were offered grass silage *ad libitum* with one of the following concentrate supplement treatments:

1. 6 kg of a barley-based concentrate offered in two (at 0800 and 1600) equal feeds daily.
2. 6 kg of a barley-based concentrate offered in one feed daily (at 0800).

3. 6 kg of a wheat-based concentrate offered in two (at 0800 and 1600) equal feeds daily.
4. 6 kg of a wheat-based concentrate offered in one feed daily (at 0800).

Not all four feeding treatments were included in each of the four experiments.

Experiment 1
Thirty Friesian steers were blocked according to weight to 5 blocks of 6 animals and randomly assigned from within blocks to 6 groups of 5 animals, with 2 groups being assigned at random to each of three feeding treatments (1, 2 and 3). Each treatment had 5 individually fed (using Calan Broadbent gates) and 5 group-fed animals. Initial carcass weight was estimated as 0.49 of initial live weight and the duration of the experiment was 152 days.

Experiment 2
Thirty six steers (24 continental × Friesian and 12 Friesian) were blocked according to breed type, weight and background into blocks of 6 and randomly assigned from within blocks to 6 groups of 6 animals, with 2 groups being assigned at random to each of three feeding treatments (1, 2 and 3). All animals were group-fed. Initial carcass weight was estimated as 0.50 of initial live weight and the duration of the experiment was 112 days.

Experiment 3
Forty Friesian steers were blocked according to initial weight to 8 groups of 5 animals with 2 groups being randomly assigned to one of four feeding treatments (1, 2, 3 and 4). In each treatment one group of animals was individually fed using Calan Broadbent gates and the second was group fed. Initial carcass weight was estimated as 0.50 of initial live weight and the duration of the experiment was 111 days.

Experiment 4
Two separate groups (early and late castrates) of 24 Friesian/Friesian cross steers were blocked within group according to initial live weight and background into 6 blocks of four animals and randomly assigned from within blocks to one of four feeding treatments (1, 2, 3 and 4). All animals were group-fed with two pen replications of 6 animals per treatment. Initial carcass weight was estimated as 0.50 of initial live weight and the duration of the experiment was 113 days.

Animals, diets and management
Prior to initiation of each experiment, animals were offered grass silage to appetite and the twice-daily allowance of concentrate was increased gradually over a 3-week period. Unfasted live weights were then recorded on two consecutive mornings and the animals were assigned to their treatment groups. When animals reached the target daily total concentrate intake under twice daily supplementation, those assigned to the once-a-day feeding treatments had their morning feed gradually increased until the target allowance was offered once daily.

During the experiments grass silage was offered daily to at least 1.1 times intake. The silage offered in all experiments was from a mainly perennial ryegrass sward harvested in late May and ensiled directly using sulphuric acid as a silage preservative when necessary. Records of silage offered and refused were collected throughout the experimental period. Silage refusals were discarded twice weekly. The concentrates comprised 0.915 barley or wheat, 0.070 soyabean meal and 0.015 minerals and vitamins in Experiments 1, 2 and 3 and 0.985 barley or wheat and 0.015 minerals and vitamins in Experiment 4.

Live weight was recorded at approximately 28-day intervals and on two consecutive days at the end. All animals were slaughtered at the end of each of the studies and hot carcass weight was recorded following removal of perinephric and retroperitoneal fat. Cold carcass weight was estimated to be 0.98 of hot carcass weight. Killing-out rate was calculated as the proportion of cold carcass weight to pre-slaughter live weight. Carcasses were graded for conformation and fatness according to the European Union Beef Carcass Classification Scheme (Commission of the European Communities, 1982).

The animals in Experiment 1 were implanted twice with both oestradiol/progesterone (Synovex-S, Gist-brocades, Ireland Ltd.) and trenbolone acetate (Finaplex, Hoechst, Ireland). No implants were used in the other experiments. At the beginning of each experiment animals were treated with anthelmintics for the control of gastro-intestinal parasites and fascioliasis. Treatment for the control of lice was given as necessary. No health problems related to the concentrate supplement treatments were observed.

