# FINAL REPORT:
# Investigation of the variation in lamb meat quality on three winter finishing systems
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Undertaken for:
**EBLEX, HCC, QMS and Defra**

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Thanks to Wynnstay Ltd for the kind donation of the compound feed.

**AUTHENTICATION**

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

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## CONTENTS

**Abstract**

180 Texel cross Mule lambs from one farm in Shropshire were allocated to a three feed treatment x two finishing period study to investigate variation in lamb meat quality by diet and date of slaughter. Lambs were finished in groups of 30 in either November 2007 or March 2008. The feed treatments were grass or grass silage (with compound supplementation where necessary), stubble turnips or *ad-libitum* compound feed. 16 wether lambs from each treatment were sent to Bristol University for meat quality and taste panel assessment and were compared with lambs from two control groups; grass-only fed British lamb (from the same Shropshire farm) slaughtered in November and New Zealand lamb delivered in May.

Analysis of the wether lamb performance data showed that concentrate lambs had significantly higher growth rates (235 g/day) than the other two feed treatments (157g and 144g for grass and turnip lambs respectively) with higher sale weights and carcass weights. Killing out % was highest for the stubble turnip group (45.6%) and lowest for the grass group (41.3%). Wether lambs slaughtered in March were significantly heavier than November finished lambs (44.9 vs. 43.3kg) and had higher cold carcass weights (19.8 vs. 18.9kg) but live weight gain and killing out % were unaffected. For wether lambs carcass conformation was unaffected by either feed or slaughter date but grass-fed lambs were significantly leaner than either of the other feed treatments and November finished lambs were leaner than March lambs.

When the performance of all lambs was compared a similar picture emerged with concentrate lambs growing significantly faster resulting in both heavier lambs at sale (44.8kg cv. 41.7 and 41.1kg for T and G lambs respectively) and a reduced average days to sale (50.5) of around 6 days over the other two treatments (56.2 and 57.0 for T and G lambs respectively). Slaughter date did not affect carcass conformation or fatness significantly but grass/silage finished lambs were shown to be leaner with poorer conformation.

Feed costs were estimated for each of the production systems and results showed that stubble turnips were the cheapest (regardless of slaughter date) both in terms of overall cost per head and cost per kg liveweight gain. Ad-lib concentrate feeding was the most expensive overall but superior growth rates in the March finished animals led to this diet being more cost effective than the March silage plus concentrates group.

Mean loin muscle pH varied between 5.5 (grass-fed slaughtered in March) to 6.1 (NZ Controls). The meat from the two control groups was significantly darker than the other groups and the NZ Controls had lower hue values, indicating more purple-red rather than a red-brown colour in the other groups.

For the grass- and concentrate-fed hoggets, there was a deterioration in some quality attributes between November and March, most notably in abnormal flavour (which increased) and flavour and overall liking (which decreased).

Compared with the UK Controls, both groups of grass-fed and concentrate-fed lambs had weaker lamb flavour and, apart from the November-slaughtered grass-fed lambs, a significantly more pronounced abnormal flavour. The UK Controls were preferred overall to any of these groups. On the other hand, both stubble turnip groups had quality ratings on a par with the UK Controls and, moreover, there were no significant effects of season of slaughter on this diet. In terms of overall liking, the most preferred were the two stubble turnip groups and the UK Controls; the least preferred groups were grass/concentrates and ad-lib concentrates slaughtered in March. The flavour changes were more important in determining overall liking than the changes in texture and juiciness between the two slaughter times, some of which favoured the March-slaughtered groups. But it is noteworthy that all lamb groups produced meat that was tender.

- Stubble turnips provide a consistent diet that delivers a high level and consistency in lamb eating quality through the winter months.
- Later slaughter tends to reduce the overall liking for grass silage and concentrate fed lambs.
- UK lamb compared favourably to this sample of NZ lamb.

## Introduction

Some supermarket buyers find British lamb less acceptable post-Christmas, preferring to buy the New Zealand product from January to April. This aversion to British lamb is founded on inconsistent quality and poorer flavour and tenderness. This could be a reflection of breed, age, sex, system of production and/or diet.

Store lambs are sold off breeding farms in the summer and autumn months as grass supplies become limiting and any remaining lambs need to be moved off the farm to give preference to the ewes for flushing and tupping. The lambs could simply be those that have not finished off grass from a February/March lambing flock or could be the majority of lambs from later lambing systems or hill and upland farms. Some farms have a deliberate policy of 'storing' lambs in early autumn in the hope of realising a higher end price after Christmas, finishing lambs on forage crops or silage-based diets. Others are specialist store finishers who buy in large numbers of lambs to finish on grass (often dairy pastures), concentrate diets indoors or on stubble turnips/other forage crops well into the New Year. Through the spring and summer months the vast majority of lambs will be finished on grass, with possibly some creep feeding, but through the late autumn and winter a variety of systems and breeds are used which could influence the consistency of lamb eating quality.

For example, stubble turnips are known to be low in vitamin E and may therefore provide a diet that is not conducive to good shelf life and colour of lamb meat, and some brassicas are associated with undesirable flavour and odour. Richardson (Bristol University) reports some commercial work done recently for a large processor that showed that including high levels of vitamin E in a supplement to lambs on stubble turnips significantly increased the keeping qualities of lamb post-slaughter.

The SEERAD report (Meat Eating Quality – A Whole Chain Approach – Factors Affecting Lamb Eating Quality 2004) highlighted the effect of season on the abnormal flavour of lamb, with lambs slaughtered in November scoring 2.83 and lambs slaughtered in January scoring 3.51. This represented a significant deterioration in flavour post Christmas. This project did not identify any specific dietary effects but recommended that the problem needed to be investigated with a specifically designed experiment.

As consistency of meat product quality is the single most important factor governing consumer purchasing, there is a need to identify a system of production that delivers consistent eating quality through the winter months that will restore retailer confidence in British lamb outside the main grazing season.

## Objective

To investigate the variation in lamb meat quality from winter finishing and the cause of retail prejudice against lamb/hogget meat post-Christmas.

## Materials and methods

### *Site*

The experiment was undertaken at Walford and North Shropshire College, Walford Campus, Baschurch, Shropshire, SY4 2HL.

### *Experimental Design*

A randomised 3 (diet) x 2 (slaughter date) design with 30 lambs per treatment. In total 180 Texel x Mule lambs born March/April 2007 were sourced from a single farm.

Meat quality and taste panel assessments were carried out on 16 wether lambs from each treatment. Control samples were provided by 16 grass-only fed British wether lambs (sourced from the same farm as the trial groups and kept on long term permanent pasture) slaughtered in November 2007 and loins from 16 grass-fed New Zealand wether lamb carcasses delivered in May 2008.

