End of Project Report

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QUALITY MEAT PRODUCTION FROM BEEF CATTLE DURING WINTER FINISHING

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SUMMARY

A series of experiments were carried out to examine the performance of the UK metabolisable energy (ME)/metabolisable protein (MP) system in an Irish context, and to determine the response in lean tissue growth to changes in the form of nutrients available for absorption from the intestine.

In Experiment 1, the response of finishing continental heifers to an increase in MP supply was examined. It was demonstrated that this type of animal responded positively to an increase in MP supply in excess of requirements as presently estimated by the UK ME/MP system. Such an anomaly requires clarification.

In Experiment 2, growth, digestibility and nitrogen retention in finishing continental steers offered *ad libitum,* concentrates based on barley and soyabean or on a mixture of industrial by-products were examined. The observed higher nitrogen retention in animals offered the by-product based ration suggested that there is opportunity to increase carcass protein content by judicious choice of feed ingredients. This suggestion was explored in Experiment 3.

In Experiment 3, nitrogen retention and carcass composition were measured in sheep offered rations which resulted in different patterns of volatile fatty acid supply from the rumen. Nitrogen retention and the growth of carcass lean tissue were increased by the inclusion of sodium propionate in a starch-based ration but not in a fibre-based ration. The apparently contradictory effects of an increase in propionate supply by dietary means (starch vs fibre-based rations) or by addition of a salt of propionic acid suggests that the pattern, as well as the total supply of propionate is physiologically important in the growing ruminant. The endocrine mechanism of changes in carcass composition was also explored in this experiment. Differences in plasma concentrations of hormones which play a major role in the partition of absorbed nutrients towards muscle or adipose tissue suggests a role for the endocrine system in the regulation of growth, independent of energy intake.

In Experiment 4, the effect of starch form and concentration (a dietary means of increasing propionate supply) in high concentrate rations on growth, efficiency and estimated lean content was examined in Friesian bulls. Supporting mechanistic measurements were made in Friesian steers fed the corresponding experimental rations. For optimum growth, ground starch should not exceed 210 g/kg of the ration. When included at approximately 300 g/kg, ground rather than rolled starch had a negative impact on growth. Coarse rations containing 300g or 480g starch/kg resulted in similar growth and efficiency. An increase in ground but not rolled starch concentration decreased the insulin response to a glucose challenge.

INTRODUCTION

Maximum muscle growth will occur when the nutrient requirements of an animal are exactly matched by the nutrients suppled by its diet. Much research is focussed, worldwide, on clarifying the nutrient requirements of beef cattle for muscle growth. While systems of nutrient requirements of beef cattle have been developed elsewhere, they may be inaccurate in an Irish content due to the types of cattle and beef production systems operated in Ireland. Such systems must therefore be tested and their limitations identified and corrected. In addition, most nutrient requirements systems currently available are directed more towards nutrient supply, particularly from the rumen, and less towards the likely response of the animal to changes in the array of nutrients available for absorption. A greater understanding of this part of the process of conversion of nutrients to meat, is required to develop mechanistic models to predict changes in body composition of growing beef cattle.

The objectives of this project were to :

(1) examine the performance of the UK metabolisable energy (ME)/metabolisable protein (MP) system in an Irish context, and (ii) determine the response in lean tissue growth to changes in the form of nutrients available for absorption from the intestine.

EXPERIMENTAL

Experiment 1: The response of finishing heifers to an increase in metabolisable protein supply

The current United Kingdom MP system has replaced the 1980/1984 system based on dietary crude protein (CP) degradability but to date there has been little evaluation of this new system in beef cattle feeding experiments.