Apparent digestibility

Apparent digestibility of the silage and concentrates was determined for experiments 1, 2 and 3 over a number of separate time periods. The digestibility of the supplemented diets in each experiment was determined using animals from within blocks across the respective treatments. For Experiment 1, three of the individually fed animals per treatment were selected using one animal in each of three periods. In Experiment 2, four animals from each of treatments 1 and 3 were selected using two animals in each of two periods. In Experiment 3, two of the individually fed animals from each of treatments 1, 2 and 3 using one animal in each of two periods, and one animal for treatment 4 in one period were used. Similarly, the digestibility of the grass silage was determined in the three experiments using additional but similar animals to those in the production trials but offered the grass silage as the sole feed. Animals selected for the digestibility study were removed from the shed and tied in stalls for a 6-day adjustment period, following which they were accommodated in metabolism stalls for a 10-day total faecal collection period. The feeding procedure was as practised in the corresponding growth study except during the faecal collection period when feed refusals were weighed and discarded daily. The silage, concentrates and faeces were collected and processed according to the methods of Moloney and O'Kiely (1995). Digestibility of the concentrate supplements was calculated by difference (Drennan, Almiladi and Moloney, 1995).

Rumen fermentation

Rumen fermentation variables were determined using eight rumen-fistulated Friesian steers (288 kg) with two animals allocated per treatment in each of two periods. Animals were initially offered grass silage *ad libitum* following which concentrate allowance was introduced at the rate of 4.7 g air dry material per 1 kg (live weight)$^{0.75}$ in one (0800) or two (0800 and 1600) feeds daily. The concentrate allowance was increased by the same increment daily until the steers consumed concentrates to appetite and 1.15 kg of grass silage DM per day. Rumen fluid samples were collected on day 0 (i.e., prior to the introduction of concentrates) and on alternate days over the 30 day concentrate feeding period, at 0, 2, 4, 6, 8, 10 and 12 h after the morning feeding as described by Moloney and Flynn (1992). In addition to pH, rumen fluid samples obtained on days 4, 8, 16, 24 and 30 were also analysed for ammonia, volatile fatty acids and lactic acid.

Chemical analysis

Dry matter of the concentrate and silage used in the feeding and digestibility studies was determined by drying to a constant weight at 98 °C and 40 °C, respectively. Representative samples of the faeces collected in the digestibility study were dried at 40 °C. These figures were used in the calculation of feed DM intake and DM digestibility (DMD). Representative samples of feeds and faeces were retained for chemical analyses. Following drying all samples were subsequently ground through a 1 mm screen (Christy and Norris Mill). Crude protein (CP) concentration (nitrogen × 6.25) was determined by Kjeldhal and ash by complete combustion in a muffle furnace. Oil concentration was determined on the basis of European Community Regulations (1984). The pH of the silage was recorded and the *in-vitro* DMD of the feeds was determined by the methods of O'Shea, Wilson and Sheehan (1972). Crude fibre (CF) concentration was determined according to Van Soest (1963). Rumen fluid variables were analysed according to Moloney and Flynn (1992).

Statistical analysis

Production data for experiments 1, 2, 3 and 4 were combined to compare barley and wheat offered twice daily and the effect of feeding frequency for barley. Similarly, production data for experiments 3 and 4 were combined to compare barley and wheat offered once daily and the effect of feeding frequency for wheat. Data were analysed using an analysis of variance with the General Linear Models procedure of the Statistical Analysis System Institute (SAS, 2001) with terms for treatment, experiment, treatment × experiment in the model. The treatment × experiment interaction was not significant for any trait and was omitted from the final model. Feed intake and associated data were analysed using animal as the experimental unit where individual intakes were available (Experiments 1 and 3) and pen as the experimental unit where group intakes (Experiments 1, 2, 3, 4) were available. The mean intake per pen of group-fed animals was included with the individual intake values (with an appropriate weighting factor) for Experiments 1 and 3. When significant effects due to treatments were detected, mean separation of pre-planned comparisons (treatments 1 v. 2 and 1 v. 3 for Experiments 1 to 4 and, treatments 2 v. 4 and 3 v. 4 for Experiments 3 and 4) was conducted by the PDIFF option of SAS. Least-squares means are reported with standard errors. In Experiment 2, two of the animals were removed from treatment 3 and, in Experiment 3, five of the animals were removed from treatment 1 for reasons not related to the treatment. Rumen fermentation data were analysed using split-split-plot analyses of variance with a 2 × 2 factorial arrangement of treatments (Genstat, 1984). The model had cereal type, feeding frequency, block and period in the main plot, day plus associated interactions in the split-plot and time of sampling (hour within day) plus associated interactions in the split-split-plot.

