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Malt distillers grains as a component of diets for ewes and lambs and its effects on carcass tissue lipid composition

J.E. Vipond[a,*], M. Lewis[a], G. Horgan[b], R.C. Noble[c]

[a]*Genetics and Behavioural Sciences Department, SAC, West Mains Road, Edinburgh EH9 3JG, UK*
[b]*Scottish Agricultural Statistics Service, University of Edinburgh, Edinburgh EH9 3JZ, UK*
[c]*SAC, Auchincruive, Ayr KA6 5HW, UK*

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Abstract

Two studies were conducted to evaluate malt distillers grains (G) as a component of diets for finishing lambs and pregnant ewes. Mineralised G fed in mixed diets in both studies proved efficacious but as a sole feed was inappropriate, leading to low levels of gain in finishing lambs and vaginal prolapse in breeding ewes.

G was fed to 70 lambs, 5 months of age, in replicated groups of seven lambs in slatted finishing pens. When supplemented with barley at 0 kg, 0.3 kg and 0.6 kg day^{-1}, finishing lambs fed ad libitum G gained 112 g, 184 g and 204 g day^{-1}, indicating a decreased response to the higher level of barley owing to substitution effects. When G was offered as a replacement for supplementary pelleted compound along with ad libitum grass silage, lower rates of daily gain resulted but similar food conversion efficiency was achieved.

Analysis of carcass tissue lipids from lambs fed G indicated a significant amount of dietary unsaturated fat escaped rumen biohydrogenation and was preferentially incorporated into the phospholipid component of muscle tissue. This gave a significant increase in the polyunsaturated fatty acid:saturated fatty acid ratio of lean tissue.

G was fed to 140 pregnant multiparous ewes in four groups of 35 ewes in straw bedded pens. G successfully replaced barley/fishmeal in a silage-based diet fed in late pregnancy to multiparous ewes; however, unrestricted access to G caused overfatness and dietary problems. It was concluded a maximum recommended feeding level of 1 kg G per 25 kg liveweight for ewes was appropriate where the remainder of the diet was cereal.

Keywords: Grains, malt distillers; Sheep; Lipid composition; Feeding

* Corresponding author at: Genetics and Behavioural Sciences Department, SAC, Bush Estate, Penicuik EH26 0QE, UK. Tel. 0131 535 3200; fax 0131 445 5687.

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1. Introduction

Malt distillers grains (G) are a by-product of the Scotch whisky industry; 220 000 t of the wet fresh material are produced annually and this production is geographically located mainly in sheep producing areas. Ensilage and feeding of the material (typically 250 g kg^{-1} dry matter) to the local sheep population is an attractive option, saving drying and transport costs. Removal of starch and water soluble components of malted barley make the high fibre residue G a rich source of dietary unsaturated fat for ruminants but one low in major mineral elements including sodium, potassium and magnesium. Inadequate attention to the mineral supplementation of G resulting in low intake and digestibility may have constrained its use in the past (Lewis and Lowman, 1987, 1989; Johnson et al., 1987; Hyslop and Roberts, 1988, 1989). Typical levels of unsaturated fatty acids of 75 g kg^{-1} in the feed contribute to low feed intake through inhibitory effects on rumen cellulolysis (El Hag and Miller, 1972; Offer and Offer, 1992a). However, it does offer potential to increase the unsaturated fatty acid composition of the carcass of lambs fed on G. The combination of unsaturated fat with highly absorbent fibre sources affords protection to the fatty acids from biohydrogenation in the rumen (Harfoot et al., 1973; Harfoot, 1978). Changing the fatty acid composition of the human diet towards a greater proportion of unsaturated fatty acids has been in the forefront of dietetic recommendations for many years (Committee on Medical Aspects of Food Policy (COMA), 1991).

This study was undertaken to investigate (a) the use of G in lamb finishing diets in order to determine optimum inclusion levels and whether it could replace more expensive compound in silage based diets, (b) the effects on carcass lipid fatty acid composition and (c) the consequences of using G to replace farm-produced grass silage and barley in diets fed to pregnant ewes as a means of reducing costs and pollution risks associated with grass silage.

