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Agriculture Branch, Hillsborough

Low input forages for beef production

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LOW INPUT FORAGES FOR BEEF PRODUCTION

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EXECUTIVE SUMMARY

Four experiments were undertaken to compare the performance and meat quality of finishing beef cattle offered legume/cereal wholecrop silages or red clover silage with animals offered grass silage. In Experiment 1, the performance of beef cattle offered lupins/triticale silage (LT) in combination with grass silage (GS) (60:40 ratio GS:LT silage on a dry matter (DM) basis) was compared with the performance of beef cattle offered solely GS or GS:maize silage (MS) (60:40 ratio GS:MS DM basis). The LT was sown by two different methods. In method 1 (LT1) the lupins and triticale were sown separately within the same field and then harvested together. In method 2 (LT2) the lupins and triticale were sown as a mixture. Two levels of concentrate supplementation were offered – 3 or 6 kg/head/day. In Experiment 2, LT and vetch/barley were offered to beef cattle as either the sole forage or in combination with grass silage (30:70 GS: VB or LT on a DM basis). Concentrates were offered at either 2 or 5 kg/head/day. In Experiment 3, LT, lupins/wheat (LW), peas/oats (PO) were offered in combination with a perennial ryegrass-based grass silage (PGS) or a fescue/perennial ryegrass-based grass silage (FGS) at a 50:50 ratio (DM basis). Concentrates were offered at 4 or 7 kg/head/day. In Experiment 4, red clover, PGS and FGS silages were offered as the sole forage to beef cattle supplemented with 1.5 or 4 kg concentrates/head/day.

Dry matter yields of the legume/cereal wholecrop forages ranged from 6.6 tonnes DM/ha for VB to 8.9 tonnes DM/ha for LW. These DM yields are considerably lower than the yield of 14.4 tonnes DM/ha reported for a 2-cut silage system and 10.4 to 13 tonnes DM/ha reported for wholecrop wheat.

In general the legume/cereal silages and red clover silage were of poor quality with low levels of lactic acid, high ammonia concentration and high pH.

Averaged over experiments 1, 2 and 3 animals offered legume/cereal wholecrop silage as a sole silage or in combination with grass silage had 15% lower liveweight gain and carcass gain

compared to animals offered PGS. Method of establishing LT had no effect on animal performance. The superiority of PGS relative to the legume:cereal wholecrop silages was greater when concentration supplementation level was less than 7 kg/head/day. At the high levels of concentrate supplementation (>7kg/head/day (Experiment 2)), any silage type effect was removed due to the low forage intake (450 g silage/kg total DMI) of which only 0.5 of silage DM intake was legume:cereal wholecrop silage. Animals offered red clover silage had similar performance to those offered grass silage.

The legume/cereal wholecrop silage and red clover silage had no or limited effect on carcass characteristics, instrumental meat quality parameters or fatty acid composition compared with PGS. This was attributed to the relatively high levels of concentrate offered and the fact that in most of the experiments the legume/cereal wholecrop forages were offered along with PGS. In addition the carcasses were all hung by the tenderstretch method post slaughter which has been shown to reduce differences in meat quality parameters.

The total costs of producing legume/cereal wholecrop silage were 15% lower than for a 2-cut grass silage system. However, when costs were expressed per tonne utilisable DM yield, legume/cereal wholecrop silages had higher (52% higher) costs due to their low yields. Combined with poor animal performance this would produce a significantly lower gross margin.

In conclusion these results demonstrate that beef producers should place increased emphasis on making good quality grass silage rather than legume:cereal wholecrop silages in order to optimise performance and reduce feed costs in finishing beef systems.

INTRODUCTION

Interest in growing legumes on-farm has increased in recent years as a means of producing a supply of protein rather than buying in expensive protein sources. In addition, from an environmental and economic perspective, there is a move towards reducing the input of nitrogen fertilisers in the production of diets for beef cattle. Through their ability to fix nitrogen, legumes fulfil this criterion. Legumes suchs as lupins and peas have been shown to have protein concentrations in the range 260 to 410 g/kg dry matter (DM) (Petterson et al 1997, Petit et al 1997) and the nutritive value is similar to other protein supplements such as rape meal or soya (Moss et al 1999). However, when harvested as a wholecrop, legumes have a low DM (162 to 190 g/kg fresh) which leads to problems with effluent production (Fraser et al 2005). One mechanism by which this can be addressed is by including high DM forage such as a cereal along with the legumes. The phenomenon of growing cereals with legumes is not new. Oats have been grown with legumes to provide physical support for climbing, to increase light interception and to facilitate mechanical harvesting (Caballero et al 1995). Intercropping legumes and cereals has also been shown to increase total DM yield and reduce fertiliser needs (Singh et al 1989). Triticale has been suggested as a suitable cereal to include with legumes as it is less competitive compared with other cereals (Ross et al 2005). However research data on the potential of legume/cereal wholecrop silages as diets for beef cattle is limited. Some research has been undertaken to evaluate the nutritive value of lupins as a wholecrop for finishing beef cattle (Fraser et al 2005) although no known information is available on the potential of lupins/triticale wholecrop. Similarly, no research information is available on the potential of vetch/cereal wholecrop. Rondahl et al (2007) observed that peas/oats wholecrop silage offered in combination with grass/clover silage had a concentrate sparing effect when offered to dairy cows. In view of this background, the first objective of the current is to assess the performance of finishing beef cattle offered lupins/triticale wholecrop silage in combination with grass silage.

Ross et al (2005) observed that the yield of berseem clover was reduced in intercropping systems with oats. Thorsted et al (2006) also observed that grain yield and clover biomass was reduced when winter wheat was intercropped with clover compared to the yield obtained when either of the forages were grown separately. These effects were attributed to competition for light, and a lower sowing rate or increased rototilled width for the cereal was recommended. While Thorsted et al (2006) observed that the yield of clover and wheat grain was greater when they were grown separately than when they were grown together, no information is available in the literature on the impact of growing legumes and cereals as two separate mixtures in the same field but harvesting and ensiling together. Therefore the second objective of the current study is to determine if the method of establishing lupins/tiricale silage influences silage quality performance of beef cattle.

Research data on the impact of legumes on instrumental quality of meat from beef cattle is limited. More information is available for sheep offered white clover or lucerne diets rather than legume/cereal mixtures and for the effect on sensory meat quality rather than instrumental meat quality. In general meat from sheep that consumed white clover or lucerne had a more intense flavour and odour than meat from grass-fed sheep (Schreurs et al 2008). However when a number of studies were compared there was no consistent effect of clover on meat quality and this was attributed to the variation in the proportion of clover in the diet (Dewhurst *et al* 2009). Similar comparative information for legume-based silages is not available and no known research data is available on the effect of legume/cereal wholecrop silages on instrumental meat quality. The third objective of the current study is therefore to evaluate the impact of legume/cereal wholecrop silage on instrumental meat quality of beef steers.

MATERIALS AND METHODS

Experiment 1

Animals

Eighty continental cross beef steers (Belgian Blue, Charolais, Blonde d'Aquitaine, Limousin and Parthenaise) sourced from 9 suckler beef farms throughout Northern Ireland were used in the trial. They were initially 530 ± 47.7 kg live weight and 18 ± 1.6 months of age.

Treatments

Eight dietary treatments were offered to the continental beef steers in a four silage x two concentrate feeding level design experiment. The silage treatments consisted of grass silage as the sole forage (GS); grass silage offered with maize silage (GS:MS), grass silage offered with lupins/triticale silage (sowing method 1) (GS:LT 1) and grass silage offered with lupins/triticale silage (sowing method 2) (GS:LT 2). Grass silage was included in the ration at a ratio of 60:40 grass silage: maize silage or lupins/triticale silage on a dry matter (DM). The silages were supplemented with 3 or 6 kg concentrates/head/day. The dietary treatments were imposed for an average of 107 days during the finishing period.

Diets

The grass silage offered to the cattle during the treatment period was harvested from predominately perennial ryegrass swards on 3 June (primary growth) and between 17 and 19 July (primary regrowth). The grasses were harvested using a precision chop forage harvester and were treated with a bacterial inoculant (Ecosyl 66®, Ecosyl Products Limited, Stokesley, North Yorkshire, England or Quicksile ® Britmilk, Ballantrae House, Dumfriesshire) prior to ensiling.

Maize was sown on 26 April and harvested on 27 October from the variety Goldcob which had been grown under the complete cover plastic mulch system. The maize was harvested direct cut using a self-propelled forage harvester fitted with a corn cracker to crack the maize grains at the time of harvest. The maize was ensiled treated with a bacterial inoculant and potassium sorbate additive (Ecocorn, Ecosyl Products Limited, Stokesley, North Yorkshire, England).

Lupins (variety Wodjil) and triticale (variety Logo) were sown on 10 May by two different methods. In sowing method 1, lupins and tritcale were sown as two separate crops within the same field (LT1); in sowing method 2 the forages were sown together as a mixture (LT2). Fertiliser (P_2O_5 and K_2O) was applied to the seedbed to achieve phosphate and potash indices of 3 (MAFF, 1994). In addition, the triticale in sowing method 1 and the lupins/triticale in sowing method 2, received 60 units of nitrogen/hectare. At harvest on 8 September, lupins/tritcale sown by both methods was harvested direct cut using a self propelled forage harvester fitted with a crimper header. However, the GS:LT 1 was harvested across both sections of forages in the field so that the two forages were mixed together in the trailer. The material was then ensiled as a single forage. The GS:LT 2 was harvested and ensiled in a separate silo. A bacterial inoculant, WholeCrop Legume (Biotal Limited, Cardiff, UK) was used to treat the lupins/triticale forages sown by both methods.

All silages were ensiled in trench silos. During filling, each silo was consolidated between loads by rolling with an industrial loader and for a further 60 minutes after filling was completed. Following consolidation two polythene sheets were used to seal each silo. The entire surface was then weighed down with a layer of tyres.

The concentrates used during the finishing period consisted of (g/kg) 485 rolled barley, 120 maize meal, 200 sugar beet pulp, 150 soyabean, 30 molasses and 25 minerals and were offered once daily on top of the grass silage. The GS, GS:MS, GS:LT 1 and GS:LT 2 were offered once daily in the morning in sufficient quantities to allow a refusal of 50 to 100 g/kg intake. For the GS:MS, GS: LT 1 and GS:LT 2, the fresh weight of each of the silages, were placed in a mixer wagon at a ratio of 60:40 GS:MS, GS:LT 1, GS:LT 2 on a DM basis. The total amounts mixed together were based on the daily DM concentrates of the forages offered the previous week.

Experiment 2

Animals

Eight continental cross beef steers (Charolais, Limousin and Belgian Blue) sourced from 8 suckler farms in Northern Ireland were used. They were initially 557 (± 32) kg live weight and mean age of 19 (±1.2) months.

Treatments

Ten treatments which consisted of 5 silages x 2 concentrate levels were offered to continental steers in a 5 x 2 factorial design experiment. The five silage diets consisted of grass silage (GS), lupins/triticale silage (LT) and vetch/barley silage (VB) offered either as the sole silage or in combination with GS at a ratio of 30:0, on a dry matter (DM) basis, GS:legume/cereal wholecrop. The silages were supplemented with either 2 or 5 kg concentrate/head/day. Protein intake was equalised over the silage treatments to a CP intake of 1140 and 1367 g/day for the 2 and 5 kg levels of concentrate supplementation respectively.

Diets

Grass silage was made from grass harvested on the 18 July (first regrowth), 20 August (second regrowth) and 27 September (third regrowth) from a predominantly perennial ryegrass sward and allowed to wilt for 24 hours. Grass was harvested with a self-propelled precision chop forage harvester and ensiled in clamp silos following treatment with a bacterial innoculant

(Ecosyl, Lactobacillus plantarum; Ecosyl Products Ltd., Middlesborough, UK) at a rate of 3 litres/tonne.

Lupins/triticale (Joseph Morton Ltd, Co Down, N.Ireland) and vetch/barley (Barenbrug UK Ltd, Bury St. Edmunds, Suffolk, England) were sown at a rate of 142 and 185 kg/ha on the 15 and 16 April, at a mixture of 51:49 and 67:33 legume:cereal, respectively and harvested on 10 August. Varieties sown for LT and VB were Wodjil (spring yellow lupin) / Logo (spring triticale) and Nitra (spring vetch) / Static (spring barley), respectively. Two days after sowing the legume/cereal seed mixtures, 55kg of N and 30kg K_2O/ha were sown and a post-emergent herbicide, Stomp (BASF plc, Agricultural Products, Cheshire) was applied at a rate of 4 l/ha. Timing of harvest of legume/cereal wholecrop silages was based on vetch and lupin pod maturity, gauged by degree of pod fill and texture and colour of lupin and vetch grains. The legume/cereal wholecrops were harvested direct cut using a self-propelled forage harvester (John Deere 6850, John Deere, Moline, Illinois, USA) fitted with a crimper header (Kemper model Champion 4500, Stadtlohn, Germany). Both legume/cereal wholecrops were treated with an innoculant (Wholecrop gold, Biotal Ltd, Cardiff, Wales) at a rate of 4 litres/tonne, before ensiling in clamp silos and rolled with an industrial loader for 30 min after filling was completed. Following consolidation two polythene sheets were used to seal each silo. The entire surface was then weighed down with a layer of tyres.