Results

Feed analysis and digestibility

Composition of feed and digestibility values are presented in Table 1. The *in vitro* DMD of the grass silages was relatively high in Experiments 1 and 3 and low to moderate in Experiments 2 and 4. The CP

Table 1. Chemical composition and *in vitro* digestibility of the feeds

Experiment		Dry matter (g/kg)	Crude protein (g/kg DM)	Crude oil (g/kg DM)	Crude fibre (g/kg DM)	Ash (g/kg DM)	pH	*In-vitro* DMD[1] (g/kg)
				Grass silage				
1		179	160	-	-	92	3.8	725
2		169	137	-	-	87	4.4	626
3		205	128	-	-	72	3.5	729
4		184	147	-	-	86	3.5	670
				Feed ingredients				
1	Barley	895	118	14	51	26	-	842
	Wheat	895	131	17	33	25	-	894
	Soya	-	519	8	42	83	-	909
2	Barley	858	117	18	54	28	-	877
	Wheat	879	125	18	30	25	-	877
	Soya	877	531	20	34	81	-	919
3	Barley	-	113	15	52	27	-	864
	Wheat	875	125	16	27	24	-	850
	Soya	-	509	13	36	73	-	913
4	Barley	869	103	15	32	21	-	842
	Wheat	868	91	14	15	19	-	863
				Concentrates				
1	Barley-based	846	142	-	-	36	-	-
	Wheat-based	879	164	-	-	42	-	-
2	Barley-based	858	120	18	51	34	-	848
	Wheat-based	881	152	19	29	34	-	878
3	Barley-based	857	157	16	49	35	-	827
	Wheat-based	884	149	17	27	31	-	865

[1]Dry matter digestibility.

concentration was lower for barley than wheat in Experiments 1, 2 and 3 while it was the reverse in Experiment 4. Barley had a higher CF concentration than wheat in all the Experiments. The *in vitro* DMD of the barley varied from 842 to 877 g/kg and the wheat varied from 850 to 894 g/kg.

The *in vivo* DMD of the grass silage and supplemented diets offered in Experiments 1, 2 and 3 are shown in Table 2. There was no effect ($P > 0.05$) of cereal type or feeding frequency on diet or concentrate supplement digestibility. The addition of cereal to grass silage increased the apparent digestibility of the diet in Experiments 1 and 2.

Intake and performance

The DM intake of the barley-based con-centrate was lower than the wheat-based concentrate (4.8 v. 5.0 kg, $P < 0.001$) but there was no effect of cereal type or feeding frequency on silage or total DM intakes (Tables 3 and 4). Final live weight, carcass weight, carcass conformation score, carcass fat score, kill-out proportion, daily live-weight gain and estimated carcass gain were not affected by cereal type or feeding frequency. Neither cereal type or feeding frequency had any effect on feed conversion efficiency (FCE), whether expressed as either live-weight gain or carcass gain per unit DM intake.

Table 2. *In vivo* dry matter digestibility (g/kg) of the grass silage, supplemented diets and of the concentrate component (by difference) in Experiments 1, 2 and 3

Experiment	Treatment					s.e.[2]	Sig[1]
	Grass silage	Barley[1]		Wheat[1]			
		Twice	Once	Twice	Once		
				Total diet			
1	742[a]	779[b]	771[b]	784[b]	-	4.6	**
2	670[a]	746[b]	-	762[b]	-	6.1	***
3[2]	752	773	766	795	782	11.6	
				Concentrate			
1	-	810	794	817	-	6.1	
2	-	817	-	839	-	9.8	
3[2]	-	792	777	825	798	18.5	

[1]Supplement offered either once or twice daily.
[2]Due to missing values the s.e. for the Wheat-once treatment is 1.4 times that presented.
[a,b]Means with a common superscript are not significantly different.

Table 3. Effect of cereal type offered twice daily and feeding frequency (once v. twice daily) of barley on dry matter intake, growth and carcass characteristics and feed conversion efficiency in finishing steers for Experiments 1, 2, 3 and 4 combined