2. Materials and methods

G fed in trials was obtained as fresh wet material and ensiled in circular welded mesh silos (diameter 4.75 m), air being excluded by polythene sheeting. Grass silage was made from predominantly ryegrass swards cut with a drum mower and lifted immediately using a precision chop harvester without additive and stored in bunker silos of over 100 t capacity. Barley used was stored at 14% moisture content and fed whole.

Specific measures were taken to ensure diets contained adequate mineral content. Diets where G was a sole or major component (see Tables 1 and 2) were supplemented with specially formulated mineral/vitamin mixtures (see Table 3) containing potassium which is almost absent in G and high levels of calcium which have been shown to increase the digestibility and intake of G (El Hag and Miller, 1972; Offer and Offer, 1992b), the major effect being attributed to the formation of insoluble soaps of fatty acids rendering them less toxic to rumen microbes (Jenkins and Palmquist, 1982). These measures ensured that potassium deficiencies were not encountered.

Table 1
Experiment 1: dietary constituents (daily amounts fed on fresh basis)

Treatment	Malt distillers grains (g)	Silage (g)	Compound pellet (g)	Whole barley (g)	Mineral 1 (g)	Mineral 2 (g)
AG	Ad lib.	–	–	–	23	–
AG 300	Ad lib.	–	–	300	23	–
AG 600	Ad lib.	–	–	600	23	–
ASG	2100	Ad lib.	–	–	–	11
ASC	–	Ad lib.	600	–	–	–

For composition of Mineral 1 and Mineral 2 see Table 3.

Feed samples were taken at twice weekly intervals throughout the feeding period for dry matter determination and chemical analyses was performed on a bulked sample. The metabolisable energy value (ME) of G was predicted from a modification of equation E3 (Thomas et al., 1988) to allow for the reduced energy losses from methane associated with this feedstuff (Wainman et al., 1984).

2.1. Experiment 1: finishing lambs

The potential for G to replace home produced silage and barley in lamb finishing diets was studied. Diets of ad libitum G (AG) were compared with ad libitum G plus 300 g barley day^{-1} (AG 300), and ad libitum G plus 600 g barley day^{-1} (AG 600) in order to determine growth response to the G:barley ratio. Diets of ad libitum silage + 600 g compound pellet (ASC) and ad libitum silage plus an equivalent weight of G dry matter (ASG) were fed to determine how replacement of the compound fraction in a silage based ration with G affected growth and finishing. The constituents of diets fed on a daily basis are

Table 2
Experiment 2: constituents of diets fed to pregnant ewes (daily amounts fed on fresh basis)

Treatment	Feeding period (weeks before lambing)	Silage (g)	Malt distillers grains (g)	Whole barley (g)	Fishmeal (g)	Mineral 3 (g)	Mineral 4 (g)
Silage/barley/fishmeal	8–4	Ad lib.	–	–	–	–	–
(ASBF)	4–0	Ad lib.	–	400	50	–	–
Silage/G (ASG)	8–4	Ad lib.	–	–	–	–	14
	4–0	Ad lib.	1600	–	–	–	14
G/barley (RGB)	8–4	–	4500	–	–	30	–
	4–0	–	4500	450	–	35	–
Restricted Glad lib. G	8–4	–	4500	–	–	30	–
(RGAG)	4–0	–	Ad lib.	–	–	45	–

For composition of Mineral 3 and Mineral 4 see Table 3.

Table 3
Analysis of mineral supplements

	Experiment 1		Experiment 2	
	Mineral 1 (G-based diets)	Mineral 2 (silage based diets)	Mineral 3 (G-based diets)	Mineral 4 (silage-based diets)
Ca ($g\ kg^{-1}$)	186	270	160	185
P ($g\ kg^{-1}$)	–	–	60	13
Mg ($g\ kg^{-1}$)	39	39	100	52
Na ($g\ kg^{-1}$)	59	78	70	50
K ($g\ kg^{-1}$)	146	–	0	132
Cu ($mg\ kg^{-1}$)	–	–	500	0
Co ($mg\ kg^{-1}$)	36	54	150	75
I ($mg\ kg^{-1}$)	140	200	300	150
Mn ($mg\ kg^{-1}$)	960	1440	4400	2200
Se ($mg\ kg^{-1}$)	4.8	7.2	20	10
Zn ($mg\ kg^{-1}$)	900	1440	1800	900
Vit A ($IU\ kg^{-1}$)	240000	360000	500000	200000
Vit D ($IU\ kg^{-1}$)	60000	70000	100000	40000
Vit E ($IU\ kg^{-1}$)	900	900	1200	750

shown in Table 1, the analysis of mineral supplements in Table 3 and the chemical composition of feeds in Table 4.