### *Diets*

1. Grass (permanent pasture) and concentrates – then grass silage and concentrates from Dec/Jan (G)
2. 4-6 weeks on ad-lib concentrates (Wynnstay, Lambmaster pellets) for fast-finishing preceded by a holding ration of grass or grass silage (C)
3. Stubble turnips (plus concentrates where needed) (T)

plus grass-only fed British lamb slaughtered in November and New Zealand lamb delivered in May.

### *Slaughter dates*

1. November (N)
2. March (M)

### *Management and feed levels*

Lambs arrived at the trial site on 10 October 2007. This was later than planned due to FMD movement restrictions. Lambs were wormed with Depidex and Levicur on 11 October and vaccinated with Heptavac $P^+$ on 15 October.

Lambs for November finishing were weighed and allocated to treatment groups on 16 October and treatment diets were fed from 17 October. The remaining lambs for March finishing were grazed as one group on grass swards, managed to allow only moderate growth rates (averaging 76g/day). The performance of lambs was monitored by weighing fortnightly. November lambs were slaughtered on two dates (30 November 2007 and 4 January 2008) with all lambs for meat quality assessment being killed on the first date.

Lambs for March finishing were allocated to treatment groups on 15 January 2008 with treatment diets fed from this date. Lambs were wormed with Allverm 4% SC on 18 January. Lamb performance was monitored by fortnightly weighing and the information used to adjust the level of compound feed fed to the silage group. Lambs were slaughtered on two dates (6 and 23 March 2008) with all lambs for meat quality assessment being killed on the first date.

Lambs on the November grass treatment were finished on high quality swards without compound supplement until the first slaughter date. From 30 November lambs received 0.3 kg/head per day at grass and on 13 November lambs were housed and fed grass silage with 0.5 kg/head of compound feed. The group finished on stubble turnips did not receive any compound feed. Feed levels for lambs on the compound ration increased gradually over the first two weeks to around 1.5 kg/head with fresh straw available to provide a source of roughage.

Lambs for March finishing were maintained on grass swards at a high stocking rate between October and January when they were weighed and allocated to their finishing rations. As above, stubble turnip lambs were finished without compound supplementation. The feed level for the compound group was restricted to a maximum of 1.6 kg/hd per day to prevent lambs becoming over finished. Compound feed for lambs on the grass silage ration rose gradually to around 0.8 kg/hd per day.

***Assessments***

Lambs were weighed at blocking and then at fortnightly intervals until sale. The aim was to finish lambs at 18 to 21 kg carcass weight and fat class 2/3L. Cold carcass weights and carcass conformation and fatness were collected at slaughter. Lambs were slaughtered at Llanidloes and the carcasses for meat quality assessment were broken down into primal cuts. These were vacuum packed and aged for 1 week before loin samples were cut and transported to Bristol University for the meat quality and taste panel assessments.

Samples of concentrate feed and grass silage were taken monthly and bulked up over the finishing period. The accumulating samples were deep frozen and were submitted for chemical analysis to Eurofins Services Ltd. All samples were analysed using conventional techniques (MAFF, 1986). Stubble turnips (cv. Sampson) were drilled on $16^{th}$ August 2007. The dry matter yield was estimated on 30 October 2007 and 30 January 2008 by sampling from measured areas in the ungrazed crop.

### *Statistical analysis*

Animal performance data were analysed using analysis of variance. Lamb carcass fatness and conformation data were analysed using the chi-square test.

### *Meat samples protocol*

Loins from one side of the carcass of sixteen lambs from each of the eight treatments were received over a period of 6 months. On arrival at Langford (day 11, slaughter = day 0)*, pH and colour (CIELAB coordinates L*, a*, b*) of the *Longissimus* muscle were measured and the samples were vacuum packed and frozen at -20 $^{o}$ C until required for sensory analysis.

*Details not known for the NZ Controls

Prior to the morning of sensory assessment, loins were removed from the freezer and thawed at +1 $^{o}$ C in a refrigerator overnight. On the morning of sensory assessment, ten 2 cm thick sections were cut from each loin.

### *Cooked meat assessment*

Loin steaks were cooked (turning every 3 minutes) under a domestic grill set at high, until the internal temperature of each sample reached 75 $^{o}$C as measured by a thermocouple probe. The steaks were then removed from the grill and placed in an incubator (60 ºC) prior to sample removal. The steaks were trimmed of all extraneous residual fat and connective tissue and the lean cores were wrapped separately in pre-coded (3-digit numbers) aluminium foil and placed in hot blocks in the sensory booths.

Ten assessors, who had been screened according to British Standards Institute methods for taste sensitivity and who had also received special training in the assessment of meat, took part in the tests. Assessors were asked to rate the samples on 8-point category scales (Table 1) for texture, juiciness, lamb flavour intensity, abnormal lamb flavour intensity and also two hedonic scales for flavour liking and overall liking. In addition, a descriptive profile (Table 2) was used for flavour attributes, using 100 mm unstructured line scales. Training sessions were conducted in which two examples of meat from each treatment were tasted, before the final flavour profile was agreed.

All sessions were conducted in a purpose built sensory suite, with individual tasting booths equipped with computer terminals linked to a fileserver running a sensory software programme (Fizz v 2.20h, Biosystemes, Couternon, France) that facilitated the direct entry of assessor ratings. At each session, assessors rated four samples that constituted one of a series of 14 blocks as given in the statistical design in Appendix 2. This design was adopted since it was not possible for assessors to consistently rate eight samples in a sitting but it did fulfil the requirement to compare all eight treatments.

Assessors received the samples of each block in a sub-design that balanced the effect of presentation order to reduce the effect of first-order carry over effects.

***Table 1. Eight point category scales used in the sensory assessment of grilled lamb loin steaks. Numerical values were allocated subsequently.***

| Score | Texture, Juiciness | Lamb flavour intensity, Abnormal flavour intensity | Flavour liking, Overall liking (hedonic) |
|---|---|---|---|
| 8 | Extremely tender/juicy | Extremely strong | Like extremely |
| 7 | Very tender/juicy | Very strong | Like very much |
| 6 | Moderately tender/juicy | Moderately strong | Like moderately |
| 5 | Slightly tender/juicy | Slightly strong | Like slightly |
| 4 | Slight tough/dry | Slightly weak | Dislike slightly |
| 3 | Moderately tough/dry | Moderately weak | Dislike moderately |
| 2 | Very tough/dry | Very weak | Dislike very much |
| 1 | Extremely tough/dry | Extremely weak | Dislike extremely |

***Table 2. Descriptive flavour profile of lamb using 100 mm unstructured line scales where nil = none to 100 = extreme***

| **Attribute** | **Description** |
|---|---|
| Fatty/Greasy | Fresh fat taste |
| Sweet | Taste associated with sugars |
| Acidic | Taste associated with acids |
| Metallic | Tangy metal taste |
| Bitter | Taste associated with caffeine or quinine |
| Rancid | Taste associated with rancid oil and fat |
| Livery | Liver flavour |
| Kidney | Kidney flavour |
| Ammonia | Pungent, stale urine flavour |
| Grassy | Taste associated with freshly mown grass |
| Fishy | Taste associated with fish |
| Soapy | Taste associated with soap |
| Dairy | Taste associated with fresh milk |

## Results and discussion

### *Compound feed and grass silage analysis*

The chemical analysis of the compound feed used for each group of lambs is shown in Table 3.