	Treatment[1]		
	Barley		Wheat
	Twice	Once	Twice
Daily dry matter (DM) intake			
Silage (kg)	4.7 (0.18)[2]	4.5 (0.18)	4.7 (0.18)
Concentrate (kg)	4.8 (0.01)	4.8 (0.01)	5.0 (0.01)
Total (kg)	9.5 (0.18)	9.3 (0.18)	9.6 (0.18)
Total (g/kg live weight)	19.0 (0.35)	18.6 (0.35)	19.0 (0.35)
Initial live weight (kg)	440 (5.6)	442 (5.2)	442 (5.4)
Final live weight (kg)	569 (6.3)	564 (5.9)	576 (6.1)
Carcass weight (kg)	303 (3.6)	297 (3.3)	302 (3.4)
Kill-out proportion (g/kg)	532 (2.4)	527 (2.3)	525 (2.3)
Daily live weight gain (g/day)	1028 (40.7)	974 (38.0)	1065 (39.1)
Daily carcass gain (g/day)	672 (24.6)	618 (23.0)	658 (23.6)
Carcass conformation score[3]	2.70 (0.091)	2.58 (0.085)	2.52 (0.087)
Carcass fat score[4]	3.56 (0.066)	3.49 (0.062)	3.51 (0.064)
Feed conversion efficiency (g/kg feed DM)			
Live-weight gain	108 (5.5)	101 (5.5)	108 (5.5)
Carcass gain	70 (2.4)	67 (2.4)	68 (2.4)

[1]Significant difference ($P < 0.001$) between barley-twice and wheat-twice for daily intake of concentrate dry matter; there were no other differences due to cereal type or feeding frequency and there were no treatment × experiment interactions.
[2]( ) = s.e.
[3]EU Beef Carcass Classification Scheme Scale 1 (poorest) to 5 (best).
[4]EU Beef Classification Scheme Scale 1 (leanest) to 5 (fattest).

Table 4. Effect of cereal type offered once daily and feeding frequency (once v. twice daily) of wheat on dry matter intake, growth and carcass characteristics and feed conversion efficiency in finishing steers for Experiments 3 and 4 combined

	Treatment[1]			s.e.
	Wheat		Barley	
	Twice	Once	Once	
Daily dry matter (DM) intake				
Silage (kg)	4.1	3.9	4.2	0.30
Concentrate (kg)	4.8	4.8	4.7	0.01
Total (kg)	8.8	8.8	8.8	0.30
Total (g/kg live weight)	17.2	17.1	17.2	0.49
Initial live weight (kg)	468	469	465	5.3
Final live weight (kg)	560	561	551	8.2
Carcass weight (kg)	290	291	287	4.4
Kill-out proportion (g/kg)	518	518	519	2.9
Daily live-weight gain (g/day)	820	829	769	53.8
Daily carcass gain (g/day)	501	501	480	27.9
Carcass conformation score[2]	2.24	2.20	2.13	0.104
Carcass fat score[3]	3.41	3.24	3.41	0.083
Feed conversion efficiency (g/kg feed DM)				
Live-weight gain	90	97	84	8.7
Carcass gain	56	57	54	3.3

[1]Significant difference ($P < 0.001$) between barley (once) and wheat (once) for daily intake of concentrate dry matter; there were no other significant effects due to either cereal type or feeding frequency and there were no interactions between treatment and experiment.
[2]EU Beef Carcass Classification Scheme Scale 1 (poorest) to 5 (best).
[3]EU Beef Classification Scheme Scale 1 (leanest) to 5 (fattest).

Rumen fermentation

Silage intake by the fistulated animals comprised 0.55 of total DM intake between days 10 and 12 of the 30-d concentrate feeding period, which was approximately comparable to the forage proportion in the growth studies. There was no interaction between cereal type and feeding frequency for any of the rumen fluid variables measured (Table 5). Mean rumen

Table 5. Effect of cereal type (barley or wheat) and feeding frequency (once or twice daily) on rumen fermentation characteristics

Variable	Treatment				s.e.d.	Significance[1]
	Barley		Wheat			Cereal type
	Twice	Once	Twice	Once		
pH	6.58	6.52	6.45	6.35	0.10	
Ammonia (mg/L)	197.9	186.1	180.7	174.8	12.60	
Lactic acid (mg/L)	19.5	22.1	25.8	19.0	7.60	
Total volatile fatty acids (mmol/L)	97.9	98.0	105.9	101.2	4.05	
Acetate (mmol/mol)	643	643	620	615	17.1	
Propionate (mmol/mol)	202	206	238	255	18.3	*
Acetate:Propionate ratio	3.5	3.5	3.2	3.0	0.25	P = 0.06
Butyrate (mmol/mol)	115	110	104	88	8.0	*
Valerate (mmol/mol)	37	40	36	39	1.4	

[1]No difference due to feeding frequency.