Seventy 5-month-old Suffolk × (Bluefaced Leicester × Blackface) wether and female lambs previously on pasture were allocated at random to the five dietary treatments from blocks balanced for initial weight (35 kg) and sex (eight females, six castrates). Lambs were housed in mid September in groups of seven lambs in ten slatted pens (two replicates per treatment). They were allowed continuous access to feed with sufficient trough space so all lambs could eat at the same time. During the first 14 days, barley/compound levels were gradually increased to reach designated levels. Intake was recorded on a group basis on 4 days in every week.

Lambs were weighed weekly and selected for slaughter when they reached a target level of fatness assessed by loin palpation. The target level of fatness at selection of the live lamb was equivalent to the Meat and Livestock Commission (MLC) fatness class 3L/3H (MLC, 1980) approximating to a subcutaneous fat level proportion of 0.12 of carcass weight. Confirmation of fatness level was by visual classification at slaughter (MLC, 1980). Lamb value was determined by carcass weight, fatness, conformation and weekly market price based on combinations of these parameters.

2.2. *Carcass lipid composition*

Fifty-gram samples of shoulder skeletal muscle, subcutaneous fat and internal fat from four lambs on treatments AG, AG 300 and ASC were taken for determination of fatty acid composition. Lambs for carcass lipid composition analysis were selected from a batch

Table 4
Composition of feeds

	Experiment 1				Experiment 2			
	Malt distillers grains	Silage	Barley	Compound pellet	Malt distillers grains	Silage	Barley	Fishmeal
DM (toluene) ($g\ kg^{-1}$)	270	203	–	–	247	225	–	–
DM (60°C) ($g\ kg^{-1}$)	268	191	858	900	251	223	865	919
pH	3.3	3.8	–	–	3.1	3.4	–	–
Ammonia N ($g\ kg^{-1}$ TN)	11	90	–	–	4	94		
AHEE ($g\ kg^{-1}$ DM)	112	–	30	66	109	–	30	78
ADF ($g\ kg^{-1}$ DM)	247	352	71	40	271	369	82	–
NDF ($g\ kg^{-1}$ DM)	618	564	162	157	639	554	169	–
Ash ($g\ kg^{-1}$ DM)	24	66	23	296	27	76	23	78
CP ($g\ kg^{-1}$ DM)	235	109	111	482	232	113	113	735
Ca ($g\ kg^{-1}$ DM)	0.4	–	–	78	0.9	4.8	–	53
P ($g\ kg^{-1}$ DM)	2.8	–	–	21	3.5	2.7	–	10
Mg ($g\ kg^{-1}$ DM)	0.8	–	–	2	1.3	1.6	–	0.9
Na ($g\ kg^{-1}$ DM)	0.1	–	–	9	0.1	–	–	3.6
K ($g\ kg^{-1}$ DM)	0.2	–	–	–	0.3	22.6	–	–
DOMD ($g\ kg^{-1}$ DM)	–	681	–	–	–	687		–
NCD ($g\ kg^{-1}$ DM)	551	–	892	680	588	–	886	–
Estimated ME ($MJ\ kg^{-1}$ DM)	11.0[2]	10.9[3]	13.2[1]	11.2[1]	11.4[2]	11.0[3]	13.2[1]	–

AHEE, acid hydrolysed ether extract; NCD, neutral detergent plus gamanase digestibility.
ME[1] = 0.014 NCD + 0.025 AHEE; ME[2] = 0.0146 NCD + 0.026 AHEE; ME[3] = DOMD × 0.016.

slaughtered on the same day and at random from those available at the same post-slaughter fatness class.