***Table 3. Analysis of compound feed***

| | November | March |
|---|---|---|
| Dry matter %* | 85.7 | 87.0 |
| Total crude protein % | 18.7 | 18.2 |
| NCGD % | 78.0 | 77.5 |
| Oil (acid hydrolysed) % | 3.98 | 5.34 |
| Total ash % | 7.98 | 7.97 |
| ME (MJ/kg DM) E3 | 11.9 | 12.2 |

* Results expressed on a dry matter basis except where stated

***Table 4. Analysis of grass silage for March-finished lambs***

| | | Jan-Feb | Feb-Mar | Mean |
|---|---|---|---|---|
| Dry matter* | g/kg | 340 | 380 | 360 |
| D value | % | 68 | 69 | 68.5 |
| ME | MJ/kg DM | 10.9 | 11.0 | 11.0 |
| FME | MJ/kg DM | 8.4 | 8.8 | 8.6 |
| NDF | g/kg | 495 | 444 | 470 |
| ADF | g/kg | 303 | 283 | 293 |
| Ash | g/kg | 78 | 90 | 84 |
| CP | g/kg | 123 | 143 | 133 |
| pH | | 4.2 | 4.3 | 4.3 |
| NH3 of Tot N | % | 4.6 | 6.2 | 5.4 |
| Tot ferm. acids | g/kg | 92 | 83 | 87.5 |
| Lactic | g/kg | 82.2 | 77.8 | 80.0 |
| Acetic | g/kg | 5.9 | 1.4 | 3.7 |
| Butyric | g/kg | 1.7 | 1.8 | 1.8 |

* Results expressed on a dry matter basis except where stated

Grass silage was 1$^{st}$ cut, harvested 21-23 May 2007 with Powerstart additive and was of good quality with high energy and good fermentation characteristics.

***Table 5. Estimation of stubble turnip yield (kg of dry matter/ha)***

| | 30 Oct 2007 | 30 Jan 2008 |
|---|---|---|
| Tops | 2880 | 1130 |
| Roots | 2230 | 3300 |
| Total DM yield | 5110 | 4430 |
| Overall yield (fresh) | 50670 | 50500 |

Stubble turnip yield was estimated by sampling from five 1m$^2$ quadrats on each occasion. Tops and roots were weighed separately to measure the relative yields. In October tops contributed 56% of total yield but by January this had fallen to 26%.

***Lamb performance data – restricted to wether lambs presented for meat quality assessment.***

Lamb live weights and growth rates for the 96 wether lambs presented for meat quality and taste panel assessment are shown in Tables 6 - 8 with carcass classification in Table 9.

***Table 6. Effect of diet on performance of wether lambs***

| | *Grass* | *Conc* | *Turnip* | *s.e.d.* | *signif.* |
|---|---|---|---|---|---|
| Number lambs | 32 | 32 | 32 | | |
| Start weight (kg) | 35.7 | 35.9 | 35.7 | 0.76 | NS |
| Sale weight (kg) | 43.0$^b$ | 46.9$^a$ | 42.6$^b$ | 0.96 | <0.001 |
| Overall DLWG (g) | 157 | 235 | 144 | 14.1 | <0.001 |
| Cold carcass weight (kg) | 17.8$^c$ | 20.8$^a$ | 19.4$^b$ | 0.50 | <0.001 |
| Killing out % | 41.3$^c$ | 44.2$^b$ | 45.6$^a$ | 0.49 | <0.001 |

* values within rows with different superscripts are significantly different ($p<0.05$)

Concentrate fed lambs were significantly heavier than either grass/silage or turnip lambs ($p<0.001$) at sale. Similarly, significant differences were seen in carcass weight with Concentrate lambs heavier than Turnip lambs which were in turn heavier than Grass/silage lambs. Overall growth rates were highest for Concentrate lambs. Killing out % was highest for turnip lambs and lowest for grass/silage lambs.

***Table 7. Effect of slaughter date on performance of wether lambs***

| | *November* | *March* | *s.e.d.* | *Signif.* |
|---|---|---|---|---|
| Number lambs | 48 | 48 | | |
| Start weight | 35.3 | 36.2 | 0.62 | NS |
| Sale weight | 43.3 | 44.9 | 0.78 | 0.048 |
| Overall DLWG | 183 | 174 | 11.6 | NS |
| Cold carcass weight | 18.9 | 19.8 | 0.41 | 0.031 |
| Killing out % | 43.5 | 43.9 | 0.40 | NS |

November lambs were significantly lighter than March lambs (p=0.048). Cold carcass weights mirrored sale weights with November lambs lighter than March lambs. Overall daily live weight gain and killing out % were unaffected by sale date.

***Table 8. Diet x slaughter date interaction for wether lambs***

| | *GN* | *CN* | *TN* | *GM* | *CM* | *TM* | *s.e.d.* | *signif.* |
|---|---|---|---|---|---|---|---|---|
| Number lambs | 16 | 16 | 16 | 16 | 16 | 16 | | |
| Start weight (kg) | 35.2 | 35.5 | 35.2 | 36.1 | 36.3 | 36.2 | 1.07 | NS |
| Sale weight (kg) | 43.3 | 46.2 | 40.5 | 42.7 | 47.5 | 44.6 | 1.34 | NS |
| Overall DLWG (g) | $184^b$ | $244^a$ | $121^c$ | $131^c$ | $226^a$ | $167^b$ | 20.0 | 0.003 |
| Cold carcass weight (kg) | 17.8 | 20.1 | 18.7 | 17.7 | 21.4 | 20.2 | 0.71 | NS |
| Killing out % | 41.1 | 43.4 | 46.0 | 41.5 | 45.0 | 45.2 | 0.70 | NS |

* Values with different superscripts are significantly different at the 5% level.

For most parameters there were no significant interactions between diet and slaughter date, the exception is overall daily liveweight gain where turnip lambs grew more slowly in the November group whereas the silage group grew slowest in the March group.