fluid pH was not influenced by either cereal type or feeding frequency (Table 5). However, rumen pH values were lower ($P < 0.05$) with wheat than with barley on day 24 at 4, 6, 10 and 12 h (5.72, 5.91, 5.77 and 5.63 v. 6.23, 6.33, 6.16, and 6.06, s.e.d. 0.17) and on day 30 at 10 and 12 h (5.71 and 5.73 v. 6.10 and 6.07, s.e.d. 0.17) post-feeding. Likewise, pH values were lower with once-daily compared with twice-daily feeding on day 12 at 4 and 6 h (6.09 and 6.05 v. 6.47 and 6.48, s.e.d. 0.17) and on day 16 at 6 and 8 h (6.12 and 5.98 v. 6.70 and 6.72, s.e.d. 0.17) post-feeding at 0800. Neither cereal type nor feeding frequency affected mean rumen fluid concentrations of ammonia or L-lactate (Table 5). The mean molar proportion of propionate was higher and that of butyrate lower ($P < 0.05$) with wheat than with barley.

As concentrate inclusion increased, rumen fluid pH declined ($P < 0.001$) with values obtained on day 0 significantly higher than those obtained on subsequent days. The molar proportion of acetate was lower and the molar proportion of propionate was higher ($P < 0.001$) on days 24 and 30 than on days 0, 8 or 16, which were similar. The molar proportion of butyrate was not significantly affected by day. Rumen ammonia concentrations increased ($P < 0.001$) from day 0 to days 8 and 16 before subsequently decreasing to the original concentrations on days 24 and 30.

Discussion

Feed chemical composition and digestibility

The unwilted grass silages offered were of low to moderate DM concentration but were well preserved as indicated by pH except for that used in Experiment 2, which tended to have a high pH value. The range of *in vitro* DMD for the grass silage across the four experiments was similar to the variation often seen in practice in Ireland. The chemical composition of the barley and wheat used in the concentrates was generally within the range reported in international databases (INRA, 1989; MAFF, 1990; CVB, 1998) and represented cereals available in Ireland (O'Grady, 1996; O'Mara, Lynch and Moloney, 2000). The *in vitro* DMD values of the cereals were comparable to those reported by MAFF (1990). The cereals on offer were rolled as the negative effects of unprocessed whole cereal grains on digestibility and performance of beef cattle are well established (Drennan *et al.*, 1995; Mathison, 1996).

When averaged over Experiments 2 and 3, the *in vitro* DMD values were higher than the *in vivo* values for both the barley-based (838 vs. 801 g/kg) and wheat-based (872 vs. 824 g/kg) supplements. These differences are consistent with the correction factors proposed by O'Mara *et al.* (1999) to predict *in vivo* organic matter digestibility (OMD) from *in vitro* OMD (–42.8 and –70.4 g/kg for barley and wheat, respectively). The similar *in vivo* digestibility of the total diet for the two cereals is consistent with other reports comparing barley and wheat as supplements to grass silage (Drennan *et al.*, 1995) or hay (Dion and Seoane, 1992) fed to beef cattle. The lack of any significant difference between the *in vivo* DMD of wheat and barley is directly comparable to the results obtained by Drennan *et al.* (1995). In that study the *in vivo* DMD of barley was numerically lower than wheat (791 vs. 812 g/kg) which is within the range of differences (7 to 33 g/kg) reported in the present experiments.

In agreement with the current results Renton and Forbes (1974) also found no significant difference in the total diet DMD when 4.2 kg of a barley-based concentrate was offered in two daily feeds as opposed to once daily to Friesian steers fed hay *ad libitum*. Similarly, Aronen (1991) reported no effect of once or twice daily feeding of a barley supplement (45 g/kg $W^{0.75}$) on the apparent digestibility of the diet of young bulls offered grass silage *ad libitum*.

Animal intake and performance
Due to a higher DM concentration in the wheat-based concentrate, the intake of wheat was proportionately 0.03 higher than barley. The similar silage intake between the two feeding frequencies is in agreement with previous research using hay-based diets (Renton and Forbes, 1974) but not with that of Aronen (1991) who reported that twice daily feeding of barley to young bulls offered grass silage had a positive effect on grass silage intake. The latter author attributed this to a more stable rumen fermentation and thereby a more suitable environment for fibre digesting bacteria of the twice daily fed animals.