The total lipid associated with the tissues was extracted with chloroform:methanol 2:1 (v/v) according to the method of Folch et al. (1957). The lipids were fractionated into the major lipid classes on thin layer chromatoplates of silica gel G, thickness 0.25 mm, using a solvent system on hexane:diethyl ether:formic acid (80:20:1, v/v). Following visualisation under ultraviolet light after spraying with 0.1% (w/v) solution of 2,7-dichlorofluorescein in methanol, the phosphoglycerides were eluted from the silica gel by washing with 3 × 5 ml of chloroform:methanol water (5:5:1, v/v) and the remaining lipid fractions with 3 × 5 ml of diethyl ether. The esterified lipid fractions were transmethylated by refluxing with methanol:toluene:sulphuric acid (20:10:1, v/v) in the presence of a pentadecanoic acid standard (Christie et al., 1970). Gas liquid chromatography of the methyl fatty acid ester derivatives on a packed column of 15% Sil 84 on Chromosorb WHP (Chrompak) enabled quantification of both the relative proportions of the major long chain fatty acids present and the absolute amounts of the lipid associated with each band.

Quantification of the fatty acid peaks was by electronic integration. The amount of the cholesterol was determined by charring and subsequent densitometry using a liquid scintillation counter as described by Shand and Noble (1980). Identification of lipid and fatty acid fractions was by comparison with known standards. All solvents were distilled before use and, where necessary, operations were performed under an atmosphere of nitrogen.

2.3. Experiment 2: pregnant ewes

One hundred and forty Scotch Mule (Bluefaced Leicester×Blackface) ewes with a spread of mating date of 21 days and which had previously carried one to four crops were scanned and those diagnosed as twin-bearing allocated at random to four dietary treatments balanced for age (mean 3 years) and initial weight (73 kg). Animals were taken from pasture and housed in four groups of 35 in straw bedded pens on 14 January. Feed was gradually increased up to the first stage of designated diets over 7 days. Supplementary feeding started 43 days later and full levels of supplementation achieved by day 47. Ewes were expected to lamb 30 days later. Ewes had the option of eating bedding straw, intake of this was not measured but, owing to the higher digestibility of other dietary components and their ad libitum availability, would not be expected to exceed 250 g day^{-1}.

Dietary treatments are shown in Table 2. Each treatment comprised two feeding periods, approximately from 8 to 4 weeks prior to the first ewe lambing and from 4 weeks prior to the first ewe lambing until the end of lambing. The control treatment of ad libitum silage, barley fishmeal (ASBF) was based on ad libitum silage in weeks 8–4 which was supplemented daily in weeks 4–0 with 0.4 kg barley and 0.05 kg fishmeal, supplementary feeding was maintained at this level over the 3 week lambing period. In treatment ad libitum silage, malt distillers grains (ASG) an equal amount of dry matter as G replaced the supplementary barley/fishmeal of the control diet. A treatment involving restricted grains and barley (RGB) was devised by feeding a restricted amount of G (4500 g day^{-1}) to replace the silage in the control diet and the final treatment, restricted grains then ad libitum grains, RGAG involved feeding restricted G for weeks 8–4 pre-lambing then ad libitum G.

Group feed intake (excluding possible straw intake from bedding material) was recorded from 28 January to lambing on a basis of 4 recording days per week. Feeds were sampled twice weekly for dry matter determination and a bulked sample used to determine the composition shown in Table 4. Supplementary feed was offered first in the morning after removal and recording of refusals of the previous feed and was completely consumed before the other feeds were presented. Minerals and fishmeal were sprinkled on to the base ration and mixed in by hand in the trough.

Ewe liveweight change and body condition (Russel et al., 1969) were monitored weekly. All ewes were blood sampled at 4 and 0 weeks pre-lambing and levels of betahydroxybutyrate, urea, albumin, protein, P and Mg recorded.

Lamb birth weight was recorded and also whether assistance was needed at lambing owing to dystocia. In addition, the adequacy of colostrum supply was quantified by recording the incidence of supplementary colostrum feeding which was based on subjective assessment of udder size and lamb behaviour.