***Table 9. Lamb carcass classification – wether lambs (number of lambs in each class)***

| | *Grass* | *Concentrate* | *Turnip* | $X^2$ | *November* | *March* | $X^2$ |
|---|---|---|---|---|---|---|---|
| Carcass conformation | | | | | | | |
| U | 0 | 1 | 0 | | 1 | 0 | |
| R | 18 | 22 | 18 | NS | 30 | 29 | NS |
| O | 14 | 9 | 13 | | 17 | 19 | |
| Carcass fatness | | | | | | | |
| 1 | 0 | 0 | 2 | p = 0.003 | 2 | 0 | p = 0.03 |
| 2 | 17 | 4 | 7 | | 15 | 13 | |
| 3L | 15 | 24 | 20 | | 31 | 28 | |
| 3H | 0 | 4 | 3 | | 0 | 7 | |

Conformation was unaffected by diet or slaughter date, although there was a tendency for a greater proportion of concentrate-fed lambs to fall into the R or better, categories. For fatness, significant differences were observed, with grass-fed lambs significantly leaner than concentrate or turnip lambs. November finished lambs were also significantly leaner than March finished lambs. Overall the aim was to slaughter lambs at fat class 2 or 3L: for grass fed lambs 100% fell into the desired classes with 88% and 84% respectively for concentrate and turnip fed lambs.

***Lamb performance data – including all lambs in trial groups***

Lamb weights and growth rates for all 180 lambs are shown in Tables 10-12 with carcass classification in Table 13.

***Table 10. Effect of diet on performance – all lambs***

| | *Grass* | *Conc* | *Turnip* | *s.e.d.* | *signif.* |
|---|---|---|---|---|---|
| Number lambs | 60 | 60 | 60 | | |
| Start weight (kg) | 33.7 | 34.3 | 34.6 | 0.68 | NS |
| Sale weight (kg) | $41.1^{b}$ | $44.8^{a}$ | $41.7^{b}$ | 0.77 | p<0.001 |
| Overall DLWG (g) | 146 | 230 | 148 | 11.2 | p<0.001 |
| Cold carcass weight (kg) | $17.1^{b}$ | $19.7^{a}$ | $19.0^{a}$ | 0.37 | p<0.001 |
| Killing out % | 41.6 | 44.0 | 45.7 | 0.38 | p<0.001 |
| Days to sale | $57.0^{a}$ | $50.5^{b}$ | $56.2^{a}$ | 2.10 | p=0.004 |

As was found above in the wether group, Concentrate lambs were significantly heavier at sale and had higher overall growth rates than either Grass/silage or Turnip lambs. Similarly, significant differences were seen in carcass weight and killing out % with Grass/silage lambs being lighter and killing out less well than Concentrate and Turnip lambs. Concentrate lambs were sold significantly earlier (by around 6 days) than Grass and Turnip lambs.

***Table 11. Effect of slaughter date on performance – all lambs***

| | *November* | *March* | *s.e.d.* | *Signif.* |
|---|---|---|---|---|
| Number lambs | 90 | 90 | | |
| Start weight (kg) | 33.4 | 35.0 | 0.56 | p=0.003 |
| Sale weight (kg) | 41.5 | 43.6 | 0.63 | p=0.001 |
| Overall DLWG (g) | 173 | 176 | 9.1 | NS |
| Cold carcass weight (kg) | 18.3 | 19.0 | 0.31 | p=0.026 |
| Killing out % | 44.0 | 43.5 | 0.31 | NS |
| Days to sale | 53.0 | 56.1 | 1.7 | NS |

When all lambs are included in the analysis there is a small but significant difference in the start weights with March lambs being 1.6 kg heavier at allocation to the finishing diets. As was found for wether lambs, there were significant differences in sale weight and carcass weight with March lambs being heavier than November lambs. Overall growth rates, killing out % and days to sale were unaffected by slaughter date.

***Table 12. Diet x slaughter date interaction for all lambs***

| | *GN* | *CN* | *TN* | *GM* | *CM* | *TM* | *s.e.d.* | *signif.* |
|---|---|---|---|---|---|---|---|---|
| Number lambs | 30 | 30 | 30 | 30 | 30 | 30 | | |
| Start weight (kg) | 33.3 | 33.5 | 33.3 | 34.1 | 35.1 | 35.9 | 0.97 | NS |
| Sale weight (kg) | 40.0 | 44.1 | 40.5 | 42.2 | 45.5 | 43.0 | 1.09 | NS |
| Overall DLWG (g) | $147^{bc}$ | $243^{a}$ | $130^{c}$ | $145^{bc}$ | $218^{a}$ | $166^{b}$ | 15.8 | 0.026 |
| Cold carcass weight (kg) | 16.7 | 19.2 | 18.9 | 17.4 | 20.2 | 19.2 | 0.53 | NS |
| Killing out % | $41.9^{d}$ | $43.7^{c}$ | $46.5^{a}$ | $41.3^{d}$ | $44.3^{bc}$ | $44.8^{b}$ | 0.54 | 0.006 |
| Days to sale | 55.3 | 47.2 | 56.5 | 58.7 | 53.8 | 55.9 | 2.97 | NS |

Significant interactions between diet and slaughter date were observed for overall daily liveweight gain and killing out %. Concentrate lambs grew consistently faster than the other lambs with Turnip lambs, finished in November, (TN) growing slowest. TN lambs did however have the highest killing out %. Sale weight, carcass weight and days to sale did not have significant, diet x slaughter date interaction.

***Table 13. Lamb carcass classification (number of lambs in each class)***

| | *Grass* | *Concentrate* | *Turnip* | $X^2$ | *November* | *March* | $X^2$ |
|---|---|---|---|---|---|---|---|
| Carcass conformation | | | | | | | |
| U | 0 | 2 | 1 | p=0.02 | 3 | 0 | |
| R | 23 | 38 | 34 | | 49 | 46 | NS |
| O | 37 | 20 | 25 | | 38 | 44 | |
| Carcass fatness | | | | | | | |
| 1 | 4 | 0 | 2 | p<0.001 | 5 | 1 | |
| 2 | 34 | 13 | 14 | | 29 | 32 | NS |
| 3L | 22 | 41 | 35 | | 51 | 47 | |
| 3H | 0 | 6 | 9 | | 5 | 10 | |

When all 180 lambs are included in the analysis it can be seen that only diet has a significant effect on conformation and fatness. Grass/silage lambs had the poorest conformation with 62% of lambs grading as O compared with 33% and 42% for Concentrate and Turnip lambs respectively. Grass/silage lambs were also seen to be leanest with 63% grading fat class 1 and 2. This compares with 22% and 27% for Concentrate and Turnip lambs respectively.