To determine the performance response to an increase in MP supply above estimated requirements, 32 continental crossbred heifers (initial live weight 466, s.d. 21.8 kg) were offered grass silage (CP = 183 g/kg dry matter (DM) and ME = 10.3 MJ/ kg DM) *ad libitum* and 3 kg of a low (L ; 26 g/kg DM) or high (H ; 164 g/kg DM), isoenergetic (13.4 MJ ME/kg DM) CP concentrate per animal daily. Within treatment, the animals were housed in pens of 8 for the 104-day experimental period before slaughter. Metabolisable protein supply was calculated from the degradation characteristics of the feedstuffs when incubated *in sacco.*

Results:

Neither total DM, ME nor fermentable ME intake differed between treatments (Table 1). There was, however, a small (5%) but non- significant difference in silage DM intake between treatments. The supply of effective rumen degradable protein (ERDP) and consequently the ratio of ERDP to fermentable ME was lower (P<0.06) on the low CP diet. The supply of digestible undegraded protein and MP were as planned, higher (P <0.05) on the high CP diet. The ratio of MP supplied to that required, based on predicted ME intake was 1.7 and 2.4 for the low and high CP diets, respectively. The corresponding values based on observed growth were 1.9 and 2.5. The increase in MP supply resulted in an increase in carcass weight (P <0.08) and in estimated carcass growth rate (P<0.05).

Conclusion:

It is concluded that at least some types of cattle respond positively to MP supply in excess of requirements as presently estimated. Whether this reflects errors in the supply and/or requirement side of MP balance or the relationship between ME and MP within the system is not clear and should be clarified before the MP system is adopted widely, in practice.

Table 1. Estimated nutrient supply and animal performance (Experiment 1)

	Concentrate crude protein			
	Low	High	s.e.d.	Significance
Daily supply/animal				
Silage dry matter (kg)	6.3	6.6	0.44	
Total dry matter (kg)	8.9	9.2	0.44	
Metabolisable energy (ME ; MJ)	100	102	4.5	
Fermentable ME (MJ)	78	80	3.2	
Effective rumen degradable protein (ERDP ; g)	584	739	38.8	P=0.06
ERDP/fermentable ME	7.5	9.2	0.15	**
Digestible undegradable protein (g)	379	82	24.7	*
Metabolisable protein (g)	750	1053	48.7	
Animal performance				
Initial weight (kg)	66	469	7.2	
Pre-slaughter weight (kg)	540	550	9.5	
Carcass weight (kg)	275	284	4.7	P=0.08
Kill-out proportion (g/kg live weight)	510	516	3.8	
Kidney plus channel fat (kg)	9.7	9.4	0.83	
Body weight gain (g/day)				
Predicted◊	858	861	--	
Actual	711	781	55.6	
Carcass growth (g/day)	404	473	29.2	*
Metabolisable protein (g/day)				
Predicted requirement≈	431	434	--	
Actual requirement∆	403	418	--	

◊From ME intake. ≈Based on predicted growth and including a safety margin of 5%.
∆Based on actual growth and including a safety margin of 5%.

Experiment 2: Growth, digestibility and nitrogen retention in finishing continental steers offered concentrates *ad libitum*

To determine the impact of ration composition on growth, digestibility and nitrogen retention in beef cattle, two concentrate rations based on a mixture of barley and soyabean (BS) or a mixture of industrial by-products (BP) (distillers grains, fishmeal, maize gluten, citrus pulp, molasses, rolled wheat and tallow) were formulated, using published information and chemical analysis, to be isonitrogenous and isoenergetic on a DM basis. These were offered *ad libitum* together with 1.2kg grass silage DM per animal, to finishing Simmental-x-Friesian steers (mean liveweight 596, s.d. 40.4, kg ; 10/treatment), for 106 days before slaughter. In a parallel study, six Friesian steers (mean initial BW 322, s.d. 14.0, kg) were used in a 2 (concentrates) by 2 (periods) changeover experiment to measure ration digestibility and nitrogen retention.

Results

Data are summarised in Table 2.

The source of energy differed considerably between rations and, consequently, the concentrations of the end-products of digestion of the rations would be expected to differ considerably. Neither group concentrate DM intake, daily bodyweight gain nor daily carcass gain differed significantly between rations. Based on the *in vivo* digestible organic matter concentration measured in growing steers, less ME was supplied by the BP-based ration. Both absolute nitrogen retention and nitrogen retention as a proportion of absorbed nitrogen were higher ($P<0.07$) for the BP-based ration.