The concentrate contained 495, 200, 150, 100, 30, 25 g/kg fresh, rolled barley, soya bean, sugar beet pulp, maize meal, molasses and minerals/vitamins respectively. The fresh weights of the legume/cereal silage (LT and VB) and grass silage were placed in the mixer wagon, at a ratio of 30:70 on DM basis GS: legume/cereal wholecrop silage, based on the daily DM concentrations of the silage offered the previous week. The diets were mixed for 5 minutes prior to feeding. Protein intake was stabilised over silage treatments by addition of soya bean meal. Animals offered 2 and 5 kg concentrate/head/day were stabilised over silage treatments to a crude protein intake of 1140 and 1367 g crude protein (CP)/day, respectively. Silage was offered once daily in sufficient quantities to allow a refusal of 50 to 100 g/kg offered.

Experiment 3

Animals

Ninety continental (Charolais, Limousin and Belgian Blue) cross steers sourced from 9 farms in Northern Ireland were used. The animals had a mean initial live weight of 555 ($\pm$ 41) kg and mean age of 19 ($\pm$ 1.6) months.

Treatments

Ten treatments which consisted of 5 silages x 2 concentrate levels were offered to continental steers in a 5 x 2 factorial design experiment. The five silage diets consisted of perennial ryegrass-based grass silage (PGS), fescue/perennial ryegrass-based grass silage (FGS) and lupins/triticale (LT), lupins/wheat (LW) and peas/oats (PO) offered in combination with PGS at a ratio of 50:50 on a dry matter (DM) basis, PGS:legume/cereal wholecrop.

Diets

The perennial ryegrass based sward was harvested for silage (PGS) on 14 May and 16 July as a first and second cut crop, respectively and allowed to wilt for 24 hours. The fescue/perennial ryegrass based sward was established in September 2006 and consisted of a seed mixture of 430, 220, 140, 70, 70 and 70 g/kg fresh of Barolex (tall fescue), Portrush (diploid perennial ryegrass), Foyle (tetraploid hybrid ryegrass), Ensign (white clover), Comer (timothy) and Barmoral (cocksfoot), respectively. The fescue/perennial ryegrass based sward received 86kg of N, 37kg K_2O and 19kg S/ha on the 21 May and was harvested for silage (FGS) on the 22 May and 24 August as first and second cut silage, respectively and allowed to wilt for 24 hours. Both the perennial ryegrass and fescue/perennial ryegrass silages were harvested with a self-propelled precision chop forage harvester and ensiled in clamp silos following treatment with a bacterial innoculant (Ecosyl, Lacrobacillus plantarum; Ecosyl Products Ltd., Middlesborough, UK) at a rate of 3 litres/tonne.

Lupins/triticale (LT), lupins/wheat (LW) and peas/oat (PO) (Joseph Morton Ltd, Co Down, N.Ireland) were sown at a rate of 149, 174 and 186 kg/ha on the 15 April, 16 April and 15 April, respectively, at a seed mixture of 51:49 legume:cereal and harvested on 28 September, 28 September and 29 August, respectively. The varieties of lupins and triticale sown in LT mixture were Kruglik (spring yellow lupin) and logo (spring triticale); for LW the varities were Kruglik (spring yellow lupin) and Belvoir (spring wheat); for PO the varieties were Prophet (spring pea) and Firth (spring oat). Two days post sowing of legume/cereal seed mixtures, fields received 55kg of N and 30kg K_2O/ha. Lupins/triticale, lupins/wheat and pea/oats all received a pre-emergent herbicide of stomp (4 l/ha), stomp (BASF plc, Agricultural Products, Cheshire) (4 l/ha) and butoxone (BASF plc, Agricultural Products, Cheshire) (4.5 l/ha) respectively. Timing of harvest of legume/cereal wholecrop silages was based on both pea and lupins pod maturity, gauged by degree of pod fill and texture and colour of pea and lupins grains. The legume/cereal wholecrops were harvested direct cut using a self-propelled forage harvester (John Deere 6850, John Deere, Moline, Illinois, USA) fitted with a crimper header (Kemper model Champion 4500, Stadtlohn, Germany). The legume/cereal wholecrops were treated with an innoculant (Wholecrop gold, Biotal Ltd, Cardiff, Wales) at a rate of 4 litres/tonne, before ensiling in clamp silos and rolled with an industrial loader for 30 min after filling was completed. Following consolidation two polythene sheets were used to seal each silo. The entire surface was then weighed down with a layer of tyres.

Silages were offered once daily through manual weighing and mixing of silages on a per pen basis, with the PGS:legume/cereal, 50:50 DM ratios calculated on the daily DM concentrations of the silage offered the previous week. A concentrate supplement of either 4 or 7 kg concentrates/head/day was placed on top of the silage. The concentrate contained 495, 200, 150, 100, 30, 25 g/kg fresh, rolled barley, soyabean, sugar beet pulp, maize meal, molasses and minerals/vitamins respectively.

Experiment 4

Animals

Forty-two beef cattle were used. These consisted of Limousin x Holstein-Friesian heifers, Limousin x Norwegian Heifers and continental (Charolais, Limousin and Belgian Blue) cross steers. The continental cross steers were sourced from 5 farms in Northern Ireland. The heifers were reared on farm at AFBI Hillsborough. Steers had a mean initial liveweight and age of 484 (± 27) kg and 565 (± 37) days and heifers had a mean initial live weight and age of 456 ± 42 kg and 656 (± 31) days. Animals were allocated to the six dietary treatments balanced for genotype, initial liveweight, sex and farm of origin with x animals per dietary treatment.

Treatments

The six treatments which consisted of 3 silages x 2 concentrate levels were offered to 42 animals in a 3 x 2 factorial design experiment. The three silage diets consisted of perennial ryegrass-based grass silage (PGS), fescue/perennial ryegrass-based grass silage (FGS) and red clover (RC) silage. Animals were offered a concentrate level of either 1.5 or 4 kg concentrate/head/day.

Diets

The fescue/perennial ryegrass sward was sown on the 11 September, 2006. The sward consisted of a seed mixture of 430, 220, 140, 70, 70 and 70 g/kg fresh of Barolex (tall fescue), Portrush (diploid perennial ryegrass), Foyle (tetraploid hybrid ryegrass), Ensign (white clover), Comer (timothy) and Barmoral (cocksfoot), respectively (Barenbrug UK Ltd, Bury St. Edmunds, Suffolk, England). The sward received 55 kg of N and 30 kg K_2O/ha from inorganic fertiliser on the 2 April and pig slurry /kg on 7 June which supplied 22 kg of N, 6 kg of P_2O_5 and 13 kg of K_2O (RB209). Red clover was sown on the 4 September and received 23 kg of N and 15 kg K_2O/ha from inorganic nitrogen on the 2 April and pig slurry /ha on 7th June which supplied 22 kg of N, 6 kg of P_2O_5 and 13 kg of K_2O (RB209).

The fescue/perennial ryegrass-based grass silage (FGS) and red clover silages were harvested in a three cut system, with the first cut harvested on the 5 June and 6 June respectively. The FGS and red clover silages were cut with a front (Claas Disco 3050 FC) and rear (Class Disco 3050 C) mounted mower combination and left to wilt for 20 hours and 65 hours respectively. The second and third cut of both FGS and red clover silage was harvested on the 7th August and 5th October following wilting for 24 hours and 65 hours respectively. Both FGS and red clover silage were baled (Krone Roundpack Multicut 1250) and wrapped (McHale Silomac 991B) at harvest with no additive used.

The perennial ryegrass based grass sward was harvested on the 24 July and 10 September as 2nd and 3rd cut silage, respectively and wilted for 48 hours. The perennial ryegrass based grass sward was harvested with a self-propelled precision chop forage harvester (John Deere 6850, John Deere, Moline, Illinois, USA) and stored in clamp silos following treated with a bacterial innoculant (Ecosyl, Lacrobacillus plantarum; Ecosyl Products Ltd., Middlesborough, UK) at a rate of 3l/t. Following filling the clamp silos, the PGS rolled with an industrial loader for 30 min. Following consolidation two polythene sheets were used to seal each silo. The entire surface was then weighed down with a layer of tyres.

The concentrate contained 495, 200, 150, 100, 30, 25 g/kg fresh, rolled barley, soyabean, sugar beet pulp, maize meal, molasses and minerals/vitamins respectively. Protein intake was stabilised over silage treatments by addition of soya bean meal. Animals offered 1.5 and 4 kg concentrate/head/day were stabilised over silage treatments to a crude protein intake of 1239 and 1468 g crude protein (CP)/day, respectively. Silage was offered once daily in sufficient quantities to allow a refusal of 50 to 100 g/kg offered.

Measurements

Forage yields (Experiments 1 and 3)

Prior to harvest, 20 randomised cuts were taken in the field from the lupins/triticale forages using a 1 m^2 quadrat placed at random 20 locations throughout the field. Herbage within each quadrat was cut 40 mm above ground level with a reciprocating-knife bar mower (Agria, Moeckmuehl, Germany).. The proportion of lupins, triticale and weeds within each of the treatments was then assessed. At harvest the total yield of the lupins/triticale and maize forage was determined by weighing each load of silage using an electronic weighbridge at the Institute.

Animal Performance (Experiments 1 to 4)

The animals were weighed twice on consecutive days at the beginning of the experiment and prior to slaughter and at fortnightly intervals throughout the experiment. Live weight gains from the start of the study to slaughter were determined by linear regression.

Food intake

Individual intakes (Experiment 1) and group intakes (Experiments 2 to 4) of food offered were recorded daily throughout the experiment by recording food offered on a daily basis. For individual intakes amount refused was also recorded daily while for group intakes refusals were removed and recorded twice per week.

Food composition (Experiments 1 to 4)

Representative samples of silage were taken daily and dried at 85°C for the determination of oven dry matter. The dried samples of silage were bulked over the week and analysed for ash, acid determent fibre (ADF) and neutral detergent fibre (NDF) concentrations. Fresh silage samples were also taken once weekly for determination of toluene dry matter, pH, crude protein (CP), ammonia-nitrogen, gross energy (GE), lactic acid and volatile fatty acids concentrations. In addition the starch concentration of maize silage was determined. Representative concentrate samples were taken daily, bulked weekly and dried at 100°C for the determination of oven dry matter. Dried concentrate samples were analysed for CP, ash and GE. Details of chemical analysis are described by Ferris et al (2010).

Diet digestibility (Experiments 1 to 4)

The digestibilities of the eight dietary treatments were determined through Holstein steers (live weight 420 $\pm$ 22.9 kg) in a four period, partially balanced, changeover design experiment, giving a total of four observations per diet, with all forages being offered ad libitum. Each period consisted of a 15 day feed-in period followed by a 6-day collection period of faeces and urine. Feed and faecal samples were bulked for 3-day periods and analysed for DM, ash, N, ADF, NDF and GE concentrations. The DM concentration of each forage was determined daily. The concentration of metabolisable energy (ME) of the total diets was determined by assuming that methane production was 0.07 of GE intake. Apparent digestibilities of the forages offered at maintenance level of energy intake were determined using four castrated male sheep per silage. The procedures for determination of digestibilities were as described by Steen (1984).

Carcass characteristics (Experiments 1 to 4)

At slaughter, the animals were stunned using a pneumatically operated captive bolt stunning system and bled immediately after stunning at an EU approved abattoir which had routine veterinary inspection by the Department of Agriculture for Northern Ireland. Carcass weight was recorded for each steer at slaughter. Daily carcass gain was calculated for each steer by assuming an initial carcass weight for all animals of 0.54 of initial live weight, which was determined from similar animals in previous studies at this Institute (Steen, 1995). The carcasses were graded visually for fatness and conformation by a supervisory grading officer of the Department of Agriculture, using the five-point scales of the European Carcass Classification Scheme as described by Kempster *et al* (1982). The carcasses were divided at the 10^{th} rib and the depth of subcutaneous fat was measured at points 0.25, 0.50 and 0.75 across the maximum width of the *M. longissimus dorsi* muscle on both sides of each carcass. The amount of marbling fat in the cut surface of the eye muscle on both sides of the carcasses was assessed independently by two individuals using the eight point scale of the United States Department of Agriculture photographic standards (Agricultural Research Council, 1965). At slaughter, the perinephric and retroperitoneal fat was removed from both sides of all carcasses and weighed.

Instrumental meat quality (Experiments 1 to 4)

After chilling at 10^{o}C for 12 hours and then 1^{o}C for 12 hours, the sirloin joint was taken from the left side of each carcass and subjected to instrumental evaluation. Measurements of pH, cooking loss, Warner-Bratzler shear force and sacromere length were recorded using the methods detailed by Okeudo and Moss (2004). In these procedures hue angle values (H^0) were determined using the equation $H^0 = \tan^{-1}(b^*/a^*)$, where a* is a measure of redness and b* is a measure of yellowness. Metric chroma values (C*) were calculated using the equation $C^* = (a^{*2} + b^{*2})^{0.5}$.