2.4. Statistical analyses

Data analyses were conducted using the computer program Genstat 5 (Lawes Agricultural Trust, 1984). Covariance analysis was used to remove effects of initial weight. Discrete variables (number of births assisted etc.) were analysed using χ^2 tests. Analysis of variance could not be performed on feed intake variables and food conversion ratios, as individual feed intakes were not recorded.

3. Results

3.1. Feed analyses

Results of analyses of mineral supplements used in experiments are shown in Table 3 and the composition of feeds is shown in Table 4. G gave a typical analysis with high neutral detergent fibre (NDF) and oil content and low levels of minerals. The ME value was close to published values for malt distillers grains (Wainman et al., 1984). Both silages were low in protein but well preserved and had high ME contents.

3.2. Experiment 1: lamb finishing

Diets were fed without any lamb losses for 70 days by which time eight lambs ex 14 were unfinished on the AG treatment and three ex 14 were unfinished on the ASG treatment. Estimates of carcass weight for these lambs were derived from the liveweight and the killing out percentage of similar lambs previously finished within treatments. Carcass grades for these lambs was estimated from live condition at slaughter.

Effects of diets on feed intake and performance are shown in Table 5. Lambs fed ad libitum G failed to finish owing to low daily liveweight gain of 100 g day^{-1} to slaughter. Feeding supplementary barley increments of 0.3 kg and 0.6 kg increased weight gains to slaughter to 177 g and 206 g day^{-1} respectively (SED 19.7 g day^{-1}) and reduced days to slaughter by 25 days ($P<0.001$) but response to the second increment was lower than response to the first owing to substitution of G dry matter intake by barley at the higher level. Lambs fed G as a supplement to silage showed lower rates of daily liveweight gain to slaughter of 132 g versus 164 g day^{-1} for lambs fed compound. Reduced silage intake

Table 5
Experiment 1: effects of dietary treatments on lamb intake and performance and food conversion ratio (FCR) (kg food DM kg^{-1} LWG)

	Treatment					SED	Level of significance
	AG	AG 300	AG 600	ASC	ASG		
G intake (kg DM day^{-1})	0.85	0.82	0.65	–	0.57		
Silage intake (kg DM day^{-1})	–	–	–	0.27	–		
Total intake (kg DM day^{-1})	0.85	1.08	1.16	1.16	0.84		
NDF intake (g kg^{-1} $W^{0.75}$ day^{-1})	34	34.5	30	34.2	32.3		
ME intake (MJ ME day^{-1})	9.3	12.4	13.9	13.4	9.2		
Liveweight gain to 49 days (g day^{-1})	112	184	204	162	176	23.4	**
Liveweight gain to slaughter (range day 49–day 87) (g day^{-1})	100	177	206	164	132	19.7	***
Days to slaughter	77	52	52	54	78	2.8	***
Carcass weight (kg)	17.3	19.4	20.1	19.1	18.6	0.57	***
Carcass fat class[a]	0.8	1.9	2.0	1.8	1.5	0.30	**
Dressing %	41.7	44.5	44.8	44.6	41.7	0.90	***
FCR	9.4	6.9	6.6	12.5	6.7	–	–

[a]0, 2; 1, 3L; 2, 3H; 3, 4L; 4, 4H (higher scores fatter).

occurred on treatment ASG, this resulted in a similar feed conversion ratio to those observed with AG 300 and AG 600 treatments. Lambs on all treatments maintained intake at similar levels of NDF of around 32 g kg^{-1} $W^{0.75}$ day^{-1}.