Conclusion:

It is concluded that cattle offered the BP-based ration used dietary nitrogen more efficiently than those offered the BS-based ration. The possibility and mechanism of increasing carcass protein content in finishing steers by appropriate choice of individual feed ingredients merits further study

Table 2. Growth performance, *in vivo* digestibility and nitrogen balance (g/day) in steers offered concentrate rations *ad libitum* (Experiment 2)

	Barley/soyabean	By-products	s.e.	Significance
Initial weight (kg)	603	589	7.1	
Final weight (kg)[1]	685	682	5.7	-
Dry matter intake (kg/day)				
Grass silage	1.17	1.17	-	-
Concentrate	10.30	10.24	-	-
Metabolisable energy intake (MJ/day)	137.4	120.1	-	-
Bodyweight gain (g/day)	1251	1123	56.5	
Kill-out proportion (g carcass/kg bodyweight)	570	562	3.2	
Carcass weight (kg)	395	379	3.8	*
Carcass weight (kg)[1]	391	383	4.7	
Carcass weight gain (g/day)	827	716	50.8	
Kidney plus channel fat (g/kg carcass)	38.2	40.3	3.22	
Carcass fatness score[3]	4.0	3.0	0.18	
Digestibility (gkg)				
Dry Matter	761	694	6.3	**
Organic Matter	777	723	5.2	**
Crude Protein	724	638	9.0	**
Neutral detergent fibre	373	580	23.3	**
Acid detergent fibre	290	642	45.1	**
Hemicellulose	427	496	11.2	*
DOMD (g/kg DM)[4]	749	658	5.3	***
Estimated metabolisable energy[4]	12.0	10.5	0.85	***
Nitrogen balance				
Intake	208.6	247.5	8.53	*
Faeces loss	57.8	89.4	2.70	**
Urinary loss	110.0	99.8	3.11	
Retention	40.9	58.3	5.12	P=0.06
Retention (g/kg intake)	195	235	19.0	
Retention (g/kg absorbed)	274	367	28.0	P=0.07

[1]Adjusted for differences in initial weight by covariance analysis.
[3] ≈5 = very fat ; 1 = little fat
[4]Metabolsable energy (MJ/kg DM) = 0.16 DOMD (g/kg) (AFRC. 1993)

Experiment 3 : Growth, digestion and metabolism in sheep offered isoenergetic rations which resulted in different concentrations of ruminal metabolites

The objective of this experiment was to determine if isoenergetic rations, designed to result in different ruminal fermentation patterns, altered growth, carcass composition and metabolism in wether lambs. Two basal rations, based either on starch (S) or a digestible fibre/sugar mixture (F) were formulated. Sodium propionate was included at 0 (C) or 40 g/kg (P) to give four isoenergetic (12 MJ ME/kg DM) and isonitrogenous (165 g CP/kg DM) rations. The rations were offered for 64 days prior to slaughter and measurement of carcass composition by dissection. During the growth phase, nitrogen balance, acetate clearance from the blood and the diurnal pattern of blood hormones and metabolites were measured. In parallel, the rations were offered to four ruminally fistulated sheep in a 4 (rations) by 4 (periods) Latin square experiment to confirm the different patterns of rumen fermentation.

Results

There was no difference between diets in mean volatile fatty acid concentrations in ruminal fluid (92, 90, 86 and 105 (se 7.5) mmol/l for SC, SP, FC and FP, respectively). The acetate to propionate ratio was lower ($P<0.001$) for S-based diets and decreased ($P<0.01$) by the inclusion of P (1.28, 0.93, 1.98 and 1.70 (se 0.035), for SC, SP, FC and FP, respectively). Digestibility and nitrogen balance data are summarised in Table 3. The digestible organic matter concentration measured *in vivo* was lower ($P<0.01$) for S-based diets but unaffected by the inclusion of P. Inclusion of P in the S-based ration increased ($P<0.05$) nitrogen retention in absolute terms or when scaled to nitrogen intake or absorbed nitrogen.