Fatty acid composition of meat (Experiments 2 to 4)

Fatty acid (FA) analysis was undertaken on lean from the LD obtained from the fore-rib joint (between $6^{th}/7^{th}$ to $10^{th}/11^{th}$ rib), frozen 4 days *post mortem* and thawed one day prior to FA analysis. Silage samples were taken on three week intervals throughout the experiment and frozen at minus $12^{o}C$ within 3 hours of being removed from the silo. Following completion of instrumental meat quality analysis, all silage samples were freeze dried and finely milled. Lipid was extracted from homogenized beef from the LD using a direct method for FA methyl ester synthesis as detailed by O'Fallon *et al.* (2007). Lipid was extracted from milled silage samples using a standard chloroform/methanol extraction method (Bligh and Dyer, 1959). The FA composition of meat and milled silage was determined using capillary column gas-liquid chromatography following preparation of the fatty acids as methyl esters (FAME) using methanolic KOH as described in BS 684-2.34 (2001). An aliquot (1.0 ul) of the FAME was injected onto a capillary column (0.25 mm id, 120 m length), WCOT fused silica-coated BPX70 (Phenomenex Cheshire, UK), in a Varian Star 3800 gas chromatography (Varian Associates Ltd., Walto*n*-o*n*-Thames, UK) equipped with a temperature programmable injector operated in the split mode and a flame ionization detector (FID). The column temperature was programmed from 50 to $225^{o}C$ to improve separation and resolution, by holding at $50^{o}C$ for $50^{o}C$ for 4 minutes initially, heating to $120^{o}C$ at $20^{o}C$/min, holding for 10 seconds heating to $180^{o}C$ at 2/ min, holding for 10 seconds and finally heating to $225^{o}C$ at $4^{o}C$/min and holding for 40 minutes. Helium at 1.0 ml/min was used as a carrier gas. An internal standard (C13:0) and a mixture of external methyl ester standards of expected FA composition of the sample (Sigma Aldrich, Gillingham, UK) were used for identification and recovery efficiency purposes. Fatty acids recorded were expressing as g FA/g tissue and g FA/100g total FA for FA composition of lean meat and milled silage samples, respectively.

Statistical analysis

Experiment 1

Animal performance, carcass and instrumental meat quality measurements were analysed as a four silage x two concentrate supplementation level design experiment using Genstat analysis of variance procedure (Payne et al 2007). The model tested for the main effects of silage treatment and concentrate supplementation level and their interaction. Genotype, days on experiment and age at slaughter were included as covariates.

Experiment 2

The data were analysed using the Genstat REML procedure for the analysis of variance of unbalanced data. The model fitted fixed effects for genotype, farm of origin and the 5 silage x 2 concentrate factorial with start weight as a covariate.

Experiment 3

The data were analysed using the Genstat REML procedure for the analysis of variance of unbalanced data. The model fitted fixed effects for genotype, farm of origin and the 5 silage x 2 concentrate level factorial with start weight as a covariate, for DM intakes, animal performance, carcass characteristics, instrumental meat quality and fatty acid composition of lean beef.

Experiment 4

The data were analysed using the Genstat REML procedure for the analysis of variance of unbalanced data. The model fitted fixed effects for sex, genotype, farm of origin and the 3 silage x 2 concentrate factorial with start weight as a covariate, for animal intakes, animal production, carcass characteristics, instrumental meat quality and fatty acid composition of lean beef.

RESULTS

Experiment 1

At harvest LT1 and LT2 yielded 8.7 and 7.5 tonnes DM/ha respectively. In treatment LT1 where the lupins and triticale were sown separately, 0.73 of the material consisted of lupins with the remaining 0.26 as weeds. The triticale was predominantly triticale with little or no weeds. In treatment LT2 where the lupins and triticale were sown together, 0.84 of the material consisted of triticale, 0.13 of lupins and 0.03 of weeds.

The grass silage offered in the study was of high quality as indicated by the crude protein concentration (151 g/kg dry matter), low ammonia-N (64 g/kg total N) and moderate D-value (694 g/kg) (Table 1). The maize silage was of moderate quality as indicated by D-value of 673 g/kg and ME of 11.2 MJ/kg DM. Starch concentration was 193 g/kg DM. The legume/cereal silages were poor quality as evidenced by the high concentrations of ammonia (182 and 173 g/kg total N), high pH (5.0 and 4.7), low lactic acid (9 g/kg DM) and low ME (10.4 and 9 MJ/kg DM) for LT1 and LT 2 respectively.

The digestibility of the diets offered is presented in Table 2. Inclusion of MS, LT1 or LT2 with GS reduced digestibility coefficients and ME concentration relative to GS only diet ($P<0.01$). The GS:LT1 diet had the lowest digestibility coefficient and ME concentration relative to GS:MS and GS:LT2 ($P<0.05$).

There were no significant interactions between silage type and concentrate supplementation level therefore main effects only have been presented. Silage type had no significant effect on slaughter live weight, liveweight gain, carcass gain, total DM intake or feed efficiency expressed as kg DMI/kg liveweight gain (Table 3). Animals offered the GS diet had a significantly lower DM intake relative to GS:MS, GS:LT 1 and GS:LT 2 ($P<0.01$) while the latter three silage types had similar intakes. Similarly, animals offered the GS diet had a lower

Table 1. Chemical composition of silage and concentrates fed

	Silage					
	GS[1]		MS	LT 1	LT 2	Conc.
	(A)	(B)				
Dry matter (g/kg fresh)	270	352	352	300	351	854
pH	3.9	4.1	3.6	5.0	4.7	-
Composition of dry matter (g/kg unless otherwise stated)						
Crude protein	122	160	81	126	114	170
Ammonia –N (g/kg total N)	52	67	108	182	173	-
Ash	86	99	44	75	55	71
Lactate	142	69	68	9	9	-
Acetate	13	21	13.3	33.9	30.2	-
Butyrate	1.6	3.3	0.6	0.8	5.4	-
Gross energy (MJ/kg DM)	19.3	18.7	19.2	18.7	18.7	18.0
ADF	352	316	290	352	302	117
NDF	597	534	580	568	518	241
D-value[2]	726	706	673	681	604	-
ME (MJ/kg DM)[2]	11.1	11.2	11.2	10.4	9.0	-

1 GS (A) offered from start to 35 days of the trail, GS (B) offered from 35 days until slaughter

[2] GS predicted from Near Infrared Reflectance Spectroscopy using the Hillsborough Feeding Information System; MS, LT1, LT2 Determined through sheep at maintenance energy intake level

GS grass silage, MS maize silage, LT1 lupins/triticale sown sepearately and harvested together, LT2 lupins/triticale sown as a mixture

Table 2 Apparent digestibilities and metabolisable energy concentrations of dietary treatments

	Silage				sem	Significance
	GS	GS:MS	GS:LT1	GS:LT2		
Digestibility coefficient						
Dry matter	0.697[c]	0.657[ab]	0.633[a]	0.675[bc]	0.0087	***
ADF	0.663[b]	0.607[ab]	0.584[a]	0.632[b]	0.0139	**
NDF	0.643[b]	0.569[a]	0.566[a]	0.620[b]	0.0133	**
Gross energy	0.683[c]	0.641[ab]	0.622[a]	0.663[bc]	0.0089	**
Nitrogen	0.570[b]	0.441[a]	0.486[a]	0.546[b]	0.0172	***
D-value (g/kg DM)	642[b]	621[b]	589[a]	632[b]	8.1	**
ME (MJ/kg DM)	11.3[c]	10.5[ab]	10.0[a]	10.9[bc]	0.18	***

GS used in the determination of apparent digestibilities was GS (B)
No significant interaction between silage type and concentrate supplementation level.
GS grass silage, MS maize silage, LT1 lupins/triticale sown sepearately and harvested together, LT2 lupins/triticale sown as a mixture
Means within rows with same superscripts are not significantly different (P>0.05)

feed efficiency when expressed as kg DMI/kg carcass gain relative to animals offered GS:LT 2 ($P<0.05$), but a similar feed efficiency to animals offered GS:MS and GS:LT 1. The higher level of concentrate supplementation reduced silage DM intake ($P<0.001$) and feed efficiency expressed as kg DM intake/kg carcass gain ($P<0.05$).

Silage type had no effect on carcass characteristics (Table 4) or instrumental meat quality (Table 5). However a significant interaction between silage type and concentrate supplementation level was observed on cooking loss (Table 6). When supplemented with 6 kg concentrates/head/day silage type had no effect on meat quality. However, when 3 kg concentrate/head/day were offered, meat from animals offered GS:MS had a higher cooking loss relative to animals offered GS or GS:LT 1 ($P<0.05$). The higher level of concentrate supplementation increased dressing proportion ($P<0.01$). However, level of concentrate supplementation had no significant effect on any other carcass parameters or meat quality characteristics.

Table 4. Effect of including maize silage or lupins/triticale silage sown by two different methods on the performance of beef cattle

	Silage type					Concentrate supplementation level (kg)			Significance	
	GS	**GS:MS**	**GS:LT 1**	**GS:LT 2**	**s.e.m.**	**3**	**6**	**s.e.m.**	**Silage**	**Conc.**
Slaughter live weight (kg)	624	635	631	625	11.0	626	632	7.7	NS	NS
Liveweight gain (kg/day)	0.84	0.81	0.81	0.72	0.060	0.76	0.83	0.042	NS	NS
Carcass gain (kg/day)	0.65	0.64	0.61	0.54	0.067	0.55	0.67	0.026	NS	**
Silage DM intake (kg/day)	5.3[a]	6.1[b]	6.1[b]	6.1[b]	0.18	6.8	5.0	0.13	**	***
Total DM intake (kg/day)	9.4	9.8	9.9	9.7	0.19	9.4	10.1	0.13	NS	***
Feed efficiency										
kg DMI/kg LWG	12.0	16.1	14.0	15.6	1.93	13.5	15.4	1.36	NS	NS
kg DMI/kg carcass gain	15.3[a]	16.7[ab]	17.7[ab]	19.5[b]	1.05	19.6	16.0	0.74	*	*

No significant interaction between silage type and concentrate supplementation level.
GS grass silage, MS maize silage, LT1 lupins/triticale sown sepearately and harvested together, LT2 lupins/triticale sown as a mixture
Means within rows with same superscripts are not significantly different (P>0.05)

Table 5. Effect of including maize silage or lupins/triticale silage sown by two different methods on the carcass characteristics of beef cattle

	Silage type					**Concentrate supplementation level (kg)**			**Significance**	
	GS	**GS:MS**	**GS:LT 1**	**GS:LT 2**	**s.e.m.**	**3**	**6**	**s.e.m.**	**Silage**	**Conc.**
Carcass weight (kg)	355	362	357	350	6.5	350	363	4.5	NS	NS
Dressing proportion (g/kg)	571	571	567	560	4.5	560	575	3.2	NS	**
Conformation classification[1]	3.4	3.3	3.5	3.3	0.12	3.3	3.4	0.09	NS	NS
Fat classification[2]	3.2	3.1	3.2	3.4	0.12	3.2	3.3	0.09	NS	NS
Kidney, cod & channel fat (kg)	15.1	15.7	15.7	15.5	0.85	15.4	15.7	0.60	NS	NS
Subcutaneous fat depth (mm)	3.6	3.8	4.4	4.5	0.38	3.9	4.3	0.27	NS	NS
Marbling score[3]	2.0	1.9	1.9	1.8	1.02	1.9	1.9	0.07	NS	NS
Eye muscle area (mm^2)	70.5	70.9	84.9	70.1	6.91	77.0	71.6	4.85	NS	NS

[1]Conformation based on the EUROP classification system where E=1 and P=5;
[2] Fat classification based on a 5 point scale where 1 = leanest and 5 = fattest
[3] 8 point scale, 1 = low marbling, 8= high marbling
No significant interaction between silage type and concentrate supplementation level
GS grass silage, MS maize silage, LT1 lupins/triticale sown sepearately and harvested together, LT2 lupins/triticale sown as a mixture

Table 6. Effect of including maize silage or lupins/triticale silage sown by two different methods on the instrumental meat quality of beef cattle

	Silage type					**Concentrate supplementation level (kg)**			**Significance**	
	GS	**GS:MS**	**GS:LT 1**	**GS:LT 2**	**s.e.m.**	**3**	**6**	**s.e.m.**	**Silage**	**Conc.**
Warner Bratzler Shear Force (kg)[1]	4.7	1.3	4.2	4.5	0.26	4.5	4.3	0.18	NS	NS
Cooking loss (g/kg)[1]	279	296	281	277	10.7	287	279	7.5	NS	NS
CIELAB colour parameters										
Lightness (L*)	38.5	38.7	42.4	38.8	2.5	38.8	40.6	1.7	NS	NS
Redness (a*)	16.8	16.9	16.2	17.4	1.02	16.6	17.1	0.71	NS	NS
Yellowness (b*)	16.1	14.5	14.7	15.7	0.91	15.4	15.1	0.63	NS	NS
Chroma (C*)	23.5	22.6	22.0	23.6	1.25	22.9	23.0	0.87	NS	NS
Hue angle (^{o})	42.0	43.4	42.2	60.1	9.98	42.6	51.7	6.96	NS	NS

[1] after 14 days aging
No significant interactions between silage type and concentrate supplementation level
GS grass silage, MS maize silage, LT1 lupins/triticale sown sepearately and harvested together, LT2 lupins/triticale sown as a mixture

Table 7 Interaction between silage type and concentrate supplementation level on cooking loss

	Concentrate supplementation level (kg/day)		s.e.m.	Significance
	3	6		
GS	273[a]	285[ab]	15.2	*
GS:MS	323[b]	270[a]		
GS:LT 1	265[a]	296[ab]		
GS:LT 2	289[ab]	266[a]		

Means with same superscripts are not significantly different (P>0.05)
GS grass silage, MS maize silage, LT1 lupins/triticale sown sepearately and harvested together, LT2 lupins/triticale sown as a mixture

Experiment 2

The chemical composition of the silages and concentrates offered are presented in Table 8. The grass silage was well preserved as indicated by its low pH and ammonia N level. Lupins/triticale and vetch/barley wholecrop silage had a pH and ammonia N level of 4.0 and 4.7 and 120 and 140 g/kg N respectively. The CP concentration in L/T wholecrop silage was low at 97 g/kg while for the V/B and grass silages the CP concentrations were 147 and 122 g/kg respectively. Lupins/triticale and vetch/barley had higher concentrations of C18:3 (50.34 and 48.21 g FA/100g total FA, respectively) compared to GS (16.41 g FA/100 g total FA). The prominent FA recorded in GS was C20:1*c* (65.8 g FA/100g total FA).