***Feed costs***

***Table 14 Overall feed costs***

| | *GN* | *CN* | *TN* | *GM* | *CM* | *TM* |
|---|---|---|---|---|---|---|
| ***Total feed use*** | | | | | | |
| No. lambs | 30 | 30 | 31* | 30 | 31* | 31* |
| Grazing days | 1454 | - | - | - | - | - |
| Turnip area (ha) | - | - | 0.71 | - | - | 0.65 |
| Grass silage (kg) | 770 | - | - | 5760 | - | - |
| Compound feed (kg) | 111 | 1615 | - | 896 | 2028 | - |
| ***Feed cost/lamb (£)*** | | | | | | |
| Grass | 2.08 | - | - | - | - | - |
| Stubble turnips | - | - | 1.83 | - | - | 1.68 |
| Grass silage | 0.59 | - | - | 4.42 | - | - |
| Compound | 0.70 | 10.23 | - | 5.67 | 12.43 | - |
| Total finishing cost | 3.37 | 10.23 | 1.83 | 10.09 | 12.43 | 1.68 |
| Early grazing | - | - | - | 3.90 | 3.90 | 3.90 |
| Total feed costs | 3.37 | 10.23 | 1.83 | 13.99 | 16.33 | 5.58 |
| Total LW gain (kg) | 6.7 | 10.6 | 7.2 | 8.1 | 10.4 | 7.1 |
| £/kg liveweight gain | 0.50 | 0.97 | 0.25 | 1.25 | 1.20 | 0.24 |

** note that some groups contained spare lambs which have been included for calculating feed usage.*

*Assumptions made in calculating feed costs*

Stubble turnips - growing and establishment costs at Walford College estimated at £80/ha (includes seed, slurry and cultivation/drilling costs)

Grazing cost - weekly headage cost of 30p/lamb without shepherding.

Grass silage (1st cut) - £23/tonne as fed. Daily intake estimated at 2.5-4kg fresh weight depending on compound intake.

Compound feed - £190/tonne

For both finishing periods the stubble turnip system had the lowest feed costs at less than £2 per lamb. Grass finishing with limited amounts of grass silage and compound feed were next cheapest with the ad-lib compound diet the most expensive. It should be noted however, that the stubble turnip growing costs on this farm were very low with no sprays or inorganic fertiliser being applied. If more typical costs of £153/ha (Eblex, 2007) are used, the cost/lamb would increase to £3.50 and £3.20 for the November and March lambs respectively. If these figures are used there is little to choose between the grass and turnip systems.

Cost per kg of liveweight gain in the finishing period was calculated and showed a wide variation from around 25 p/kg for stubble turnips (47 p/kg if typical cost used) up to £1.25/kg for the silage and compound system for March finishing. Although total costs were highest for the compound group in March their superior growth rate made this system more cost effective than the silage/compound group.

***Meat Quality***

***A. Muscle pH and colour***

Ultimate **pH** (i.e. after the post mortem biochemical changes involving the depletion of muscle glycogen are complete) in lamb tends to be higher than that in beef or pork, with mean values often in the 5.7 - 5.8 part of the range, compared to 5.3 - 5.6 in the other species. However, it is unusual in the UK to encounter very high (>6.0) pH values in lamb, such meat being described as DFD (dark, firm and dry).

Mean pH varied between 5.5 (grass-fed slaughtered in March) to 6.1 (NZ Controls), with the highest individual value in the latter being 6.47 and 10 of the 14 samples having values >6.0. Because these values were atypically high, a second set of measurements was recorded using a separate, different probe. These confirmed that the NZ Controls did have high pH values (the two sets of measurements are shown in Appendix 3). A Meat NZ R&D Briefing Note (1999) refers to 'rising pH' in sheepmeat during extended storage in vacuum or in $CO_2$ packs. This claims there is a linear increase of the order of 0.3 unit at 16 weeks and that results suggest the rise in pH probably does not have the same effect on meat quality attributes as high ultimate pH. However, it has not been possible to validate this phenomenon in any supporting scientific publication and the aetiology of high pH in the NZ Controls in this study is not known.

It is interesting to note that the March-slaughtered grass and concentrate-fed groups had significantly lower pH values than the corresponding November groups and there was a similar trend in the stubble turnip groups.

There was an association between the group means for pH and **lightness (L*)**, the higher pH groups having darker meat; this was particularly evident for the NZ Controls. High pH meat has a high moisture retention and an 'open' muscle structure that makes it appear dark. However, the UK Controls had relatively dark meat but not a particularly high pH.

The main difference in **hue** and **saturation** was between the NZ Controls and the other groups. For hue, the NZ Control mean was significantly lower than for other groups, indicating a more red-purple rather than a red-brown appearance. The only significant difference in saturation was between the NZ and UK Controls, the latter having a more intense colour.

***B. 8-point category scales***

The mean panel scores for descriptors covering eight points on category scales for texture, juiciness, lamb flavour intensity, abnormal flavour, flavour liking and overall liking, are shown in Table 16. There were very highly significant differences between the lamb groups for each of the attributes. A summary for each attribute is given below.

### ***Texture***

The New Zealand controls were more tender than all the other groups and the *ad-libitum* concentrate lambs slaughtered in November were tougher than all other groups. All groups had mean scores in the top half of the texture range (i.e. values > 4.0) so all were classed as tender.

It should be noted that the high pH of NZ Controls may have been a factor in determining its tenderness. It is well documented that DFD meat is tender, as found here, but flavour is impaired. The NZ Controls also had a prolonged period between slaughter and tasting, thus allowing proteolysis to continue longer.

### ***Juiciness***

The grass-fed lambs slaughtered in March had juiciness scores higher than all other groups except the ad-libitum concentrate lambs slaughtered in March and the two control groups. The least juicy were the ad-libitum concentrate lambs slaughtered in November although they were not significantly different from the grass-fed November group or either of the stubble turnip groups. The March-slaughtered groups had juicier meat than the November-slaughtered groups although this was not significant for the stubble turnip lambs.

### ***Lamb flavour***

Lamb flavour was highest in the two control groups and the stubble turnip lambs slaughtered in March; it was not significantly different between the remaining groups.

### ***Abnormal flavour and flavour liking***

Overall, abnormal flavour ratings tended to be in the weak categories (ranging from very to moderately weak). It was highest in the grass-fed and ad-libitum concentrate lambs slaughtered in March and, rather surprisingly, in the NZ controls (a high score for abnormal flavour is usually associated with a low score for lamb flavour). The lowest abnormal flavour was found in the early grass–fed lambs (November slaughtered and UK controls) and in both stubble turnip groups. The net result was that the flavour was most liked in both stubble turnip groups and in the UK controls and disliked most in the March-slaughtered grass-fed and ad-libitum concentrate groups.

### ***Overall liking***

The overall liking scores closely matched the differences in flavour liking rather than tenderness differences. This may be because, as noted above, all the lamb groups were tender and preferences for flavour are more strongly expressed in this context. So the best liked meat was from the two stubble turnip groups and the UK control group, the least liked from the March-slaughtered grass-fed group and both the ad-libitum concentrate groups.