Overall, the results in the present study are in agreement with experiments in the literature comparing barley and wheat under different feeding systems. Thomas and Geissler (1968) examined the stepped replacement of barley by wheat when offered to fattening steers on a basal diet of hay *ad libitum* and reported no significant difference in animal gain. Similarly, Dion and Seoane (1992) compared the nutritive value of barley and wheat, comprising 0.53 of the diet, when fed with medium quality hay to fattening steers and found no significant difference in total intake, average daily gain or feed efficiency. Owens *et al.* (1997) reviewed feeding trials of cattle fed high concentrate diets (greater than 0.85 concentrate or greater than 0.7 concentrate if based on maize silage) published in North American Journals and Experiment station bulletins since 1974 and found no significant difference in average daily gain, DM intake or feed-to-gain ratio between barley or wheat averaged across a range of processing methods. Furthermore, the similar live-weight and estimated carcass gain and FCE between the feeding frequencies is also consistent with the studies of Aronen (1991) and Keady, Carson and Kilpatrick (2004).

Rumen fermentation
The absence of any effect of cereal type on overall rumen pH is in agreement with previous findings from this centre comparing these grains and processing methods (Almiladi, Moloney and Drennan, 1990). In contrast, Scollan *et al.* (1996) reported a lower rumen pH in steers offered grass silage *ad libitum* and supplemented with rolled wheat as opposed to rolled barley at only 0.10 of the total DM intake. Similarly, De Smet *et al.* (1995) reported that the decline in pH using *in vitro* methodology was greater for wheat than barley. However, in the present study rumen pH was often lower for the wheat-based than the barley-based concentrate when the concentrate proportion of the diet was high, circa 0.80 of the total DM intake. The higher molar proportion of propionate and the lower acetate to propionate ratio on the wheat-based than on the barley-based concentrate is also consistent with the findings of Almiladi *et al.* (1990).

The decline in rumen pH as the proportion of concentrates in the diet increased agrees with previous studies of diets based on grass silage (Almiladi *et al.,* 1990; Jaakkola and Huhtanen, 1993). The fact that increasing the dietary concentrate proportion from 0 to approximately 0.60 by day 16 did not significantly affect rumen acetate, propionate or butyrate concentrations demonstrates that the fermentation characteristics of grass silage can be a major determinant of rumen fermentation pattern (Van Vuuren, Huhtanen and Dulphy, 1995). However, the literature is inconsistent regarding the effects of supplementation of grass silage with cereal-based concentrates on rumen fermentation patterns in cattle (Aronen and Vanhatalo, 1992; Jaakkola and Huhtanen, 1993; Shiels, 1998; Thorp *et al.,* 1999, 2000).

Cereal feed value

Information in databases concerning feeding value indicate that barley is inferior to wheat with a feeding value ranging from 0.91 to 0.97 times that of wheat (INRA, 1989; MAFF, 1990; NRC, 1996; CVB, 1998; Rostock Feed Evaluation System, 2003; INRA-AFZ, 2004). Owens *et al.* (1997) calculated ME values from intake and animal performance on high concentrate diets and attributed a value of 3.46 Mcal/kg DM to wheat and 3.55 Mcal/kg DM to barley across a range of processing methods. Those authors pointed out that the value for wheat and barley was 9% and 17% higher, respectively, than the NRC (1996) estimates. This was partly attributed to the use of ionophores in the animal production studies (which would increase the ME value by about 6%) and possibly grain processing methods. However, corresponding values for dry-rolled, processed wheat and barley were 3.29 and 3.57 Mcal/kg DM. Steen (1993) concluded that the feeding value of wheat was 0.98 that of barley when given as a supplement to grass silage. Using the efficiency of estimated carcass gain, the data from the present experiments suggest that barley has a feeding value of 0.97 that of wheat but when adjusted for the higher intake of wheat (due to its higher DM), this differential is diminished.

In conclusion, estimated carcass weight gains and FCE to carcass gain were not significantly different between barley- and wheat-based supplements, given as either one or two equal daily feeds to finishing steers offered grass silage *ad libitum*. The consequences of this are positive for beef producers due to the opportunity to utilise more cost-effective cereal-based concentrate supplements and to increased labour efficiency.

Acknowledgements

The authors thank Mr. Bill Davis, Mr. John Marron and Mr. Padraig Gormley for skilled technical assistance and the staff of Grange Laboratories for feed analysis.

References

Almiladi, A.A., Moloney, A.P. and Drennan, M.J. 1990. Rumen fermentation in steers fed grass silage supplemented with either barley or wheat. *Irish Journal of Agricultural Research* **29:** 103.

Aronen, I. 1991. Influence of frequency and accuracy of supplement feeding on rumen fermentation, feed intake, diet digestion and performance of growing cattle. 1. Studies with growing bulls fed grass silage ad libitum. *Animal Feed Science and Technology* **34:** 49–65.