Table 8 Chemical composition of the silage and concentrate as fed.

	Silage			
	GS	LT	VB	Concentrate
Dry matter (DM) (g/kg fresh)	251	291	304	846
pH	3.87	4.04	4.68	-
Composition of DM (g/kg unless otherwise stated)				
Crude Protein	122	97	147	140
Ammonia N (g/kg N)	90	120	140	-
Acetic Acid	15.9	19.6	41.8	-
Propionic acid	0.99	2.79	11.52	-
n-Butyric Acid	0.87	0.86	0.66	-
Lactic Acid	100.5	48.3	6.4	-
Acid Detergent fibre	336	360	320	92
Neutral detergent fibre	598	561	594	210
Ash	88.3	82.1	121.5	57.9
Starch	5.6	112.3	101.3	-
Gross Energy (MJ/kg DM)	20.6	18.7	18.4	18.2
DOMD (g/kg)a	680			

[1] NIR prediction of grass silage D-value GS grass silage, LT lupins/triticale, VB vetch/barley

Silage digestibilities determined through sheep at maintenance level are presented in Table 9. No differences in DM, nitrogen, organic matter (OM) digestibilities or nitrogen retention were recorded between L/T and V/B wholecrop silage. Offering L/T wholecrop silage increased digestible organic matter (DOMD) ($P<0.05$) compared to V/B wholecrop silage.

Table 9. Silage digestibilities determined through sheep at maintenance level.

Digestibility coefficient	Silage LT	VB	sed	*Sig*
Dry matter	0.617	0.630	0.0242	NS
Organic matter	0.636	0.639	0.0197	NS
DOMD (g/kg)[a]	581	544	17.4	*
Nitrogen	0.322	0.484	0.1911	NS
Nitrogen retained	0.322	0.484	0.1911	NS

[a] Digestibility of organic matter in the dry matter (g/kg); LT lupins/triticale, VB vetch/barley

The effects of silage type on total diet digestibilities and nitrogen retention are presented in Table 10. Offering a diet of solely grass silage increased DM ($P<0.05$), N ($P<0.05$), OM ($P<0.01$), ADF ($P<0.001$) and NDF ($P<0.001$) digestibilities, DOMD ($P<0.01$) and ME concentrations ($P<0.05$) of the diet when compared to L/T, L/T:GS, V/B and V/B:GS diets. Animals offered L/T had a lower ($P<0.001$) NDF digestibility than L/T:GS, V/B and V/B:GS while diet was found to have no effect on nitrogen retention.

Table 10. Effects of silage type on total diet digestibilities

	Silage						
	GS	LT	LT:GS	VB	VB:GS	SED	sig
Digestibility coefficient							
Dry matter	0.779[b]	0.655[a]	0.692[a]	0.646[a]	0.654[a]	0.0287	**
Organic matter	0.779[b]	0.650[a]	0.694[a]	0.646[a]	0.655[a]	0.0291	**
DOMD (g/kg DM)[1]	673[b]	564[a]	600[a]	535[a]	549[a]	25.5	**
Acid detergent fibre	0.757[b]	0.498[a]	0.560[a]	0.498[a]	0.556[a]	0.0429	***
Neutral detergent fibre	0.823[c]	0.648[a]	0.732[b]	0.708[b]	0.746[b]	0.0250	***
Nitrogen	0.703[c]	0.555[a]	0.611[ab]	0.655[bc]	0.654[bc]	0.0369	*
ME (MJ/kg DM)[2]	11.72[b]	9.48[a]	10.07[a]	10.11[a]	9.43[a]	0.581	*
Nitrogen retention	29.5	20.6	30.7	39.8	32.7	6.34	NS

GS Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio;
VB Vetch/barley; Vetch/barley : Grass silage on a 70:30 DM ratio; [1]Digestibility of organic matter in the dry matter (g/kg); [2] metabolisable energy.

The effects of silage type and concentrate feed level on protein and dry matter intakes are presented in Table 11 There were no silage type by concentrate feed level interactions for silage, total DMI or CP intake. Silage type had no effect on silage, total DMI, CP intake or ME intake (MEI). Animals offered V/B or V/B:GS received a smaller ($P<0.05$) amount of soyabean meal than animals offered GS or L/T:GS, with animals on the L/T wholecrop silage receiving the highest ($P>0.05$) amount of soyabean meal. Increasing concentrate level offered to animals decreased silage DMI ($P<0.05$), had no effect on soyabean meal or total DMI ($P>0.05$) and increased CP intake ($P<0.001$).

The effects of silage type and concentrate feed level on animal performance are presented in Table 12. Relative to grass silage, animals offered V/B or L/T wholecrop silage as either a sole forage or in combination with grass silage had a lower liveweight gain ($P<0.01$), carcass gain and carcass weight ($P<0.001$). Animals offered L/T, V/B and V/B:GS had a lower liveweight at slaughter than animals offered GS. Increasing concentrate feed level from 2 to 5 kg/day increased ($P<0.001$) final liveweight, liveweight gain, carcass gain and carcass weight. Concentrate level offered to animals had no effect on ($P>0.05$) marbling score, dressing percentage, carcass conformation, subcutaneous fat depth or eye muscle area of the LD muscle at the 10/11th rib. Silage type recorded no effect on DMI/liveweight gain, liveweight gain/MEI, DMI/carcass gain and carcass gain/MEI.

Table 11. Effects of silage type and concentrate feed level on dry matter, protein and energy intake.

	Silage (S)						Concentrate (C) (kg/day)			*Sig*[1]	
	GS	LT	LT:GS	VB	VB:GS	SED	2	5	SED	S	C
Silage DMI (kg/day)	6.50	6.89	7.25	6.14	6.65	0.547	7.18	6.2	0.346	NS	*
Soya bean DMI (kg/day)	0.30[b]	0.53[c]	0.33[b]	0.05[a]	0.03[a]	0.072	0.26	0.24	0.045	*	NS
Total DMI (kg/day)	9.82	10.48	10.68	9.19	9.69	0.560	9.18	10.76	0.354	NS	**
CP[2] intake (g/day)	1353	1348	1358	1344	1362	18.7	1239	1468	11.6	NS	***
Total ME[3] intake (MJ/day)[a]	109.8	88.7	99.2	83.1	85.6	8.24				NS	

GS Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio; VB Vetch/barley; VB:GS Vetch/barley : Grass silage on a 70:30 DM ratio; [1]No significant interaction between silage and concentrate supplementation. [2] Crude Protein. [3] Metabolisable Energy

Table 12. Effect of silage and concentrate level on food intake and animal performance

	Silage (S)						Concentrate (kg/day) (C)			*Sig*[1]	
	GS	LT	LT:GS	V/B	V/B:GS	SED	2	5	SED	S	C
Liveweight at slaughter (kg)	665[b]	649[ab]	633[a]	635[a]	644[a]	8.9	623	668	6.3	**	***
Liveweight gain (kg/day) [2i]	0.94[b]	0.75[a]	0.63[a]	0.63[a]	0.71[a]	0.076	0.55	0.91	0.046	***	***
DMI/liveweight gain (kg/kg) [j]	10.7	16.7	15.4	25.9	16.3	3.64				NS	
Liveweight gain/MEI (g/MJ) [j]	7.76	6.91	6.59	4.80	6.97	0.546				NS	
Carcass gain (kg/day) [3]	0.51[b]	0.40[a]	0.31[a]	0.35[a]	0.37[a]	0.043	0.28	0.49	0.026	***	***
Carcass weight (kg)	366[b]	353[a]	347[a]	345[a]	348[a]	4.5	339	365	2.7	***	***
DMI/carcass gain (kg/kg) [j]	13.5	29.5	29.8	35.5	67.1	24.52				NS	
Carcass gain/MEI (g/MJ) [j]	4.30	3.15	3.19	3.01	2.76	0.683				NS	

GS Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio; VB Vetch/barley; VB:GS Vetch/barley : Grass silage on a 70:30 DM ratio; [1] No significant interaction between silage and concentrate supplementation. [2]Values predicted from regression analysis [3] Carcass gain was calculated per steer using an equation to calculate initial carcass weight derived by Keady and Kilpatrick (2005).

The effects of silage type and concentrate feed level on carcass characteristics are presented in Table 13. Silage type offered to animals had no effect ($P>0.05$) on marbling score, dressing proportion, carcass conformation, fat class, subcutaneous fat depth or eye muscle area of the LD muscle at the 10/11th rib. Increasing concentrate feed level from 2 to 5kg/day increased ($P<0.001$) KCC fat weight. Concentrate level had no effect on ($P>0.05$) marbling score, subcutaneous fat depth or eye muscle area of the LD muscle at the 10/11th rib.

Effect of silage type and concentrate feed level on lean colour and meat quality is presented in Table 14. Silage type had no effect on pH or instrumental meat quality of the LD. Concentrate level had no effect on instrumental meat quality of the LD although animals offered 5 kg concentrate/head/day had a higher pH (5.59) ($P<0.05$) compared with animals offered 2 kg concentrate/head/day (5.53).

Table 13. Effect of silage and concentrate level on carcass characteristics

	Silage (S)						Concentrate (kg/day) (C)			*Sig*[1]	
	GS	LT	LT:GS	VB	VB:GS	SED	2	5	SED	S	C
Dressing proportion (g carcass weight/kg liveweight)	556	544	546	542	542	7.9	544	548	4.7	NS	NS
Conformation class [2]	3.37	3.42	3.36	3.23	3.10	0.179	3.20	3.38	0.107	NS	NS
Fat class [3]	2.98	2.91	2.80	3.05	2.82	0.191	2.70	3.13	0.114	NS	***
Sub fat depth (mm)	7.1	5.51	5.13	5.85	5.23	0.839	5.15	6.38	0.502	NS	*
Eye muscle area (cm^2)	78.0	74.7	77.5	74.9	73.1	4.42	77.9	93.5	2.87	NS	NS
Kidney, cod and channel fat (kg)	15.9[b]	14.4[a]	13.4[a]	13.4[a]	13.4[a]	1.07	12.7	15.6	0.64	*	***
Marbling score [4]	1.88	1.43	1.43	1.74	1.70	0.288	1.44	1.65	0.187	NS	NS
Estimated carcass composition (g/kg)[5]											
Subcutaneous fat	38.2	41.3	37.0	37.2	41.3	11.70	37.6	41.6	7.20	NS	NS
Intramuscular fat	228	212	265	230	242	60.2	224	255	37.1	NS	NS
Lean	496	506	460	510	469	54.2	499	471	30.4	NS	NS
Bone	221	239	238	221	242	14.0	239	232	8.6	NS	NS

GS Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio; VB Vetch/barley; VB:GS Vetch/barley : Grass silage on a 70:30 DM ratio; [1] No significant interaction between silage and concentrate supplementation; [2] EUROP scale: 5,4,3,2,1 respectively; [3] EU fat classification where 5 = fat, 1 = lean; [4] Marbling score based on a score of 1 = low marbling, 8 = high marbling. [5] Based on dissection of forerib joint

Table 14. Effect of silage type and concentrate feed level on lean colour and instrumental meat quality of *longissimus dorsi* (LD).