Performance and carcass composition of wethers are summarised in Table 4. Dry matter intake and consequently ME intake were greater ($P < 0.001$) on the F-based diets due to the higher than expected DM concentration of these rations. There was no difference between rations for whole body or carcass growth, or for the efficiency of conversion of DM or ME to whole body or carcass. The size of the omentum fat depot tended (P <0.10) to be greater and carcass protein concentration (g/kg soft tissues) tended (P <0.10) to be lower in animals offered the S-based diets. Inclusion of P in the rations decreased the weight (P <0.01) and the proportion (P <0.05) of dissectible fat in the carcass, and tended (P <0.10) to decrease the size of the kidney/pelvic fat depot (but did not affect the size of the omentum fat depot). There was an interaction (P <0.10) between ration type and and P level with respect to carcass protein yield, the growth of carcass lean tissue and the efficiency of carcass lean tissue growth. Thus, P increased (P <0.05) these variables when included in the S-based diet but not when included in the F-based diet.

On days 19 and 60, blood samples were collected via a jugular catheter at 20 min. intervals between 0800 and 2000h. Insulin and GH concentrations were measured in all samples, IGF-1 in samples collected 160 min after each meal and metabolite concentrations in hourly samples. Mean plasma concentrations of urea, non-esterified fatty acids and GH were higher (P <0.05) and IGF-1 tended (P =0.06) to be lower on day 19 compared to day 60 but there were no day x ration type interactions for these variables. Overall mean plasma urea concentrations were 7.2, 6.5, 5.3 and 5.9 (se 0.39) mmol/l for SC, SP, FC and FP, respectively. The corresponding values were 3.7, 3.7, 3.7 and 3.8 (se 0.12) mmol/1 for glucose, 0.18, 0.18, 0.11 and 0.12 (s.e. 0.18) mEq/l for non-esterified fatty acids and 0.32, 0.36, 0.37 and 0.50 (se 0.059) mmol/1 for beta-hydroxybutyrate. Mean plasma insulin concentrations were 12.4, 10.5, 13.6 and 14.0 (se 1.17) µIU/ml for SC, SP, FC and FP respectively. The corresponding values were 0.82, 0.68, 0.60 and 0.91 (se 0.094) ng/ml for GH, 18.0, 17.3, 24.0 and 17.3 (se 2.58) for the insulin to GH ratio, 465, 459, 454 and 475 (se 26.4) ng/ml for IGF-1 and 1.8×10^{-3}, 1.5×10^{-3}, 1.4×10^{-3} and 2.0×10^{-3} (s.e. 1.2×10^{-4}) for the GH to IGF-1 ratio. The daily pattern of plasma insulin concentrations was examined by considering the mean values in the hour before the first meal, the 2 h period after each meal and the 2 h period before the second and third meals. There was no effect of ration type on plasma insulin concentrations before any meal. Mean plasma insulin concentrations after the first meal were 11.2, 10.6, 20.1 and 19.9 (se 1.95) µIU/ml for SC, SP, FC and FP, respectively. The corresponding values were 15.4, 12.2, 14.7 and 20.9 (se 2.30) µIU/ml for the second meal and 15.7, 12.9, 14.1 and 15.1 (se 1.66) µIU/ml for the third meal.

Conculsions

It is concluded that a decrease in the acetate to propionate ratio in ruminal fluid, by addition of P, resulted in a decrease in fat deposition in both S and F-based rations and increased skeletal muscle growth in the S-based ration. Rations which supply similar amounts of ME and CP, but which differ in the end-products of their fermentation in the rumen, can result in (i) different plasma concentrations of metabolites, particularly non-esterified fatty acids and beta-hydroxybutyrate, and (ii) different plasma concentrations and ratios of hormones, that have primarily lipogenic or lipolytic actions.