Aronen, I. and Vanhatalo, A. 1992. Effect of concentrate supplementation to grass silage diets on rumen fermentation, diet digestion and microbial protein synthesis in growing heifers. *Agricultural Science in Finland* **1:** 177–188.

Central Statistics Office (CSO) 2005. Cereals Supply Balance, August 2005. ISSN 1393–3825, 4 pages.

Commission of the European Communities. 1982. Commission of the European Communities (Beef Carcass Classification) Regulations. Council Regulations 1358/80, 1208/81, 1202/82. Commission Regulations 2930/81, 563/82, 1557/82, Commission of the European Communities, Brussels.

CVB. 1998. Verkorte tabel 1998. Voedernormen landbouwhuisdieren en voederwaarde veevoeders, *CVB-reeks no. 24*, Centraal Veevoederbureau, Lelystad, The Netherlands.

De Smet, A.M., de Boever, J.L., de Brabander, D.L., Vanacker, J.M. and Boucque, Ch.V. 1995. Investigation of dry matter degradation of some feedstuffs by means of in sacco and *in vitro* incubations. *Animal Feed Science and Technology* **51:** 297–315.

Dion, S. and Seoane, J.R. 1992. Nutritive value of corn, barley, wheat and oats fed with medium quality hay to fattening steers. *Canadian Journal of Animal Science* **72:** 367–373.

Drennan, M.J. and Keane, M.G. 1987. Responses to supplementary concentrates for finishing steers fed silage. *Irish Journal of Agricultural Research* **26:** 115–127.

Drennan, M.J., Almiladi, A.A. and Moloney, A.P., 1995. Digestibility of cereal grains, sugar beet pulp and molasses in cattle. *Irish Journal of Agricultural and Food Research* **34:** 1–11.

European Communities (Marketing of Feedstuff) Regulations. 1984. Statutory instruments S.I. No. 200 of 1984.

Genstat. 1984. Lawes Agricultural Trust, Rothamsted Experimental Station.

Herrera-Saldana, R.E., Huber, J.T. and Poore M.H. 1990. Dry matter, crude protein and starch digestibility of five cereal grains. *Journal of Dairy Science* **73:** 2386–2393.

Huntington, G.B. 1997. Starch utilisation by ruminants: From basics to the bunk. *Journal of Animal Science* **75:** 852–867.

INRA. 1989. "Ruminant Nutrition: recommended allowances & feed Tables" (ed. R. Jarrige), INRA and John Libbey Eurotext, London Paris, 389 pages.

INRA-AFZ. 2004. "Tables of composition and nutritional value of feed materials: Pigs, poultry, cattle, sheep, goats, rabbits, horses and fish", (ed. D. Sauvant, J.-M. Perez and G. Tran), INRA Editions, Wageningen Academic Publishers, The Netherlands & INRA, Paris France, 304 pages.

Jaakkola, S. and Huhtanen, P. 1993. The effects of forage preservation method and proportion of concentrate on nitrogen digestion and rumen fermentation in cattle. *Grass and Forage Science* **48:** 146–154.

Keady, T.W.J., Carson, A.F. and Kilpatrick, D.J. 2004. The effects of two pure dairy breeds and their reciprocal crosses, and concentrate feeding management, on the performance of beef cattle. *Proceedings of the British Society of Animal Science*, p187.

Mathison, G.W. 1996. Effects of processing on the utilisation of grain by cattle. *Animal Feed Science and Technology* **58:** 113–125.

McGee, M. 2005. Recent developments in feeding beef cattle on grass silage-based diets. In: "Silage production and utilisation". (ed. R.S. Park and M.D. Stronge). Proceedings of the XIVth International Silage Conference (a satellite workshop of the XXth International Grassland Congress), July 2005, Belfast, Northern Ireland. Wageningen Academic Publishers, pages 51–64.

Ministry of Agriculture, Fisheries and Food (MAFF). 1990. "UK Tables of Nutritive Value and Chemical Composition of Feedingstuffs" (ed. D.I. Givens), Holmes McDougal Ltd., Edinburgh, 420 pages.

Moloney, A.P. and Flynn, A.V. 1992. Rumen fermentation and *in sacco* degradability in steers of grass hay treated with urea and sodium hydroxide, alone or in combination. *Irish Journal of Agricultural and Food Research* **31:** 129–142.