3.3. Lipid and fatty acid composition of carcass tissues

Lean tissue lipids were separated into their five major components. Their proportion by weight were: cholesterol esters 0.01 (SE 0.0016), triglycerides 0.71 (SE 0.023), free fatty acids 0.02 (SE 0.0022), phospholipids 0.24 (SE 0.023) and free cholesterol 0.02 (SE 0.001). Subcutaneous and internal fat tissues were comprised wholly of triglyceride. Results shown in Table 6 are a summary of analyses of the fatty acid composition of the major lipid components. Data from treatments AG and AG 300 were not significantly different and the combined results of these predominantly G based treatments compared with the non G based treatment are presented. There was a 260% increase in the proportion of the major polyunsaturated fatty acid 18:2 (linoleic) in lean tissue lipids of lambs fed wet malt distillers grains as a major component of the diet. Within the fatty acids of the total lean tissue inclusion of G as a major component of the diet increased significantly the proportion of linoleic present, from 2.0 to 5.2% ($P<0.01$). Table 6 shows that this overall increase in linoleic acid level was affected through a large increase in the major carrier of the linoleic acid, namely the phospholipid fraction, 15–39 g kg^{-1} (SED 1.4; $P<0.001$). This change was accompanied by a significant decrease in the proportion of mono unsaturated fatty acid 18:1 (oleic) in the phospholipid. Although not significant there was also an increase in the 18:2 levels in the internal fat depots. Despite the very small amounts of material present significant increases in the content of 20:3 in subcutaneous fat on the ASC diet and 20:5 on the AG and AG 300 diets were seen.

As a result of the fatty acid changes the polyunsaturated fatty acid:saturated fatty acid ratio in lean tissue was increased from 0.28 for lambs fed silage plus compound feed to 0.49 for lambs fed G.

3.4. Experiment 2: pregnant ewe diets

Mean lambing date was not significantly different between treatments, dietary treatments were thus calculated to have occurred over days 77–117 of gestation (unsupplemented period) and days 117–147 (supplemented period). Litter size was similar on the four treatments: ASBF 2.10, ASG 2.07, RGB 2.07, RGAG 2.13. Diets had to be modified for ewes on RGAG on day 132 of gestation owing to problems of vaginal and intestinal prolapse and pregnancy toxaemia in 20% of the ewes (diagnosed by behavioural observation and response to treatment). From day 132 the restricted G diet was replaced by one of ad libitum access to both G and silage plus 0.45 kg barley day^{-1}, the latter introduced gradually in 0.15 kg day^{-1} increments. Cognisance of the departures from the dietary protocol needs to be taken into account in interpretation of results. Effects of dietary treatments on performance during the two feeding phases up to lambing are shown in Tables 7 and 8 with lambing data in Table 9.

The pattern of intake was consistent up to the start of supplementary feeding with a reduction in intake as lambing approached. Supplementary feeds reduced both silage and

Table 6
Effect of dietary treatment on the fatty acid composition (g kg^{-1}) of lipid extracted from lean tissue and fat samples of four lambs per treatment for treatments AG (ad libitum malt distillers grains), AG 300 (ad libitum malt distillers grains plus 300 g barley day^{-1}) and ASC (ad libitum silage plus 500 g compound pellet day^{-1})

(a) Fat tissues

	Subcutaneous				Internal			
	AG + AG 300	ASC	SED	Level of significance	AG + AG 300	ASC	SED	Level of significance
C14:0	34	28	4.8	NS	19	27	2.9	*
C16:0	194	193	21.4	NS	183	187	9.9	NS
C16:1	31	27	3.6	NS	23	21	2.9	NS
C18:0	221	225	27	NS	299	324	27.8	NS
C18:1	286	280	25.8	NS	272	288	21.1	NS
C18:2	48	44	18.2	NS	63	38	15.6	NS
C18:3	20	16	3.5	NS	17	18	1.6	NS
C20:3	0	0.8	0.35	*	0	0	0.0	NS
C20:4	0.5	0.4	0.12	NS	0.6	0.5	0.25	NS
C20:5	0.34	0.05	0.090	*	0.8	0.6	0.58	NS
C22:5	0.6	0.4	0.30	NS	0.22	0.56	0.110	*
C22:6	0.1	0.1	0.14	NS	0.2	0.1	0.21	NS