	Silage (S)						Concentrates (kg/day) (C)			*Sig*[1]	
	GS	LT	LT:GS	VB	VB:GS	SED	2	5	SED	S	C
Ultimate pH	5.54	5.53	5.53	5.55	5.63	0.041	5.53	5.59	0.026	NS	NS
Sarcomere length (um)	2.96	2.65	2.54	2.78	2.74	0.127	2.67	2.69	0.081	NS	NS
Cooking Loss (%)										NS	NS
7 day	31.7	30.1	30.8	29.9	30.0	0.78	30.7	30.1	0.49	NS	NS
21 day	31.1	31.8	32.1	31.3	31.6	0.69	31.7	31.6	0.44	NS	NS
WBSF[2] (kg/cm^2)										NS	NS
7 day	3.10	3.04	2.98	2.97	3.21	0.164	3.08	3.03	0.104	NS	NS
21 day	3.05	3.21	3.22	3.09	3.17	0.139	3.12	3.17	0.088	NS	NS
Lean Colour										NS	NS
L*	34.2	30.9	32.8	33.4	34.3	1.95	33.0	33.2	1.24	NS	NS
a*	19.7	19.9	20.2	19.3	19.5	1.15	20.1	19.3	0.73	NS	NS
b*	14.3	13.5	12.9	13.2	13.6	0.89	13.7	13.4	0.56	NS	NS
Chroma	24.4	24.1	24.0	23.4	23.8	1.36	24.3	23.5	0.86	NS	NS
Hue	36.0	34.3	32.5	34.4	34.7	0.32	34.2	34.6	0.83	NS	NS

GS Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio; VB Vetch/barley; VB:GS Vetch/barley : Grass silage on a 70:30 DM ratio; [1] No significant interaction between silage and concentrate supplementation; [2] Warner Bratzler Shear Force

Effect of silage type and concentrate feed level on FA composition of the LD of continental finished steers, espressed as g FA/100g FA is presented in Table 15, with fatty acids expressed as g FA/g of tissue presented in Table 16.

When expressing fatty acids as g FA/100g FA meat from animals offered V/B:GS had a higher ($P<0.05$) concentration of C18:1*c*11 than animals offered L/T:GS or GS. Increasing concentrate level offered to animals from 2 to 5 kg increased ($P<0.05$) concentration of C16:0 and *n*-6:*n*-3 PUFA ratio whilst decreasing ($P<0.05$) the concentration of C18:3*n*-3 of lean meat.

When expressing fatty acids as mg FA/g of tissue meat from animals offered V/B:GS had a lower ($P<0.05$) concentration of C18:1*t*9 compared to animals offered V/B or L/T wholecrop silage. Animals offered V/B:GS had a higher ($P<0.05$) *n*-6:*n*-3 ratio from lean meat in comparison to animals offered GS and L/T:GS wholecrop silage. Increasing concentrate level offered to animals from 2 to 5 kg increased ($P<0.05$) concentration of C12:0 of lean meat.

Table 15. Effect of silage type and concentrate feed level on fatty acid (FA) composition from the *longissimus dorsi* (g FA/100g FA) of continental finished steers

	Silage (S)						Concentrate (C) (kg/day)			*Sig*[1]	
Fatty acid	GS	LT	LT:GS	VB	VB:GS	SED	2	5	SED	S	C
C12:0	0.095	0.106	0.090	0.088	0.061	0.0146	0.081	0.095	0.0079	NS	NS
C14:0	1.96	1.72	2.20	2.35	1.79	0.298	1.96	2.04	0.171	NS	NS
C16:0	27.3	26.2	26.6	27.5	26.6	0.94	26.2	27.5	0.54	NS	*
C18:0	17.6	17.2	17.8	17.8	17.4	0.86	17.8	17.3	0.49	NS	NS
C18:1*c11*	1.16[a]	1.27[ab]	1.27[ab]	0.961[a]	1.66[b]	0.229	1.25	1.27	0.131	*	NS
C18:1*c9*	36.1	37.3	35.7	36.1	34.6	0.96	35.8	36.2	0.55	NS	NS
C18:1*t9*	0.388	0.545	0.350	0.391	0.391	0.1052	0.404	0.422	0.0602	NS	NS
C18:2*n*-6	3.48	4.03	3.26	3.37	5.04	0.736	4.01	3.66	0.421	NS	NS
C18:3*n*-3	1.02	0.95	0.97	0.97	1.17	0.141	1.10	0.93	0.081	NS	NS
C20:4*n*-6	0.968	1.146	0.959	0.899	1.44	0.224	1.16	1.00	0.128	NS	NS
C20:5*n*-3	0.396	0.405	0.355	0.302	0.542	0.1026	0.411	0.389	0.0588	NS	NS
Total MUFA[2]	43.9	45.0	43.9	43.4	42.8	0.83	43.7	43.9	0.45	NS	NS
Total SFA[3]	49.2	47.3	49.0	49.9	47.9	1.26	48.3	49.0	0.69	NS	NS
n-4[4]	1.89	1.90	1.99	1.75	2.42	0.366	2.16	1.89	0.206	NS	NS
n-6[5]	4.25	5.04	4.38	4.25	6.29	0.962	5.17	4.67	0.540	NS	NS
Total PUFA[6]	6.43	7.28	6.66	6.25	8.93	1.284	7.63	6.79	0.722	NS	NS
PUFA : SFA	0.135	0.156	0.137	0.128	0.188	0.0295	0.160	0.142	0.0166	NS	NS
n-6:*n*-3 ratio	2.20	2.63	2.20	2.42	2.63	0.167	2.35	2.48	0.091	NS	*
Total CLA[7]	0.435	0.447	0.401	0.402	0.366	0.1035	0.408	0.393	0.0588	NS	NS
Total *trans*-FA[8]	3.66	3.58	3.78	3.36	3.45	0.635	3.73	3.43	0.347	NS	NS

Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio; VBVetch/barley; [8]VB:GSVetch/barley : Grass silage on a 70:30 DM ratio; [1] No significant interaction between silage and concentrate supplementation. [2] Monounsaturated fatty acid (C14:1*c*9; C15:1*c*10; C16:1*t*9; C16:1*c*9; C17:1*c*10; C18:1*c*9; C18:1*c*11) [3] Saturated fatty acid (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0) [4] *n*-3 (C18:3*n*-3; C20:5*n*-3) [5] *n*-6 (C18:2*n*-6; C20:4*n*-6) [6] Polyunsaturated fatty acid (C18:2 *n*-6; C18:3 *n*-3; C20:4 *n*-6; C20:5 *n*-3; C22:5 *n*-3; C22:6 *n*-3). [7] Conjugated linoleic acid (C18:2 c9 *t*11; C18:2 *t*10 *c*12). [8] *trans*-FA (C18:1*t*9; C18:1*t*11; C18:2).

Table 16. Effect of silage type and concentrate feed level on fatty acid (FA) composition from the *longissimus dorsi* (mg FA/kg of lean) of continental finished steers

	Silage (S)						Concentrate (C) (kg/day)			*Sig*[1]	
Fatty acid	GS	LT	LT:GS	VB	VB:GS	SED	2	5	SED	S	C
C12:0	0.011	0.016	0.015	0.008	0.012	0.0129	0.005	0.020	0.0072	NS	*
C14:0	1.14	0.65	1.26	1.57	0.48	0.572	0.81	1.23	0.318	NS	NS
C16:0	15.9	12.8	15.1	18.1	9.0	5.13	11.7	16.7	2.85	NS	NS
C18:0	10.9	8.8	10.2	11.8	6.1	3.04	8.2	10.9	1.69	NS	NS
C18:1*t*9	0.206[ab]	0.293[b]	0.197[ab]	0.247[b]	0.138[a]	0.0543	0.194	0.239	0.0302	*	NS
C18:1*c*9	20.6	19.2	20.0	23.4	12.0	5.97	16.2	21.9	3.32	NS	NS
C18:1*c*11	0.696	0.753	0.649	0.625	0.633	0.1813	0.574	0.768	0.1009	NS	NS
C18:2 *n*-6	1.70	1.91	1.89	1.95	1.71	0.249	1.76	1.91	0.139	NS	NS
C18:3 *n*-3	0.536	0.444	0.570	0.573	0.384	0.1072	0.506	0.497	0.5963	NS	NS
C20:4 *n*-6	0.473	0.542	0.507	0.487	0.492	0.0508	0.495	0.506	0.0283	NS	NS
C20:5 *n*-3	0.205	0.196	0.189	0.173	0.180	0.0235	0.186	0.192	0.0131	NS	NS
TOTAL FA	57.7	49.8	55.8	64.2	33.9	16.84	44.4	60.1	9.37	NS	NS
Total MUFA[2]	23.4	21.7	23.0	26.5	13.9	6.84	18.4	25.0	3.80	NS	NS
Total SFA[3]	28.8	22.9	27.5	32.4	16.0	8.99	21.4	29.6	5.00	NS	NS
n-3[4]	1.05	0.96	1.08	1.03	0.83	0.135	0.97	1.00	0.075	NS	NS
n-6[5]	2.17	2.45	2.39	2.44	2.20	0.283	2.25	2.41	0.157	NS	NS
Total PUFA[6]	3.22	3.41	3.47	3.47	3.03	0.405	3.23	3.41	0.225	NS	NS
PUFA : SFA	0.135	0.154	0.130	0.125	0.192	0.0284	0.157	0.138	0.0158	NS	NS
n-6:*n*-3 ratio	2.24[a]	2.66[b]	2.28[a]	2.51[ab]	2.78[b]	0.180	2.47	2.52	0.100	*	NS
Total CLA[7]	0.237	0.235	0.230	0.230	0.086	0.1485	0.149	0.258	0.0827	NS	NS
Total *trans*-FA[8]	2.06	1.56	1.62	1.61	0.94	0.784	1.28	1.83	0.436	NS	NS

GS Grass silage; LT Lupins/triticale; LT:GS: Lupins/triticale : Grass silage on a 70:30 DM ratio; VB Vetch/barley; [g] Vetch/barley : Grass silage on a 70:30 DM ratio; [1] No significant interaction between silage and concentrate supplementation. [2] Monounsaturated fatty acid (C14:1*c*9; C15:1*c*10; C16:1*t*9; C16:1*c*9; C17:1*c*10; C18:1*c*9; C18:1*c*11) [3] Saturated fatty acid (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0) [4] *n*-3 (C18:3*n*-3; C20:5*n*-3) [5] *n*-6 (C18:2*n*-6; C20:4*n*-6) [6] Polyunsaturated fatty acid (C18:2 *n*-6; C18:3 *n*-3; C20:4 *n*-6; C20:5 *n*-3; C22:5 *n*-3; C22:6 *n*-3). [7] Conjugated linoleic acid (C18:2 c9 *t*11; C18:2 *t*10 *c*12). [8] *trans*-FA (C18:1*t*9; C18:1*t*11; C18:2).

Experiment 3

The chemical composition of the silage and concentrate offered are presented in Table 17. Both PGS and FGS were well preserved as indicated by their low pH and high lactic acid levels. The legume/cereal wholecrop silages had a less successful fermentation than the two grass silages. However L/T wholecrop silage had the highest dry matter of 457 g/kg and a more successful fermentation with a lower pH (4.5) and higher lactic acid concentration (23.63 g/kg DM) than L/W and P/O (4.9 and 4.7 and 4.23 and 2.67 g/kg DM for pH and lactic acid concentration, respectively).

Table 17. Chemical composition of the silages and concentrates as fed.

	Silage type					
	PGS	FGS	LT	LW	PO	Concentrates
Oven Dry Matter (g/kg)	268	264	457	354	293	851.1
pH	3.9	4.0	4.5	4.9	4.7	-
Composition of DM (g/kg)						
Crude protein	132	124	233	182	102	140
Ammonia N (g/kg N)	76	88	125	142	109	-
Acetic Acid	12.3	14.7	17.4	34.4	46.6	-
Propionic Acid	1.32	0.90	1.75	9.02	8.34	-
Butyric Acid	2.43	0.39	0.27	0.57	0.52	-
Lactic Acid	125.2	84.7	23.6	4.2	2.7	-
Acid detergent fibre	316	302	387	409	349	89
Neutral detergent fibre	545	520	638	628	578	213
Water soluble carbohydrate	10.75	10.75	4.27	2.68	2.56	44.91
Ash	117	101	88	92	99	59
Starch	4.70	4.20	129	108	145	-
Gross Energy (MJ/kg DM)	20.5	19.3	18.9	19.1	20.2	18.1
DOMD (g/kg DM)[1]	690	673	-	-	-	-

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
[1] NIR prediction of grass silage D-value.

Field samples of the legume/cereal wholecrops indicated that peas/oats had the highest proportion of foreign species (plant material that is neither a cereal or legume plant sown) and lowest proportion of legumes (Table 18). In contrast LW had a similar proportion of legume and cereal plants with LT having a lower proportion of legume than cereal plants.

Table 18. Plant identification of legume:cereal crops pre-harvest.

Legume/cereal	Proportion of crop sampled (fresh weight)		
	Legume	Cereal	Foreign species[a]
Lupins/triticale	0.29 (10)	0.59 (128)	0.12
Lupins/wheat	0.47 (13)	0.49 (148)	0.04
Peas/oats	0.16 (11)	0.58 (94)	0.26

[a] plant material that is neither a cereal or legume plant sown.
(In backets is the number of plants)

Silage digestibilities determined through sheep at maintenance level are presented in Table 19. Perennial ryegrass based grass silage and FGS produced a higher (P<0.001) dry matter, organic matter, DOMD and ME digestibility relative to the legume/cereal wholecrop silages. Lupins/wheat wholecrop silage had a higher (P<0.001) dry matter, organic matter, DOMD and ME digestibility relative to P/O wholecrop silage. Animals offered PGS had a higher (P<0.001) nitrogen retention than animals offered FGS. Animals offered FGS had a higher (P<0.001) nitrogen retention than animals offered any of the legume/cereal wholecrop silages.

Table 19. Silage digestibilities determined through sheep at maintenance level.