Further exploration of the data showed that the fat class of the lambs did not affect any of the sensory scores.

### *C. 100mm line scales*

Lamb groups differed significantly in 11 of the 13 flavour descriptors used (Table 5). Although some of these descriptors implicitly convey positive qualities (e.g. 'sweet') and others convey negative qualities (e.g. 'rancid'), this interpretation does not apply to the majority and this assessment is not hedonic but is purely descriptive. However, it is possible to link the flavour liking mean scores to individual descriptor ratings, as follows:

**The three preferred lamb groups** (UK control and the two stubble turnip groups) had the highest values for Sweet (significantly different from other groups for the UK control and the March-slaughtered stubble turnip group) and the lowest values for Rancid (significantly different from all other groups in the cases of the UK control and the November-slaughtered stubble turnips group). They also had the lowest values for Ammonia (significantly different from all other groups apart from grass-fed slaughtered in November) and Soapy.

**The two least preferred lamb groups** (March slaughtered grass-fed and ad-libitum concentrate-fed) tended to have low values for Sweet, high values for Bitter and Rancid and, particularly, Livery, Kidney and Soapy (significantly greater than all other groups except NZ Control in all three cases). The grass-fed March group also had the highest value for Metallic (significantly greater than all other groups except NZ Control).

**The NZ Control group** had a very similar flavour profile to the two least preferred groups detailed above. In fact, the NZ Controls, although not significantly different from the November–slaughtered groups fed grass or ad-libitum concentrates in Flavour Liking, did have the third lowest score. It did differ from the March slaughtered grass-fed and ad-libitum concentrate-fed groups in having a significantly lower value for Acidic and for Ammonia, factors that may have contributed to its slightly higher flavour liking score.

In the **grass versus concentrate comparison**, considering both groups within each feed type together, very little difference emerges between them. However, within each feed type, there is **an effect of slaughter month**, as suggested above (the two least liked groups – both March–slaughtered).

This was particularly evident in the values for Livery, Kidney and Ammonia which were all higher in the March groups than in the November groups. This was not the case for the stubble turnip groups slaughtered at the two times, there being only one significant difference between the two groups, namely Sweet which was greater in the March group.

Table 15. Influence of feed and slaughter date on pH and colour of grilled lamb loin. Values are the means derived from General Linear Models with Type as a factor

| Variable | Grass Nov. | Grass Mar. | Ad-lib concs. Nov. | Ad-lib concs. Mar. | Stubble. Turnips Nov. | Stubble. Turnips Mar. | NZ control | UK control | LSD | P |
|---|---|---|---|---|---|---|---|---|---|---|
| Ultimate pH | 5.77$^{b}$ | 5.51$^{e}$ | 5.75$^{b}$ | 5.59$^{de}$ | 5.71$^{bc}$ | 5.62$^{cd}$ | 6.13$^{a}$ | 5.63$^{cd}$ | 0.07 | <0.001 |
| L* (lightness) | 43.99$^{b}$ | 46.96$^{a}$ | 45.36$^{ab}$ | 47.19$^{a}$ | 45.39$^{ab}$ | 46.30$^{a}$ | 40.70$^{c}$ | 41.74$^{c}$ | 1.368 | <0.001 |
| Hue | 26.29$^{ab}$ | 27.53$^{a}$ | 27.96$^{a}$ | 26.86$^{ab}$ | 26.94$^{ab}$ | 25.16$^{b}$ | 22.25$^{c}$ | 26.44$^{ab}$ | 1.512 | <0.001 |
| Saturation | 20.72$^{ab}$ | 20.07$^{ab}$ | 20.66$^{ab}$ | 20.78$^{ab}$ | 19.97$^{ab}$ | 18.68$^{ab}$ | 18.41$^{b}$ | 21.22$^{a}$ | 1.830 | 0.009 |

Means in a row with the same letter do not differ significantly, Tukey-Kramer test at the 0.05 level, post hoc

Table 16. Influence of feed and slaughter date on the eating quality of grilled lamb loin.  Values are the means derived from General Linear Models with lamb Group and assessor as factors, with 14 replications.

| **Attribute** | Grass Nov. | Grass Mar. | Ad-lib concs. Nov. | Ad-lib concs. Mar. | Stubble. Turnips Nov. | Stubble. Turnips Mar. | NZ control | UK control | LSD | P |
|---|---|---|---|---|---|---|---|---|---|---|
| Texture | 5.22$^{b}$ | 4.94$^{c}$ | 4.48$^{d}$ | 5.26$^{b}$ | 5.40$^{b}$ | 5.17$^{bc}$ | 6.18$^{a}$ | 5.33$^{b}$ | 0.25 | <0.0001 |
| Juiciness | 4.75$^{cde}$ | 5.09$^{a}$ | 4.63$^{e}$ | 4.88$^{abcd}$ | 4.70$^{de}$ | 4.85$^{bcde}$ | 5.07$^{ab}$ | 4.93$^{abc}$ | 0.23 | 0.0002 |
| Lamb | 4.10$^{c}$ | 3.92$^{c}$ | 4.05$^{c}$ | 4.08$^{c}$ | 4.21$^{bc}$ | 4.49$^{ab}$ | 4.54$^{a}$ | 4.48$^{ab}$ | 0.31 | <0.0001 |
| Abnormal | 2.66$^{c}$ | 3.47$^{a}$ | 2.99$^{b}$ | 3.47$^{a}$ | 2.47$^{c}$ | 2.51$^{c}$ | 3.15$^{ab}$ | 2.37$^{c}$ | 0.33 | <0.0001 |
| **Hedonic** | | | | | | | | | | |
| Flavour liking | 4.59$^{b}$ | 3.94$^{c}$ | 4.36$^{b}$ | 3.82$^{c}$ | 4.98$^{a}$ | 5.00$^{a}$ | 4.30$^{b}$ | 5.25$^{a}$ | 0.30 | <0.0001 |
| Overall liking | 4.54$^{b}$ | 3.90$^{d}$ | 4.13$^{cd}$ | 3.85$^{d}$ | 4.90$^{a}$ | 4.85$^{a}$ | 4.27$^{bc}$ | 5.06$^{a}$ | 0.29 | <0.0001 |

Table 17. Influence of feed and slaughter date on flavour descriptors used for grilled lamb loin. Values are the means derived from General Linear Models with lamb Group and assessor as factors, with 14 replications.