Table 3. Ration digestibility *in vivo* (g/kg), nitrogen balance (g/day) and acetate clearance in sheep offered starch (S) of fibre (F) rations with or without sodium propionate (P) (Experiment 3)

	Ration					Significance		
	SC	SP	FC	FP	s.e.	Ration	P	Ration x P
Digestibility								
Dry matter (DM)	818	846	850	881	8.5	***	***	NS
Crude protein	778	797	764	811	9.6	NS	***	NS
Neutral detergent fibre	654	578	787	823	20.9	****	NS	**
Organic matter	847	868	886	909	7.5	****	**	NS
DOMD[a]	803	812	831	841	7.0	***	NS	NS
Metabolisable energy (MJ/kg DM)[b]	12.9	13.0	13.3	13.5	0.12	***	NS	NS
Nitrogen balance								
Intake	24.8	25.6	26.0	26.3	1.00	NS	NS	NS
Faeces	5.5	5.2	6.1	5.0	0.39	NS	*	NS
Urine	13.8	11.5	11.0	13.3	0.74	NS	NS	***
Retention	5.5	8.9	8.8	8.0	0.90	NS	NS	**
Retention/intake (g/kg)	221	348	341	313	29.4	NS	NS	**
Retention/absorbed (g/kg)	281	435	444	386	37.5	NS	NS	**
Acetate clearance								
Initial concentration (mmol/l)	0.05	0.13	0.87	0.54	0.133	****	NS	NS
Clearance rate (min^{-1})	0.056	0.051	0.031	0.033	0.0064	***	NS	NS

[a]DOMD, digestible organic matter content of the dry matter
[b]Metabolisable energy = 0.16 DOMD (AFRC, 1993)

Table 4. Growth, carcass composition and feed conversion efficiency in sheep offered starch (S) or fibre (F), based rations with or without sodium propionate (P) (Experiment 3)

	Ration					Significance		
	SC	SP	FC	FP	s.e.	Ration	P	Ration x P
Initial weight (kg)	46.5	46.1	46.2	46.1	0.63	NS	NS	NS
Pre-slaughter weight (kg)	54.2	53.8	54.8	53.7	1.88	NS	NS	NS
Cold carcass weight (kg)	26.2	26.9	27.7	26.6	0.87	NS	NS	NS
Fat depth (mm)	5.3	5.2	6.0	4.3	0.57	NS	NS	NS
Omentum fat (kg)	1.48	1.38	1.23	1.02	0.171	*	NS	NS
g/kg carcass	55	51	43	39	6.9	*	NS	NS
Kidney/pelvic fat (kg)	0.94	0.90	1.03	0.68	0.110	NS	*	NS
g/kg carcass	34	34	37	25	4.1	NS	NS	NS
Carcass composition								
Fat (g/kg)	267	233	250	223	10.3	NS	**	NS
Lean (g/kg)	542	586	570	586	11.9	NS	**	NS
Bone (g/kg)	191	181	180	191	11.1	NS	NS	NS
Carcass fat (kg)	6.9	6.2	6.9	6.0	0.40	NS	*	NS
Carcass lean (kg)	14.2	15.7	15.7	15.5	0.53	NS	NS	NS
Protein in carcass soft tissue								
kg	3.05	3.52	3.46	3.46	0.124	NS	*	*
g/kg	149	163	157	164	2.8	*	***	NS
LD area (cm2)[a]	14.6	15.8	17.2	15.6	1.94	NS	NS	NS
Growth (g/day)								
Bodyweight	123	123	136	120	26.0	NS	NS	NS
Carcass	76	90	102	86	12.3	NS	NS	NS
Carcass lean (g/day)	38	64	63	62	0.80	NS	NS	*
Dry matter intake (DMI ; g/day)	910	961	1026	1017	20.0	****	NS	NS
Metabolisable energy intake (MEI; MJ/day)	11.8	12.5	13.6	13.7	0.272	****	NS	NS
Feed conversion efficiency (g/kg DMI)								
Bodyweight	133	129	132	118	5.7	NS	NS	NS
Carcass	80	92	97	85	10.4	NS	NS	NS
Carcass lean	40	66	61	62	7.8	NS	*	NS
(g/MJ MEI)								
Bodyweight	10.3	9.9	9.9	8.8	1.97	NS	NS	NS
Carcass	6.2	7.1	7.3	6.3	0.79	NS	NS	NS
Carcass lean	3.1	5.1	4.6	4.6	0.59	NS	NS	*