	Silage type						
Digestibility coefficient	PGS	FGS	LT	LW	PO	sed	sig
Dry matter	0.731^{c}	0.723^{c}	0.571^{ab}	0.595^{b}	0.532^{a}	0.0264	***
Organic matter	0.738^{c}	0.733^{c}	0.594^{ab}	0.618^{b}	0.555^{a}	0.0251	***
DOMD [1]	651^{c}	636^{c}	539^{ab}	562^{b}	502^{a}	20.7	***
ME (MJ/kg DM)	11.4^{d}	11.3^{d}	10.7^{c}	10.3^{b}	9.8^{a}	0.08	***
Nitrogen retention (g/day)	36.1^{c}	22.8^{b}	12.6^{a}	7.7^{a}	12.4^{a}	5.148	***

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
[1] Digestibility of organic matter

The effects of silage type on total diet digestibilities are presented in Table 20. Offering either PGS or FGS increased dry matter and organic matter digestibility (P<0.01) and DOMD (P<0.001) relative to L/T, L/W or P/O wholecrop silage. Animals offered PGS, L/T or L/W wholecrop silage had a higher (P<0.01) ADF digestibility than FGS or P/O wholecrop silage.

Animals offered PGS had a higher (P<0.001) NDF digestibility than FGS or L/T wholecrop silage which also had a higher (P<0.001) NDF digestibility compared to animals offered L/W or P/O wholecrop silage. Animals offered either PGS or FGS had a higher (P<0.05) ME concentration than animals offered L/W and P/O wholecrop silage. Animals offered L/T wholecrop silage had a higher (P<0.05) ME concentration than animals offered L/W wholecrop silage.

Table 20. Effects of silage type on total diet digestibilities

	Silage type						
Digestibility coefficient	PGS	FGS	LT	LW	PO	sed	sig
Dry matter	0.762^{c}	0.722^{b}	0.701^{ab}	0.697^{ab}	0.680^{a}	0.0182	**
Organic matter	0.773^{d}	0.748^{cd}	0.721^{bc}	0.694^{ab}	0.680^{a}	0.0182	**
DOMD [1]	660^{c}	646^{c}	613^{b}	601^{ab}	584^{a}	10.1	***
ME (MJ/kg DM)	12.01^{c}	11.97^{c}	11.56^{bc}	10.88^{a}	10.99^{ab}	0.327	*
Acid detergent fibre	0.657^{b}	0.560^{a}	0.669^{b}	0.640^{b}	0.566^{a}	0.0246	**
Neutral detergent fibre	0.784^{c}	0.713^{b}	0.727^{b}	0.695^{a}	0.658^{a}	0.0191	***

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
[1] Digestibility of organic matter

A significant silage type by concentrate level interaction for silage (P<0.001) and total dry matter intake (DMI) (P<0.001) was obtained (Table 21). Silage DMI decreased by 1.99 kg DM for animals offered L/T wholecrop silage when concentrate level increased from 4 to 7 kg head/day, in contrast to animals offered P/O wholecrop silage where no difference in silage DMI between concentrate supplementation levels was obtained. Animals offered P/O wholecrop silage had a lower total DMI relative to animals offered PGS, L/T and L/W wholecrop silage at 4 kg concentrate/head/day. However for animals offered 7 kg concentrate/head/day animals offered P/O wholecrop silage had the highest total DMI.

Table 21. Effects of silage type and concentrate feed level on dry matter intake.

	Concentrate level (C) (kg/day)	Silage (S) PGS	FGS	LT	LW	PO	sed	Significance S	C	S x C
Silage DMI (kg/day)	4	6.71[f]	5.71[de]	6.80[f]	6.80[f]	6.07[e]	0.219	***	***	***
	7	5.31[cd]	4.30[a]	4.81[b]	5.26[c]	5.90[e]				
Total DMI (kg/day)	4	10.04[b]	9.04[a]	10.12[b]	10.12[b]	9.40[a]	0.219	***	***	***
	7	11.13[d]	10.13[b]	10.64[c]	11.08[cd]	11.72[e]				

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.

The effect of silage type and concentrate feed level on animal performance and feed efficiency is presented in Table 22. Silage type had no effect on liveweight at slaughter, liveweight gain, carcass weight or carcass gain. However animals offered PGS, FGS or P/O wholecrop silage had a lower DMI/liveweight gain and DMI/carcass gain and a higher liveweight gain/MEI and carcass gain/MEI relative to animals offered L/T wholecrop silage ($P<0.05$). Increasing concentrate level from 4 to 7kg head/day increased liveweight at slaughter ($P<0.05$), liveweight gain ($P<0.01$), carcass weight ($P<0.01$) and carcass gain ($P<0.01$).

Silage type and concentrate feed level had no effect on carcass characteristics (Table 23). Animals offered solely PGS produced a higher fat concentration in fore-rib joint in comparison to animals offered FGS, L/T and P/O wholecrop silage.

A silage type by concentrate feed level interaction was recorded for carcass weight ($P<0.05$) and KCC ($P<0.01$) fat weight as seen in Table 24. At a concentrate inclusion rate of 4 kg head/day, animals offered L/T and P/O wholecrop silage had a lower ($P<0.05$) carcass weight compared to animals offered L/W, FGS and PGS and animals offered any of the 5 silage types when supplemented with 7 kg concentrate head/day. No difference ($P>0.05$) was recorded between KCC fat weight when comparing the two concentrate feed levels in any of the individual legume:cereal wholecrop silages offered. However animals offered PGS with 4 kg concentrate head/day or FGS with 7 kg concentrate head/day had a greater ($P<0.01$) KCC fat weight than animals offered PGS with 7 kg concentrate head/day and FGS with 4 kg concentrate head/day.

Table 22. Effect of silage type and concentrate feed level on animal performance and feed efficiencies.

	Silage (S)						Concentrate (kg/day) (C)			Significance		
	PGS	FGS	LT	LW	PO	sed	4	7	sed	S	C	S x C
Liveweight at slaughter (kg)	685	678	664	672	680	7.7	669	682	4.9	NS	*	NS
Liveweight gain (kg/day)	1.06	0.97	0.90	0.97	1.02	0.670	0.92	1.05	0.043	NS	**	NS
DMI/liveweight gain (kg/kg) [c]	8.67[a]	8.56[a]	12.92[b]	10.90[ab]	9.45[a]	1.266				*		
Liveweight gain/MEI (g/MJ) [c]	10.2[bc]	10.2[bc]	7.8[a]	8.9[ab]	10.8[c]	0.95				*		
Carcass weight (kg)	376	375	362	368	370	5.1	365	375	3.3	NS	**	*
Carcass gain (g/day)	0.612	0.611	0.513	0.550	0.567	0.0432	0.527	0.614	0.0276	NS	**	NS
DMI/carcass gain (kg/kg)	18.2[ab]	15.8[a]	25.4[c]	22.3[bc]	19.7[ab]	2.54				*		
Carcass gain/MEI (g/MJ)	5.0[bc]	5.8[c]	3.9[a]	4.5[ab]	5.2[bc]	0.59				*		

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
MEI metabolisable energy intake, DMI dry matter intake

Table 23. Effect of silage type and concentrate feed level on carcass characteristics.

	Silage (S)						Concentrate (kg/day) (C)			Significance		
	PGS	FGS	LT	LW	PO	sed	4	7	sed	S	C	S x C
Conformation class[1]	3.10	3.16	3.18	3.05	2.95	0.139	3.07	3.11	0.090	NS	NS	NS
Fat class[2]	3.51	3.65	3.43	3.40	3.68	0.210	3.53	3.53	0.136	NS	NS	NS
Sub fat depth (mm)	8.77	8.21	8.25	7.34	7.87	1.000	7.66	8.51	0.642	NS	NS	NS
Marble score	3.26	2.67	3.00	2.59	3.07	0.322	2.79	3.04	0.205	NS	NS	NS
Eye muscle area	73.5	76.8	69.5	76.4	68.7	4.02	71.1	74.8	2.59	NS	NS	NS
KCC fat (kg)[3]	16.2	14.7	14.4	15.6	15.2	1.38	15.2	15.2	0.90	NS	NS	**
Estimated carcass composition (g/kg)[4]												
Lean concentration	475	489	502	499	492	18.0	498	485	10.2	NS	NS	NS
Fat concentration	341^{b}	296^{ab}	281^{a}	296^{ab}	296^{ab}	23.6	295	309	13.4	*	NS	NS
Bone concentration	184^{a}	215^{b}	217^{b}	205^{ab}	212^{b}	12.2	270	206	6.9	*	NS	NS

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
[1] EUROP scale : 5,4,3,2,1, respectively. [2] EU fat classification, 5 = fat, 1 = lean. [3] KCC Kidney, cod and channel fat [4] Based on dissection of forerib joint

Table 24. Interaction between silage type and concentrate feed level on animal performance and carcass assessments.

	Concentrate level (C) (kg/day)	Silage (S)					sed	Sig
		PGS	FGS	LT	LW	PO		S x C
Carcass weight (kg)	4	376^{d}	376^{cd}	351^{a}	362^{abc}	359^{ab}	7.2	*
	7	375^{cd}	374^{cd}	373^{bcd}	374^{bcd}	380^{d}		
KCC fat (kg)	4	19.0^{d}	11.7^{a}	14.1^{abc}	15.9^{bcd}	15.5^{abcd}	1.94	**
	7	13.4^{ab}	17.6^{cd}	14.7^{abc}	15.3^{abcd}	14.9^{abc}		

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS KCC Kidney cod and channel fat .

Effect of silage type and concentrate feed level on lean colour and meat quality is presented in Table 25. Silage type had no effect on LD weight, pH or instrumental meat quality of the LD. Concentrate level had no effect (P>0.05) on LD weight, pH, cooking loss or shear force of the LD. An increase in concentrate level offered from 4 to 7 kg head/day produced an increase (P<0.05) in a*, b* and chroma values.

A silage type by concentrate feed level interaction was recorded for Hue as seen in Table 26. Animals offered L/W and P/O wholecrop silage at both 4 and 7 kg concentrate head/day, PGS and FGS with 4 kg concentrate head/day and L/T wholecrop silage with 7 kg concentrate head/day had a higher Hue than animals offered L/T wholecrop silage with 4 kg concentrate head/day.

Effect of silage type and concentrate feed level on FA composition of the LD of continental finished steers, expressed as g FA/100g FA is presented in Table 27, with fatty acids expressed as g FA/g of tissue presented in Table 28.

When expressing fatty acids as g FA/100g FA silage type had no effect on fatty acid composition of lean beef. Increasing concentrate feed level from 4 to 7 kg concentrate head/day increased the concentration of C18:1*c*9 (P<0.001) and total MUFA (P<0.01), whilst decreasing the concentration of C16:0 (P<0.05), C17:0 (P<0.01), C18:3*n*-3 (P<0.05) and total SFA (P<0.01).

When expressing fatty acids as mg FA/g of tissue, silage type had no effect on fatty acid composition of lean beef. Increasing concentrate feed level from 4 to 7 kg concentrate head/day increased the concentration of C18:1c9 (P<0.05), C18:2 *n*-6 (P<0.05), CLA 10 12 (P<0.01), C20c (P<0.05), total MUFA (P<0.05), *n*-6 PUFA (P<0.05) and total PUFA (P<0.05).

Table 25. Effect of silage type and concentrate feed level on lean colour and instrumental meat quality of *longissimus dorsi*.

	Silage (S)					Concentrate (kg/day) (C)		sed	Significance		
	PGS	FGS	LT	LW	PO	4	7	sed	S	C	S x C
LD weight	1.23	1.31	1.14	1.27	1.16	1.18	1.26	0.124	NS	NS	NS
pH	5.59	5.57	5.57	5.57	5.57	5.56	5.58	0.030	NS	NS	NS
Sarcomere	2.35	2.35	2.25	2.32	2.34	2.32	2.33	0.173	NS	NS	NS
Cooking loss (%)											
Day 7	27.4	26.3	27.6	27.7	27.6	27.5	27.1	0.87	NS	NS	NS
Day 21	29	28.4	29.7	29.7	29.3	29.6	28.8	1.07	NS	NS	NS
Shear force 1 – selected data											
Day 7	4.88	4.34	4.55	4.79	4.61	4.51	4.76	0.307	NS	NS	NS
Day 21	4.4	4.16	4.44	4.42	4.16	4.27	4.36	0.218	NS	NS	NS
Lean Colour											
L*	40.5	40.7	39.9	41.7	40.3	41.2	40	1.87	NS	NS	NS
a*	25.6	25.6	25	24.3	26	24.5	26.1	1.61	NS	*	NS
b*	17.1	16.9	15.8	16.3	17.6	16.2	17.3	1.26	NS	*	NS
Hue	33.8	33.5	32.1	33.9	33.8	33.4	33.4	1.12	NS	NS	*
chroma	30.8	30.6	29.6	29.3	61.4	29.3	31.4	1.96	NS	*	NS

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.

Table 26. Effect of silage type and concentrate level on meat colour.

	Concentrate level (kg/day)	Silage type (S)					SED	Sig
		PGS	FGS	LT	LW	PO		
Hue	4	34.8[b]	34.4[b]	30.8[a]	33.6[b]	33.4[b]	1.12	*
	7	32.8[ab]	32.6[ab]	33.3[b]	34.14[b]	34.2[b]		

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.