| **Attribute** | Grass Nov. | Grass Mar. | Ad-lib concs. Nov. | Ad-lib concs. Mar. | Stubble. Turnips Nov. | Stubble. Turnips Mar. | NZ control | UK control | LSD | P |
|---|---|---|---|---|---|---|---|---|---|---|
| Fatty/greasy | 13.23 | 14.39 | 12.65 | 9.98 | 11.74 | 11.59 | 13.25 | 14.50 | - | 0.1320 |
| Sweet | 11.56$^{b}$ | 10.59$^{b}$ | 11.93$^{b}$ | 10.75$^{b}$ | 13.49$^{b}$ | 17.18$^{a}$ | 10.73$^{b}$ | 16.80$^{a}$ | 3.25 | <0.0001 |
| Acidic | 12.90$^{a}$ | 10.87$^{ab}$ | 10.94$^{ab}$ | 11.21$^{ab}$ | 10.33$^{ab}$ | 8.65$^{bc}$ | 6.40$^{c}$ | 6.34$^{c}$ | 3.28 | 0.0003 |
| Metallic | 7.86$^{c}$ | 12.75$^{a}$ | 6.27$^{c}$ | 8.52$^{bc}$ | 6.55$^{c}$ | 7.26$^{c}$ | 11.74$^{ab}$ | 7.94$^{c}$ | 3.41 | 0.0005 |
| Bitter | 4.83$^{abc}$ | 6.56$^{a}$ | 6.14$^{a}$ | 6.64$^{a}$ | 4.09$^{bc}$ | 5.10$^{ab}$ | 6.43$^{a}$ | 3.03$^{c}$ | 2.06 | 0.0024 |
| Rancid | 3.13$^{bcd}$ | 4.31$^{ab}$ | 3.52$^{bc}$ | 3.87$^{b}$ | 1.56$^{d}$ | 1.98$^{cd}$ | 5.96$^{a}$ | 1.58$^{d}$ | 1.89 | <0.0001 |
| Livery | 10.78$^{b}$ | 21.26$^{a}$ | 11.90$^{b}$ | 20.86$^{a}$ | 11.68$^{b}$ | 9.14$^{b}$ | 21.04$^{a}$ | 11.60$^{b}$ | 4.37 | <0.0001 |
| Kidney | 6.75$^{b}$ | 21.68$^{a}$ | 9.60$^{b}$ | 22.90$^{a}$ | 7.18$^{b}$ | 5.51$^{b}$ | 23.94$^{a}$ | 6.51$^{b}$ | 4.19 | <0.0001 |
| Ammonia | 1.60$^{c}$ | 7.41$^{a}$ | 4.16$^{b}$ | 8.57$^{a}$ | 1.10$^{c}$ | 1.03$^{c}$ | 3.94$^{b}$ | 0.91$^{c}$ | 1.81 | <0.0001 |
| Grassy | 7.96$^{ab}$ | 3.94$^{c}$ | 6.39$^{bc}$ | 6.84$^{bc}$ | 6.87$^{bc}$ | 7.11$^{ab}$ | 5.13$^{bc}$ | 10.13$^{a}$ | 3.16 | 0.0113 |
| Fishy | 2.29 | 1.71 | 0.68 | 0.75 | 1.10 | 1.81 | 2.48 | 1.81 | - | 0.1061 |
| Soapy | 3.59$^{bc}$ | 6.86$^{a}$ | 4.92$^{ab}$ | 6.63$^{a}$ | 3.48$^{bc}$ | 3.40$^{bc}$ | 6.99$^{a}$ | 2.67$^{c}$ | 2.08 | <0.0001 |
| Dairy | 6.75$^{bcd}$ | 4.47$^{d}$ | 7.14$^{bc}$ | 5.07$^{cd}$ | 7.82$^{ab}$ | 7.71$^{ab}$ | 5.85$^{bcd}$ | 9.59$^{a}$ | 2.31 | 0.0003 |

Means in a row with the same letter do not differ significantly, Tukey-Kramer test at the 0.05 level, post hoc

## Conclusions

Wether lambs on the ad-lib concentrate diet had significantly higher growth rates than the other two diets with heavier sale weights and carcass weights. Killing out % was highest for the stubble turnip group and lowest for the grass group. Wether lambs slaughtered in March were heavier than November lambs and had higher cold carcass weights but live weight gain and killing out % were unaffected. Carcass conformation of wethers was unaffected by either diet or slaughter date but grass-fed lambs were significantly leaner than either of the other feed treatments and November finished lambs were leaner than March lambs.

Similar results were obtained when the performance of all lambs was compared, with concentrate lambs growing significantly faster, resulting in lambs being sold 6 days earlier and being heavier at sale. Slaughter date did not affect carcass conformation or fatness significantly but grass/silage finished lambs were shown to be leaner with poorer conformation.

Overall feed costs during the finishing period were lowest for the stubble turnip treatment, averaging £1.76/head, irrespective of slaughter date. Grazed grass was next cheapest at £3.37 with all the other treatments costing over £10.00/head. This resulted in costs/kg DLWG ranging from 25p for turnips to £1.25 for grass silage lambs. For lambs finished in March there was an additional grazing cost of £3.90 to cover the pre-finishing store period.

For the grass- and concentrate-fed hoggets, there was a deterioration in some quality attributes between November and March, most notably in abnormal flavour (which increased) and flavour and overall liking (which decreased). These flavour changes were more important in determining overall liking than the changes in texture and juiciness between the two slaughter times, some of which favoured the March-slaughtered groups, particularly juiciness. But it is noteworthy that all lamb groups produced meat that was tender. A further exploration of the data plotted fat classification against the attributes in the 8-point score and there was no relationship.

Compared with the UK Controls, both groups of grass-fed and concentrate-fed lambs had weaker lamb flavour and, apart from the November-slaughtered grass-fed lambs, a significantly more pronounced abnormal flavour. On the other hand, both stubble turnip groups had quality ratings on a par with the UK Controls and, moreover, there were no significant effects of season of slaughter on this diet. These three groups were the most preferred of all lamb groups. A variety of stubble turnip had been previously shown (Koch et al. 1987) to produce lamb meat that did not differ in flavour from lambs reared on grass/grain. The overall conclusion is that a diet of stubble turnips delivers a high level and consistency of lamb eating quality through the winter months.

## Glossary

| | |
|---|---|
| DM | Dry matter |
| MAFF | Ministry of Agriculture, Fisheries and Food |
| ME | Metabolisable Energy |
| MJ | Megajoule |
| NCGD | Neutral cellulose gamanase digestibility |
| P | Statistical probability |
| s.e.d. | Standard error of difference |
| NS | Not significant |
| $X^2$ | Chi-square test |

**References**

**EBLEX – Better Returns Programme (2007).** Out-wintering on Fodder Crops – A producers guide to out-wintering beef cattle and sheep on fodder crops.

**Koch, D. W., Ernst, F. C., Leonard, N. R., Hedberg, R. R., Blenk, T. J. and. Mitchell, J. R. (1987).** Lamb performance on extended-season grazing of Tyfon J. Anim. Sci. 64:1275-1279.