[a]**Longissimus thoracis et lumborun**

Experiment 4 : Growth, digestion and metabolism in bulls offered different amounts and forms of starch

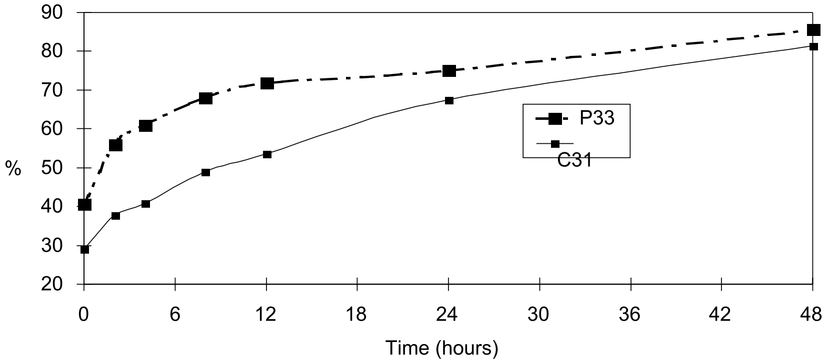
To examine the effect of starch form and concentration in high concentrate rations on growth and estimated lean content in beef cattle, 30 bulls from each of two age groups (11 months and 7 months) were penned in pairs and offered *ad libitum* one of 3 ground and pelleted rations containing 139, 239 or 327 g starch/kg DM, a coarse ration based on rolled barley, corn gluten and sugar beet pulp (311 g starch/kg DM) or a coarse ration based on rolled barley and soyabean (492 g starch/kg DM). Prior to slaughter after 19 weeks, urea space was measured by urea dilution and ribeye area and fat cover by ultrasound. The experimental rations were also offered individually *ad libitum,* to Friesian steers for measurement of *in vivo* digestibility and rumen fermentation. In addition, blood samples were collected before (n=8; -4.5 to 0 h) and after (n=12; 0 to +2 h) intravenous injection of 200 mg glucose/kg BW for measurement of glucose tolerance and insulin secretion. Digestion characteristics of the form of starch were measured by *in sacco* incubation in ruminally fistulated steers.

"A prior" contrasts were carried out between (i) starch concentration in pelleted rations, (ii) Beef 30 and Grange 14 (i.e. two rations with a similar starch concentration but which differed in the expected rate of ruminal fermentation), and (iii) the two coarse rations.

Results

Animal data are summarised in Table 5. There were few significant interactions between age at the beginning of the study and the treatments imposed. An increase in ground starch concentration in the ration resulted in a linear decrease in the acetate to propionate ratio in rumen fluid, a quadratic decrease in carcass growth, without an effect on feed conversion efficiency, or fatness but caused a linear decrease in the insulin response to a glucose challenge (Table 6). An increase in rolled starch concentration resulted in a decrease in the acetate to propionate ratio in rumen fluid, a decrease in ration consumption without a significant effect on performance, or fatness and an increase in baseline plasma glucose concentration. An increase in starch degradability (Figure 1) by grinding prior to pelleting, resulted in a decrease in the acetate to propionate ratio in rumen fluid, a decrease in feed consumption and carcass growth but not efficiency, an increase in urea space but no effect on glucose challenge variables.

Figure 1. Ruminal dry matter degradability of concentrates containing 300g/kg of either rolled (---) or ground (—) starch



Conclusions

For concentrates offered *ad libitum* (i) increasing the concentration and grinding rather than rolling starch resulted in a decrease in the acetate to propionate ratio in rumen fluid, (ii) for optimum growth, ground starch should not exceed 210 g/kg of the ration, (iii) when included at approximately 300 g/kg, ground rather than rolled starch has a negative impact on growth, (iv) coarse rations containing 300g or 480 g starch/kg resulted in similar growth and efficiency and (v) an increase in ground but not rolled starch concentration decreased the insulin response to a glucose challenge.