Table 27. Effect of silage type and concentrate feed level on fatty acid (FA) composition from the *longissimus dorsi* (mg FA/100 g FA) of continental finished steers

	Silage type (S)						Concentrate level (k/day) (C)			Significance[1]	
	PGS	FGS	LT	LW	PO	sed	4	7	sed	S	C
C14:0	3.91	3.37	3.50	3.38	3.12	3.777	3.62	3.29	0.233	NS	NS
C16:0	28.2	27.8	28.3	28.3	28.1	0.65	28.5	27.7	0.40	NS	NS
C17:0	0.969	1.06	1.04	1.07	1.05	0.062	1.09	0.98	0.038	NS	**
C18:0	15.2	16.3	16.0	16.4	16.0	0.85	16.2	15.8	0.53	NS	NS
C18:1 *c*9	42.4	42.0	41.6	40.9	41.8	0.93	40.7	42.8	0.57	NS	***
C18:1 *c*11	0.330	0.382	0.343	0.422	0.349	0.0683	0.353	0.377	0.0422	NS	NS
C18:1 *t*11	0.302	0.268	0.201	0.431	0.673	0.2983	0.430	0.320	0.1842	NS	NS
C18:2 *n*-6	2.10	2.62	2.62	2.87	2.67	0.375	2.53	2.62	0.231	NS	NS
C18:3 *n*-3	0.603	0.736	0.606	0.638	0.604	0.0787	0.697	0.578	0.0486	NS	*
CLA *c*9 *t*11	0.252	0.234	0.245	0.237	0.284	0.0400	0.247	0.254	0.0247	NS	NS
CLA *t*10*c*12	0.159	0.150	0.094	0.122	0.167	0.0377	0.120	0.157	0.0233	NS	NS
C20:4*n*-6	0.429	0.509	0.568	0.649	0.538	0.1061	0.534	0.544	0.0655	NS	NS
C20:5*n*-3	0.095	0.164	0.098	0.139	0.114	0.0328	0.127	0.117	0.0202	NS	NS
C22:5*n*-3	0.0693	0.0464	0.0134	0.0696	0.0894	0.03239	0.0552	0.0600	0.02000	NS	NS
Total MUFA[2]	47.1	46.0	46.0	44.9	45.7	0.93	45.0	46.9	0.57	NS	**
Total SFA[3]	48.7	49.0	49.4	49.7	48.8	0.90	50.0	48.2	0.55	NS	**
n-3[4]	0.79	0.957	0.712	0.849	0.852	0.1188	0.892	0.772	0.0733	NS	NS
n-6[5]	2.53	3.13	3.19	3.53	3.20	0.473	3.07	3.16	0.292	NS	NS
Total PUFA[6]	3.32	4.08	3.90	4.38	4.05	0.570	3.96	3.94	0.352	NS	NS
Total CLA[7]	0.411	0.384	0.339	0.359	0.451	0.0655	0.367	0.411	0.0404	NS	NS
Total trans FA[8]	0.537	0.536	0.429	0.648	0.988	0.3112	0.722	0.534	0.1922	NS	NS
P:S ratio	0.0699	0.0840	0.0818	0.0902	0.0840	0.01242	0.0811	0.0829	0.00767	NS	NS

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
[1]No significant interaction between silage and concentrate supplementation. [2] Monounsaturated fatty acid (C14:1*c*9; C15:1*c*10; C16:1*t*9; C16:1*c*9; C17:1*c*10; C18:1*c*9; C18:1*c*11) [3] Saturated fatty acid (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0) [4] *n*-3 (C18:3*n*-3; C20:5*n*-3; ???) [h] *n*-6 (C18:2*n*-6; C20:4*n*-6) [5]Polyunsaturated fatty acid (C18:2 *n*-6; C18:3 *n*-3; C20:4 *n*-6; C20:5 *n*-3; C22:5 *n*-3; C22:6 *n*-3). [6] Conjugated linoleic acid (C18:2 c9 *t*11; C18:2 *t*10 *c*12). [7] *trans*-FA (C18:1*t*9; C18:1*t*11; C18:2).

Table 28. Effect of silage type and concentrate feed level on fatty acid (FA) composition from the *longissimus dorsi* (mg FA/kg of lean) of continental finished steers

	Silage type (S)						Concentrate level (k/day) (C)			Significance[d]	
	PGS	FGS	LT	LW	PO	sed	4	7	sed	S	C
C14:0	2.07	1.97	1.75	1.62	1.71	0.591	1.65	2.00	0.365	NS	NS
C16:0	20.3	19.2	17.9	17.2	18.6	5.38	16.2	21.1	3.32	NS	NS
C17:0	0.797	0.779	0.755	0.744	0.769	0.1959	0.719	0.819	0.1210	NS	NS
C18:0	12.6	12.1	11.8	11.7	11.9	3.00	10.9	13.2	1.86	NS	NS
C18:1 *c*9	30.8	30.1	26.3	25.2	27.8	7.38	23.3	32.8	4.56	NS	*
C18:1 *c*11	0.309	0.326	0.275	0.303	0.273	0.0985	0.255	0.340	0.0608	NS	NS
C18:1 *t*11	0.340	0.323	0.325	0.447	0.632	0.3279	0.402	0.425	0.2025	NS	NS
C18:2 *n*-6	1.44	1.60	1.36	1.46	1.59	0.371	1.20	1.78	0.229	NS	NS
C18:3 *n*-3	0.390	0.435	0.315	0.339	0.344	0.0863	0.340	0.389	0.0533	NS	NS
CLA *c*9 *t*11	0.171	0.181	0.160	0.159	0.193	0.0612	0.144	0.202	0.0378	NS	NS
CLA *t*10*c*12	0.128	0.138	0.083	0.092	0.122	0.0448	0.076	0.149	0.0277	NS	**
C20:4*n*-6	0.294	0.330	0.304	0.339	0.309	0.0776	0.261	0.369	0.0479	NS	*
C20:5*n*-3	0.0642	0.0906	0.0509	0.0686	0.0647	0.01972	0.0591	0.0765	0.01218	NS	NS
C22:5*n*-3	0.0656	0.0530	0.0252	0.0612	0.0721	0.02644	0.0513	0.0597	0.01633	NS	NS
Total MUFA[2]	33.6	32.8	28.5	27.2	30.1	8.16	25.3	35.5	5.04	NS	*
Total SFA[3]	36.1	34.4	32.6	31.6	33.4	9.08	29.8	37.4	5.61	NS	NS
n-3[4]	0.550	0.598	0.393	0.464	0.491	0.1334	0.456	0.542	0.0824	NS	NS
n-6[5]	1.74	1.93	1.67	1.80	1.89	0.446	1.46	2.15	0.275	NS	*
Total PUFA[6]	2.29	2.53	2.06	2.26	2.38	0.572	1.92	2.69	0.353	NS	*
Total CLA[7]	0.299	0.319	0.243	0.251	0.315	0.1020	0.219	0.351	0.0630	NS	*
Total trans FA[8]	0.537	0.535	0.462	0.631	0.943	0.3685	0.611	0.632	0.2276	NS	NS
P:S ratio	0.0699	0.0840	0.0818	0.0902	0.0840	0.01242	0.0811	0.0829	0.00767	NS	NS

PGS Perennial ryegrass-based grass silage. FGS Fescue/perennial ryegrass-based grass silage.
LT lupins/triticale, LW lupins/wheat, PO peas/oats, legume/cereal wholecrop offered on 50:50 DM ratio with PGS.
[1]No significant interaction between silage and concentrate supplementation. [2] Monounsaturated fatty acid (C14:1*c*9; C15:1*c*10; C16:1*t*9; C16:1*c*9; C17:1*c*10; C18:1*c*9; C18:1*c*11) [3] Saturated fatty acid (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0) [4] *n*-3 (C18:3*n*-3; C20:5*n*-3; ???) [h] *n*-6 (C18:2*n*-6; C20:4*n*-6)
[5]Polyunsaturated fatty acid (C18:2 *n*-6; C18:3 *n*-3; C20:4 *n*-6; C20:5 *n*-3; C22:5 *n*-3; C22:6 *n*-3). [6] Conjugated linoleic acid (C18:2 c9 *t*11; C18:2 *t*10 *c*12). [7] *trans*-FA (C18:1*t*9; C18:1*t*11; C18:2).

Experiment 4

The chemical composition of the silages and concentrate offered are presented in Table 29. Perennial ryegrass based grass silage (PGS) and red clover silage had a high dry matter of 353 and 379 g/kg, respectively when compared to FGS (196 g/kg). PGS had a slightly higher crude protein concentration than FGS. FGS had a higher butyric acid concentration, proportion of N in the form of NH_3-N and a neutral detergent fibre (NDF) content in comparison to PGS. Red clover silage had a higher crude protein (155 g/kg) and lower NDF (467 g/kg) concentration when compared to PGS or FGS.

Table 29. Chemical composition of the silage

	Silage type		
	PGS	**FGS**	**RC**
Dry matter (g/kg)	353	196	310
pH	4.10	4.10	4.58
Composition of DM (g/kg unless otherwise stated)			
Crude protein	130	116	165
Ammonia N (g/kg N)	76	133	170
Acetic Acid	10.7	20.7	15.4
n-Butyric Acid	3.33	17.51	2.40
Lactic Acid	67.2	68.4	62.2
Acid detergent fibre	347	385	318
Neutral detergent fibre	594	648	467
Ash	79.4	91.1	110.4
Starch	3.81	9.38	24.64
Gross Energy (MJ/kg DM)	20.20	19.76	18.67

PGS Perennial based grass silage. FGS Fescue based grass silage. RC red clover

Silage digestibilities determined through sheep at maintenance level are presented in Table 30. Silage type had no effect on (P>0.05) dry matter, organic matter, DOMD, metabolisable energy, nitrogen digestibilities or nitrogen retention

The effects of silage type on total diet digestibilities are presented in Table 31. Silage treatment had no effect (P>0.05) on dry matter, organic matter, DOMD, NDF, ADF, gross energy

(GE), metabolisable energy (ME) digestibility or nitrogen retention. Nitrogen digestibility of FGS was lower (P<0.05) than offering either PGS or red clover silage.

Table 30. Silage digestibilities determined through sheep at maintenance level.

	Silage type				
	PGS	FGS	RC	sed	Sig
Dry mater	0.650	0.628	0.637	0.0225	NS
Organic matter	0.659	0.652	0.656	0.0161	NS
DOMD[1]	637	627	647	21.6	NS
Nitrogen	0.484	0.439	0.367	0.1083	NS
N retained	48.4	48.5	32.2	14.24	NS
ME (MJ/kg DM)	11.46	10.9	11.97		

PGS Perennial based grass silage. FGS Fescue based grass silage. RC red clover
[1] Digestibility of organic matter

Table 31. Effects of silage type on total diet digestibilities

	Silage				
	PGS	FGS	RC	Sed	Sig
Dry matter	0.717	0.695	0.722	0.0382	NS
Organic matter	0.725	0.699	0.735	0.0444	NS
DOMD [1]	680	657	671	14.0	NS
ADF [2]	0.662	0.683	0.673	0.0390	NS
NDF [3]	0.743	0.724	0.683	0.0352	NS
Gross energy	0.712	0.696	0.737	0.0339	NS
Nitrogen	0.589	0.512	0.574	0.0583	NS
ME (MJ/kg DM) [4]	11.39	10.79	11.91	0.659	NS
Nitrogen retained	20.1	19.4	29.5	8.70	NS

PGS Perennial based grass silage. FGS Fescue based grass silage. RC red clover
[1] Digestibility of organic matter [2] Acid detergent fibre
[3] Neutral detergent fibre [4] metabolisable energy

The effects of silage type and concentrate feed level on protein and dry matter intakes are presented in Table 32.

Table 32. Effects of silage type, soya and concentrate feed level on protein and dry matter intake.

	Concentrate level (kg/day)	Silage type				
		PGS	FGS	RC	sed.	Significance
Silage dry matter intake (kg/day)	1.5	6.50^{d}	4.21^{a}	5.69^{c}	0.124	***
	4	5.18^{b}	4.11^{a}	5.21^{b}		
Total dry matter intake (kg/day)	1.5	8.21^{c}	6.48^{a}	6.97^{b}	0.124	***
	4	9.17^{e}	8.38^{c}	8.64^{d}		
Soyabean meal (kg/day)	1.5	0.429	0.993	0.003	0.0095	***
	4	0.572	0.851	0.008		
Crude protein intake (g/day)	1.5	1142	1139	1140		
	4	1364	1366	1367		

PGS Perennial based grass silage. FGS Fescue based grass silage. RC red clover

A significant (P<0.001) silage type by concentration feed level interaction was obtained for silage dry matter intake, total dry matter intake and soya bean meal dry matter intake. When supplemented with 4 kg concentrates/head/day, animals offered PGS or red clover silage had a higher silage dry matter intake relative to animals offered FGS. However, when supplemented with 1.5 kg concentrates/head/day animals offered PGS had a higher silage DMI compared to animals offered red clover silage and animals offered FGS had the lowest silage DMI. When animals were offered 1.5 kg concentrate head/day, relative to animals offered PGS, total DMI was 0.15 to 0.21 lower for animals offered FGS and Red clover silage. However, when 4 kg concentrates/head/day was offered, DMI was only 0.06 to 0.09 lower than PGS. At the higher level of concentrate supplementation, a lower inclusion rate of soyabean meat was required to equalize protein intake across forage treatments (P<0.001).