**Ministry of Agriculture, Fisheries and Food (1986).** The analysis of agricultural materials. Reference book **427** 3rd edition. *HMSO London.*

**Meat New Zealand (1999).** R and D brief No. 39. The effect of pH and chilled storage on the flavour and odour of sheepmeat. MIRINZ Food Technology and Research.

## Appendix 1.

## Experiment Diary

| | |
|---|---|
| 10.10.07 | 177 lambs arrived on site |
| 11.10.07 | All lambs wormed with Depidex & Levicur |
| 15.10.07 | All lambs vaccinated Heptavac $P^+$ |
| 16.10.07 | Lamb 23203, pneumonia, treatment Alamycin 10% 4ml, Flunixin 1ml. |
| 16.10.07 | All lambs weighed and early finish trial groups selected (30 lambs/group). |
| 17.10.07 | Lamb 23203 died. |
| 17.10.07 | All lambs footbathed (Formalin) |
| 17.10.07 | Lambs onto trial diets, 1 spare large lamb on turnips (31 in total) |
| 23.10.07 | Remaining 9 lambs arrived on site. |
| 23.10.07 | Concs group eating 0.5kg/hd/day. |
| 30.10.07 | Trial lambs weighed, Concs. group eating 1.5kgs/head/day |
| 30.10.07 | Lambs with bad eyes, 8 treated with Aureomycin powder |
| 13.11.07 | All lambs weighed. |
| 14.11.07 | All lambs footbathed (Formalin) |
| 14.11.07 | Lamb 23999 lame, treatment; trim + Penstrep 4mls. |
| 27.11.11 | Trial lambs weighed, first batch selected for slaughter |
| 27.11.07 | Lamb 23999 lame, treatment Betamox LA 3ml. |
| 30.11.07 | Concentrates introduced to grass group @ 0.3kg/head/day |
| 30.11.07 | 72 lambs to slaughter (Randall Parker Foods, Llanidloes) |
| 01.12.07 | Lambs with bad eyes, 10 treated with Aureomycin powder for 3 days |
| 07.12.07 | Lamb 23980 died, cause unknown |
| 10.12.07 | Trial lambs weighed |
| 13.12.07 | Grass group housed, grass silage plus 0.5kg concs |
| 02.01.08 | Trial lambs weighed |
| 02.01.08 | All lambs footbathed (Formalin) |
| 04.01.08 | 19 lambs to slaughter |
| 15.01.08 | Lambs weighed, trial groups selected |
| 18.01.08 | trial lambs wormed. Allverm 4% SC |
| 18.01.08 | All lambs foot bathed (formalin) |
| 23.01.08 | Trial lamb 240 put down, broken leg |
| 29.01.08 | Trial lambs weighed |
| 31.01.08 | Silage lambs supplemented with concentrates. 0.25kg/lamb/day |
| 05.02.08 | Silage lambs concentrates increased to 0.5kg/lamb/day |
| 12.02.08 | Trial lambs weighed |
| 13.02.08 | Silage lambs concentrates increased to 0.75kg/lamb/day |
| 13.02.08 | All lambs foot bathed (formalin) |
| 15.02.08 | Silage lambs concentrates increased to 0.83kg/lamb/day |
| 26.02.08 | Trial lambs weighed |
| 06.03.08 | 68 lambs sold for slaughter |
| 26.03.08 | 24 lambs sold for slaughter |

**Appendix 2. Trial design**

Hoggets on three diets, two slaughter ages (dates), plus NZ and UK grass-only 'control' lambs

| 180 hoggets |
|---|

Diet level

| Diet 1. Grass/silage | Diet 2. Ad lib concentrates | Diet 3. Stubble turnips |
|---|---|---|
| 60 | 60 | 60 |

* in addition, lambs on each diet will receive some concentrates that reflect current commercial practice.

Age level

| Nov | March | Nov | March | Nov | March | NZ Control | UK Control |
|---|---|---|---|---|---|---|---|
| 30 | 30 | 30 | 30 | 30 | 30 | 16 | 16 |

Sensory will receive ***<u>16 lambs per treatment</u>***, within diet randomly selected. This will include samples required for training of assessors and validation of descriptive profiles (8 lambs)

**Sensory design**

Use an incomplete block design where t=8 (number of treatments), k=4 (number of units per session), r=7 (replicates required), b= 14 (number of blocks) E=0.86 (efficiency)

| **Blocks** | **Treatments** | **Replicate** |
|---|---|---|
| Block 1 | 1,2,3,4 | 1 |
| Block 2 | 5,6,7,8 | 1 |
| Block 3 | 1,2,7,8 | 2 |
| Block 4 | 3,4,5,6 | 2 |
| Block 5 | 1,3,6,8 | 3 |
| Block 6 | 2,4,5,7 | 3 |
| Block 7 | 1,4,6,7 | 4 |
| Block 8 | 2,3,5,8 | 4 |
| Block 9 | 1,2,5,6 | 5 |
| Block 10 | 3,4,7,8 | 5 |
| Block 11 | 1,3,5,7 | 6 |
| Block 12 | 2,4,6,8 | 6 |
| Block 13 | 1,4,5,8 | 7 |
| Block 14 | 2,3,6,7 | 7 |

Repeat this structure once, which will require 14 lambs for each treatment, i.e. 14 reps x 8 treatments

**List of treatments**

| Treatment | Description | Numbers of samples |
|---|---|---|
| 1 | Grass/Silage, November | 16 |
| 2 | Grass/Silage, March | 16 |
| 3 | Ad lib Concentrates, November | 16 |
| 4 | Ad Lib Concentrates, March | 16 |
| 5 | Stubble turnips, November | 16 |
| 6 | Stubble turnips, March | 16 |
| 7 | New Zealand controls | 16 purchased from 1 farm in NZ |
| 8 | UK controls (off grass) | 16 purchased off grass |

## Appendix 3. Repeat pH measurements (NZ Controls)

| Lamb | Probe A* | Probe B |
|---|---|---|
| 1 | 5.92 | 6.15 |
| 2 | 6.23 | 6.25 |
| 3 | 6.33 | 6.41 |
| 4 | 6.18 | 6.10 |
| 5 | 6.06 | 6.03 |
| 6 | 6.05 | 5.91 |
| 7 | 5.91 | 5.89 |
| 8 | 6.47 | 6.48 |
| 9 | 6.16 | 6.18 |
| 10 | 5.80 | 5.85 |
| 11 | 6.30 | 6.11 |
| 12 | 6.12 | 6.12 |
| 13 | 6.35 | 6.30 |
| 14 | 5.87 | 6.01 |

* Values produced by this probe used throughout