(b) Lean tissues

	Total extracted fat (%)				Phospholipid fraction (g kg^{-1})			
	AG + AG 300	ASC	SED	Level of significance	AG + AG 300	ASC	SED	Level of significance
C16:0	7.5	8.2	1.35	NS	17	19	0.8	*
C16:1	1.1	1.3	0.34	NS	1.3	3.0	1.1	NS
C18:0	6.4	7.0	1.24	NS	17	16	0.6	NS
C18:1	11.9	14.4	2.28	NS	10	31	1.0	***
C18:2	5.2	2.0	0.77	**	39	15	1.4	***
C18:3	0.9	1.2	0.22	NS	1.6	2.5	0.34	*
C20:3	0.06	0.03	0.013	*	0.6	0.4	0.045	***
C20:4	0.7	0.4	0.01	NS	7.2	4.8	0.47	***
C20:5	0.3	0.4	0.07	NS	2.6	3.7	0.44	*
C22:5	0.4	0.2	0.09	NS	3.0	3.0	0.3	NS
C22:6	0.1	0.1	0.04	NS	0.8	0.7	0.3	NS

G intake, the lower ME on diet ASG was a result of a higher level of substitution of G for silage than occurred in the control diet. Diets provided ME in amounts slightly above requirement prior to supplementation, and below theoretical requirements close to lambing. This was reflected in a rise in betahydroxybutyrate levels in blood analyses between 4 and 0 weeks pre-lambing but there was no significant differences between treatments and levels were below those associated with pregnancy toxaemia. Feeding of G was associated with significantly greater ewe weight gain and increase in condition score than silage feeding. Overfatness occurred on treatments RGAG with resultant problems of prolapse, this led to inappetance followed by pregnancy toxaemia.

Table 7
Effects of dietary treatments on performance and blood analyses of pregnant ewes (days of gestation 77–117)

	ASBF	ASG	RGB	AGRG	SED	Significance
DM intake (kg day^{-1})	1.19 (silage)	1.20 (silage)	1.08 (malt distillers grains)	1.08 (malt distillers grains)	–	
ME intake (MJ ME day^{-1})	13.0	13.2	12.4	12.4	–	
Ewe weight change (kg)	0	+0.6	+5.5	+3.1	0.89	***
Condition score change (units)	−0.2	0	+0.2	+0.1	0.069	***
Blood analyses (day 105 of gestation)						
Protein (g l^{-1})	63	64	73	72	1.1	***
Albumin (g l^{-1})	26	26	33	33	0.6	***
Urea (g l^{-1})	1.6	1.6	4.9	4.9	0.18	***
Magnesium (μmol l^{-1})	0.95	0.99	0.90	0.98	0.230	**
Phosphorus (μmol l^{-1})	1.6	1.6	1.8	1.8	0.07	*
Betahydroxybutyrate (μmol l^{-1})	0.56	0.38	0.45	0.50	0.080	NS

Table 8
Effects of dietary treatments on performance and blood analyses of pregnant ewes (days of gestation 117–147)

	ASBF	ASG	RGB	AGRG	SED	Significance
DM intake (kg day^{-1})	0.83 (silage)	0.75 (silage)	0.89 (malt distillers grains)	0.5[a] (malt distillers grains)		
Supplement intake (kg DM day^{-1})	0.45	0.45 (malt distillers grains)	0.45			
ME intake (MJ ME day^{-1})	14.4	12.8	15.4	14.7		
Ewe weight change (kg)	6.4	8.3	6.5	7.5	1.2	NS
Condition score change (units)	−0.2	0	0	+0.1	0.07	**
Blood analyses (day 133 of gestation)						
Protein (g l^{-1})	59	63	67	67	1.1	***
Albumin (g l^{-1})	26	28	31	32	0.6	***
Urea (g l^{-1})	1.6	1.9	3.5	2.2	0.24	***
Magnesium (μmol l^{-1})	0.99	0.99	0.95	1.03	0.030	*
Phosphorus (μmol l^{-1})	1.55	1.61	1.77	1.84	0.070	***
Betahydroxybutyrate (μmol l^{-1})	0.93	0.80	0.76	0.85	0.270	NS

[a]Additional 0.3 kg silage and 0.39 kg barley DM fed from day 132 to 147.