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Table 5. Growth, efficiency, digestibility and rumen fermentation in beef cattle offered concentrates *ad libitum* (Experiment 4)

	Ration						Contrast		
	Beef 10	Beef 20	Beef 30	Grange 14	Barley Soya	sed	Starch Level◊	Starch Proc.≈	Coarse rations∆
Growth									
Initial bodyweight (BW;kg)	404	409	410	410	417	5.2	NS	NS	NS
BW gain (g/day)	1141	1228	1087	1327	1293	84.1	NS	*	NS
Carcass weight (kg)	297	308	294	312	311	8.9	NS	*	NS
Carcass gain (g/day)	594	646	568	685	668	46.5	Q+	*	NS
Fat score	3.63	3.85	4.00	4.10	4.23	0.309	NS	NS	NS
Kidney/channel fat (g/kg carcass)	37.3	40.4	39.3	40.6	42.1	4.0	NS	NS	NS
Fat Depth (mm/kg)	99	115	129	122	122	25.4	NS	NS	NS
Urea Space (l/kg bodyweight)	463	473	517	446	468	30.4	NS	*	NS
Dry matter (DM) intake (kg/day)[4]									
Concentrate	15.4	15.9	13.9	17.3	16.3	0.50	L*Q*	*	*
Total	16.8	17.3	15.3	18.6	17.6	0.50	L*Q*	*	*
Feed conversion efficiency									
kg DM/kg BW	7.5	7.2	7.1	7.1	6.9	0.46	NS	NS	NS
kg DM/kg carcass	14.5	13.6	13.5	13.7	13.4	0.94	NS	NS	NS
Digestibility (g/kg)									
DM	672	712	705	719	785	25.2	NS	NS	*
Organic matter	694	735	728	749	805	24.0	NS	NS	*
Crude protein	639	695	690	690	753	29.1	NS	NS	*
DOMD	636	681	678	697	759	22.4	NS	NS	*
Rumen fermentation									
pH	6.18	6.31	6.05	6.74	6.61	0.174	NS	*	NS
Volatile fatty acids (mmol/l)	95	89	101	61	70	11.4	NS	*	NS
Acetate[5]	540	534	474	605	496	19.9	L*Q*	*	*
Propionate[5]	258	315	411	226	424	28.2	L*	*	*
Butyrate[5]	158	118	84	139	50	20.4	L*	*	*

◊L and Q are linear and quadratic effets of level of starch inclusion in pelleted rations, respectively; NS = not significant, *=P<0.05, +=P<0.1 ≈Beef 30 vs. Grange 14 ∆Grange 14 vs. Barley/Soya [4]Animals penned in pairs according to treatment, efficiency is calculated on a pen basis. [5]mmol/mol

Table 6. Glucose challenge variables in beef cattle offered concentrates *ad libitum* (Experiment 4)

	Ration						Contrast◊		
	Beef 10	Beef 20	Beef 30	Grange 14	Barley Soya	sed	Starch Level	Starch Proc.	Coarse rations
Glucose									
Baseline (mmol/l)	4.0	4.2	4.3	4.2	4.6	0.15	NS	NS	*
Peak (mmol/l)	10.7	10.7	11.4	11.4	10.5	0.71	NS	NS	NS
Clearance (h^{-1})	0.020	0.017	0.018	0.018	0.017	0.0029	NS	NS	NS
Insulin									
Baseline (uU/ml)	10.7	8.9	11.1	11.7	13.2	1.39	NS	NS	NS
Area Under Curve[1] (uU.mm/ml)	2.96	2.68	2.73	2.65	2.68	0.14	*	NS	NS

[1]Data logarithmically transferred prior to analysis.
◊L and Q are linear and quadratic effects of level of starch inclusion in pelleted rations, respectively; NS = not significant, *=P<0.05, +=P<0.1

PUBLICATIONS FROM THIS PROJECT

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