Moloney, A.P. and O'Kiely, P. 1995. Growth, digestibility and nitrogen retention in finishing continental steers offered concentrates *ad libitum. Irish Journal of Agricultural and Food Research* **34:** 115–121.

NRC. 1996. "Nutrient Requirements of Beef Cattle" Update 2000, National Academy Press, Washington, D.C., 232 pages.

Offner, A., Back, A. and Sauvant, D. 2003. Quantitative review of in situ starch degradation in the rumen. *Animal Feed Science and Technology* **106:** 81–93.

O'Grady, J.F. 1996. Feed Tables 1996. R&H Hall Technical Bulletin. Issue No. 5, R&H Hall, Dublin, Ireland.

O'Mara, F.P., Lynch, B. and Moloney A.P. 2000. Feed Evaluation in Ireland. Report on a project funded by the Research Stimulus Fund, 1996–1999, 68 pages.

O'Mara, F.P., Harty, S., Kenny, M., McEntee, C., Young, P., Reilly, P. and Cunningham, D. 1999. The use of correction factors or regression equations to predict the digestibility of concentrate feed ingredients for ruminants. *Proceedings of the Agricultural Research Forum*, 25th and 26th March, 137–138.

O'Shea, J., Wilson, R.K. and Sheehan, W. 1972. Prediction of silage digestibility by *in vitro* and chemical methods. *Irish Journal of Agricultural Research* **11:** 175–179.

Owens, F.N., Secrist, D.S., Hill, W.J. and Gill, D.R. 1997. The effect of grain source and grain processing on performance of feedlot cattle: A review. *Journal of Animal Science* **75:** 868–879.

Owens, F.N., Secrist, D.S., Hill, W.J. and Gill, D.R. 1998. Acidosis in cattle: A Review. *Journal of Animal Science* **76:** 275–286.

Renton, A.R. and Forbes, T.J. 1974. A note on the effect of once, twice or three times a day feeding with concentrate on the efficiency of utilization of a diet given to beef cattle. *Animal Production* **19:** 111–114.

Rostock Feed Evaluation System 2003. "Rostock Feed Evaluation System: reference numbers of feed value and requirement on the base of net energy", (ed. W. Jentsch, A. Chundy and M. Beyer), Gottlob Volkhardtsche Druckerei, Richterstrasse 2, 63916 Amorbach.

Scollan, N.D., Kim, H.J., Maeng, W.J., Park, H., Neville, M.A., Evans, R.T. and McAllan, A.B. 1996. The effect of cereal carbohydrate supplementation on intake, rumen fermentation characteristics and digestibility in steers given grass silage. *Animal Science* **62:** 631–632.

Shiels, P. 1998. Defining the conditions under which benefits accrue from the use of bacterial inoculants as silage additives. *PhD. Thesis*, National University of Ireland, 413 pages.

SAS. 2001. Version 8.02, SAS Institute Inc., Cary, NC, USA.

Steen, R.W.J. 1993. A comparison of wheat and barley as supplements to grass silage for finishing beef cattle. *Animal Production* **56:** 61–67.

Thomas, O.O. and Geissler, B.R. 1968. Substitution of wheat for barley in cattle fattening rations. *Journal of Animal Science* **27:** 1115. (Abstract)

Thorp, C.L., Wylie, A.R.G., Steen, R.W.J., Shaw, S. and McEvoy, J.D. 1999. Effect of dietary forage: concentrate ratio on the behaviour, rumen fermentation and circulating concentrations of IGF-1, insulin, glucagon and metabolites of beef steers and their potential effects on carcass composition. *Animal Science* **68:** 533–546.

Thorp, C.L., Wylie, A.R.G., Steen, R.W.J., Shaw, S. and McEvoy, J.D. 2000. Effects of incremental changes in forage: concentrate ratio on plasma hormone and metabolite concentrations and products of rumen fermentation in fattening beef steers. *Animal Science* **71:** 93–109.

Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds III. A rapid method for the determination of fibre and lignin. *Journal of the Association of Official Analytical Chemists* **46:** 829–835.

Van Vuuren, A.M., Huhtanen, P. and Dulphy, J.P. 1995. Improving the feeding and health value of ensiled forages. In: “Recent advances in the nutrition of herbivores”, Proceedings of the IVth International symposium on the nutrition of herbivores, (ed. M. Journet, E. Grenet, M-H. Farce, M. Thereiez and C. Demarquilly), INRA editions, Paris, pages 279–307.

Received 8 September 2005