Table 9
Effects of dietary treatments on lambing performance

	Dietary treatment				SED	Level of sig.
	ASBF	ASG	RGB	AGRG		
Pre-lambing weight	83.9	85.0	92.4	90.0	1.58	***
Pre-lambing condition score	3.1	3.3	3.6	3.6	0.09	***
Weight change pre- to post-lambing (kg)	−16.2	−17.4	−20.3	−17.7	1.22	**
Litter weight (kg)	8.8	8.3	8.4	9.0	0.36	NS
Lamb birth weight (kg) adjusted for litter size	4.3	4.3	4.3	4.5	0.14	*
Proportion birth assisted	0.17	0.26	0.43	0.35	–	NS
Proportion of ewes with lambs receiving supplementary colostrum	0.27	0.13	0.37	0.40	–	NS

Feeding of G was associated with elevated blood protein, albumin and urea levels, and higher parturition weight loss. There was a significant effect on lamb birth weight, with lambs fed G being 0.25 kg heavier but there were no effects on the proportion of lambs needing assistance or supplementary colostrum.

4. Discussion

4.1. Experiment 1: lamb finishing

The optimum usage of G for lamb finishing diets was when it was fed ad libitum (1 kg G per 10 kg liveweight approximately) supplemented with 0.3 kg cereals per day plus minerals. Where G was used to supplement silage in place of concentrates the high NDF content resulted in reduced silage intake and liveweight gain resulting in a feed efficient but slow finishing system.

Although extensively investigated (Christie, 1979; Noble, 1984) change in the polyunsaturated fatty acid:saturated fatty acid ratio (P:S ratio) of carcass lipids of ruminant animals has not been achieved by conventional dietary means. Only the use of specialist and expensive techniques have reduced biohydrogenation and therefore increased P:S ratio of carcass lipid (Scott et al., 1970). The extensive alteration in fatty acid composition of lean tissues of lambs fed G presents a practical low cost technique to manipulate lean tissue P:S ratio during the finishing period of lambs and thereby meet current dietetic recommendations (COMA, 1991).

4.2. Experiment 2: pregnant ewe diets

Whilst G proved successful as a component of ewe diets in pregnancy as a sole feed it was unsuitable. Although G was high in protein the low amount of fermentable energy available for microbial growth in the rumen (only approximately 0.67 of ME fermentable) coupled with the toxicity of unsaturated fat to rumen microorganisms could have resulted in low rumen microbial protein activity and yield in those diets where G was the sole dietary constituent.

This was confirmed by the observed high levels of urea in the blood of pregnant ewes fed unsupplemented G indicating poor conversion of rumen degradable protein into microbial protein. The problems of vaginal and intestinal prolapse in multiple-bearing ewes fed unsupplemented G ad libitum could possibly be attributed to excessive fat deposition as a result of combined high levels of dietary fat (109 g kg^{-1} DM) and low level of protein supply. Impacted rumen contents in cattle fed ad libitum G has been observed previously (M. Lewis, personal communication, 1994) and is associated with lowered microbial activity, resulting in greater rumen size and turgidity contributing to prolapse. The higher birth weight of lambs on G was a further contributing factor.

The reduction in incidence of prolapse observed when G was supplemented with a readily fermentable carbohydrate source (barley) was associated with a lower blood urea level than observed previously when no supplement was given suggesting increased rumen microbial activity.

5. Conclusion

Given the observed propensity of pregnant ewes to gain weight and condition when fed G and the danger of overfatness, care is needed in ration formulation for ewes with G. The results of treatment RGB where 4.5 kg of fresh malt distillers grains and 0.45 kg barley were fed daily to ewes weighing 75 kg resulted in 43% of ewes requiring assistance at lambing, this some producers would find unattractive. Where 1.6 kg of fresh malt distillers grains were fed with silage 26% of births were assisted, similar levels to those observed with diets of silage and barley/fishmeal. Whilst the experiment does not give an optimum level of G feeding for pregnant ewes the results suggest that a feeding level of 1 kg fresh material per 25 kg liveweight (equivalent to 3 kg day^{-1} in this experiment) together with barley in the last 4 weeks of pregnancy would be a prudent maximum level given regular attention to condition of ewes and good management at lambing.

Diets for pregnant ewes where G replaced barley/fishmeal supplement fed with ad libitum silage resulted in a reduction in total DM intake of 6% owing to greater substitution rate with replacement of concentrate with G, gave adequate performance. Historically the cost of barley/fishmeal dry matter has been over 1.6 times that of G dry matter, thus significant savings in feed costs by replacing barley/fishmeal with G can be made.

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