The effects of silage type and concentrate feed level on animal performance and carcass characteristics are presented in Table 33. Silage type offered had no effect on animal performance. Increasing concentrate level offered to animals significantly increase liveweight at slaughter

(P<0.01), carcass weight (P<0.01) and carcass gain (P<0.01) however had no effect (P>0.05) on liveweight gain.

The effect of silage type and concentrate feed level on carcass characteristics and composition of the fore-rib is seen in Table 34. Animals offered PGS produced a heavier weight of kidney fat, subcutaneous fat (from fore-rib joint) and a higher marbling score than animals offered either FGS or red clover silage (P<0.05). Animals offered PGS also had a higher (P<0.05) weight of channel fat, lean from the fore rib joint and subcutaneous fat depth compared to animals offered FGS. Increasing concentrate level, increased eye muscle area (P<0.05), weight of kidney fat (P<0.05), cod fat (P<0.05) and kidney, cod and channel (KCC) fat (P<0.01) from the carcass and subcutaneous (P<0.05) and intramuscular (P<0.01) fat weight from the fore-rib joint.

A significant silage type by concentrate feed level interaction was recorded for fat classification (P<0.01) and dressing proportion (P<0.05) (Table 35). Fat classification was higher (P<0.01) for animals offered PGS when supplemented with 4 kg concentrate/head/day in comparison to animals offered FGS with 4 kg concentrate/head/day and all silage types when 1.5 kg concentrate/head/day was offered. Animals offered FGS with 4 kg concentrate/head/day also had a higher dressing proportion relative to animals offered red clover silage and PGS at the same concentration supplementation level (4 kg concentrate/head/day). Dressing proportion (P<0.05) was significantly higher for animals offered FGS at the higher level of concentrate supplementation of 4 kg concentrate/head/day in comparison to 1.5 kg concentrate/head/day.

Table 33. Effect of silage type and concentrate feed level on animal performance and carcass characteristics.

	Silage (S)				Concentrate level (kg/day) (C)			Significance		
	PGS	FGS	RC	sed	1.5	4	sed	S	C	S x C
Liveweight at slaughter (kg)	554	533	552	8.7	536	557	7.0	NS	**	NS
Liveweight gain (kg/day)[1]	0.63	0.52	0.62	0.078	0.53	0.65	0.062	NS	NS	NS
DMI/liveweight gain (kg/kg)[2]	18.3	17.6	13.1	3.69				NS		
Liveweight gain/MEI (g/MJ)[2]	5.6	5.5	7.2	1.40				NS		
Carcass weight (kg)	290	281	290	6.1	279	294	4.9	NS	**	NS
Carcass gain (kg/day)[3]	0.32	0.25	0.32	0.049	0.24	0.35	0.039	NS	**	NS
DMI/carcass gain (kg/kg)[2]	41.5	48.0	36.6	4.14				NS		
Carcass gain/MEI (g/MJ)[2]	3.1	2.2	3.9	0.82				NS		

PGS Perennial based grass silage. FGS Fescue based grass silage. RC red clover

[1]Values predicted from regression analysis; [2] Mean figures of animals offered 2 kg concentrate/head/day; [3] Carcass gain was calculated per steer using an equation to calculate initial carcass weight derived by Keady and Kilpatrick (2005).

Table 34. Effect of forage type and concentrate feed level on animal performance and carcass characteristics.

	Silage (S)				Concentrate level (kg/day) (C)			Significance		
	PGS	FGS	RC	sed	1.5	4	sed	S	C	S x C
Dressing proportion (g carcass weight/kg liveweight)	52.2	52.6	52.3	0.56	52.1	52.7	0.45	NS	NS	*
Conformation classification[1]	2.72	2.56	2.78	0.142	2.59	2.78	0.114	NS	NS	NS
Fat classification [2]	2.97	2.52	2.81	0.184	2.66	2.87	0.147	NS	NS	**
Sub fat depth (mm)	7.13[b]	5.25[a]	5.84[ab]	0.646	5.99	6.16	0.516	*	NS	NS
Eye muscle area (cm^2)	71.8	67.3	66.4	4.09	64.4	72.6	3.28	NS	*	NS
Channel Fat (kg)	1.33[b]	0.96[a]	1.08[ab]	0.135	1.05	1.19	0.108	*	NS	NS
Kidney Fat (kg)	9.14[b]	6.74[a]	7.38[a]	0.85	6.84	8.67	0.679	*	**	NS
Cod Fat (kg)	4.24	3.54	3.59	0.407	3.43	4.14	0.325	NS	*	NS
Kidney, cod and channel Fat (kg)	14.7[b]	11.2[a]	12.0[a]	1.20	11.3	14.0	0.96	*	**	NS
Marbling score [3]	3.22[b]	2.79[a]	2.76[a]	0.17	2.94	2.91	0.136	*	NS	NS
MSA score	434	421	411	25.8	421	423	20.6	NS	NS	NS
Estimated carcass composition (g/kg)[4]										
Lean	514	444	498	34.0	514	457	27.2	NS	*	NS
Fat	253	303	247	32.8	231	304	26.2	NS	**	NS
Bone	233[a]	254b	256[b]	8.5	256	239	6.8	*	*	NS

PGS Perennial based grass silage. FGS Fescue based grass silage. RC red clover
[1] EUROP scale: 5,4,3,2,1 respectively; [2] EU fat classification where 5 = fat, 1 = lean; [3] Marbling score based on a score of 1 = low marbling, 8 = high marbling. [4] Based on dissection of forerib joint

Table 35. Effect of forage type by concentrate level interaction on fat classification and dressing proportion.

	Concentrate level (kg/day)	PGS [d]	FGS [e]	RC	sed.	Sig
Fat classification [1]	1.5	2.55[ab]	2.74[ab]	2.69[ab]	0.261	**
	4	3.38[c]	2.30[a]	2.93[bc]		
Dressing proportion (g carcass weight/kg liveweight)	1.5	52.38[ab]	51.3[a]	52.52[ab]	0.801	*
	4	52.06[a]	53.97[b]	52.09[a]		

PGS Perennial based grass silage. FGS Fescue based grass silage RC Red clover. [1] Europe scale fat classification, 5 = fat, 1 = lean.

Effect of silage type and concentrate feed level on LD weight, lean colour and meat quality is presented in Table 36. Silage type offered had no effect (P>0.05) on LD weight or instrumental meat quality. Increasing concentrate level offered to animals significantly (P<0.05) increased LD weight but had no effect on meat quality parameters.

A significant silage type by concentrate feed level interaction was observed for shear force values of 21 day aged meat as presented in Table 37. Animals offered red clover silage with 1.5 kg concentrate/head/day had a lower shear force value relative to the PGS (P<0.05) compared to animals offered red clover silage. However, when 4 kg concentrate/head/day was offered forage type had no effect on Warner Bratzler Shear force.

Table 36. Effect of silage type and concentrate feed level on LD (*longissimus dorsi*) weight and instrumental meat quality.

	Silage (S)			Concentrate level (kg/day) (C)		SxC	Significance		
	PGS	FGS	RC	1.5	4	sed	S	C	S x C
LD weight (kg)[1]	1.08	1.06	1.07	1.03	1.11	0.062	NS	*	NS
pH	5.53	5.5	5.53	5.53	5.51	0.028	NS	NS	NS
sarcomere length	2.87	2.9	2.91	2.92	2.87	0.094	NS	NS	NS
Cooking loss									
7 day	30.5	31	30.4	31	30.3	1.14	NS	NS	NS
21 day	31.8	31.6	31	31.9	31.1	1.16	NS	NS	NS
Shear force (kg/cm2)									
7 day	3.56	3.44	3.52	3.52	3.5	0.295	NS	NS	NS
21 day	3.46	3.3	3.29	3.35	3.36	0.179	NS	NS	*
Lean Colour									
L*	33.7	33.9	32.7	33.2	33.6	2.46	NS	NS	NS
a*	19.2	18.8	20.6	19.2	19.9	1.57	NS	NS	NS
b*	14.1	13.2	15	14.1	14.1	1.2	NS	NS	NS
Hue	36.4	35.3	35.9	36.5	35.2	2.07	NS	NS	NS
Chroma	23.9	23	25.5	23.9	24.4	1.78	NS	NS	NS

PGS Perennial based grass silage. FGS Fescue based grass silage RC Red clover. [1] LD: *Longissimus dorsi*

Table 37. Effect of silage type by concentrate level interaction on shear force of meat at 21 day aging.

	Concentrate level (kg/day)	Silage type PGS	FGS	RC	Sed	Sig
Shear force (kg/cm^2), 21 day	1.5	3.66^{b}	3.27^{ab}	3.11^{a}	0.180	*
	4	3.26^{ab}	3.33^{ab}	3.48^{b}		

PGS Perennial based grass silage. FGS Fescue based grass silage RC Red clover

Effect of silage type and concentrate feed level on fatty acid (FA) composition of lean meat from the *longissimus dorsi* (g FA/100g total FA and g FA/100 g tissue) is presented in Tables 38 to 40. Silage type had a limited effect on fatty acid composition of lean meat. Meat from animals offered red clover silage had a higher (P<0.05) *n*-3 concentration compared to meat from animals offered either PGS or FGS. Animals offered FGS had a higher ($P<0.01$) *n*-6:*n*-3 ratio than animals offered PGS and red clover silage. Increased concentrate supplementation significantly ($P<0.05$) decreased the concentration of C18:0 and total CLA from lean tissue.

Table 38. Effect of forage type and concentrate feed level on individual fatty acids (FA) from the *longissimus dorsi* (g FA/100g total FA) of finished heifers and steers.

	Silage (S)				Concentrate level (kg/day) (C)			Significance[1]	
	PGS	FGS	RC	sed	S	C	sed	S	C
C14.0	2.26	2.43	2.42	0.277	2.35	2.39	0.229	NS	NS
C15.0	0.410	0.462	0.461	0.0360	0.461	0.427	0.0298	NS	NS
C16.0	26.3	27.3	27.2	1.05	26.8	27.2	1.11	NS	NS
C18.0	16.3	17.2	17.1	0.71	17.5	16.2	0.59	NS	*
C18.1*t*11	1.73	1.63	1.70	0.151	1.71	1.66	0.125	NS	NS
C18.1*c*9	37.2	35.8	34.2	1.17	35.5	36.0	0.97	NS	NS
C18.1*c*11	1.25	1.16	1.38	0.145	1.20	1.33	0.120	NS	NS
C18.2*t*9*t*12	0.328	0.332	0.329	0.0332	0.324	0.335	0.0275	NS	NS
C18:2*n*-6	3.35	3.33	3.85	0.560	3.22	3.80	0.464	NS	NS
C18:3*n*-3	1.14	0.935	1.39	0.2150	1.04	1.27	0.178	NS	NS
CLA *c*9*t*11	0.354	0.300	0.372	0.0618	0.391	0.293	0.0511	NS	NS
CLA *t*10*c*12	0.209	0.172	0.179	0.0246	0.194	0.179	0.0204	NS	NS
C20:4*n*-6	1.18	1.04	1.26	0.208	1.12	1.20	0.172	NS	NS
C20:5*n*-3	0.539	0.436	0.579	0.0905	0.505	0.531	0.0749	NS	NS
C22:5*n*-3	0.652	0.541	0.716	0.1002	0.616	0.657	0.0830	NS	NS
C22:6*n*-3	0.0840	0.0222	0.0549	0.02798	0.0555	0.0519	0.02445	NS	NS
Total SFA[2]	47.4	48.9	48.7	1.07	48.9	47.8	0.85	NS	NS
Total MUFA[3]	44.5	43.0	42.2	1.08	42.8	43.7	0.85	NS	NS
n-3[4]	1.63[a]	1.50[a]	2.03[b]	0.190	1.67	1.78	0.150	*	NS
n-6[5]	3.74	3.93	4.27	0.468	3.73	4.23	0.432	NS	NS
n-6:*n*-3 ratio	2.34[a]	2.66[b]	2.12[a]	0.135	2.32	2.42	0.368	**	NS
Total PUFA[6]	5.37	5.43	6.30	0.635	5.40	6.00	0.106	NS	NS
PUFA:SFA ratio	0.113	0.112	0.131	0.1441	0.111	0.127	0.0113	NS	NS
Total CLA[7]	0.445	0.388	0.478	0.1015	0.524	0.350	0.0799	NS	*
Total *trans*-FA[8]	2.32	2.29	2.25	0.199	2.40	2.17	0.156	NS	NS

PGS Perennial based grass silage. FGS Fescue based grass silage RC Red clover. [1] No significant interaction between silage and concentrate supplementation. [2] Saturated fatty acid (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0). [3] Monounsaturated fatty acid (C14:1*c*9; C15:1*c*10; C16:1*t*9; C16:1*c*9; C17:1*c*10; C18:1*c*9; C18:1*c*11). [4] *n*-3 (C18:3*n*-3; C20:5*n*-3;). [5] *n*-6 (C18:2*n*-6; C20:4*n*-6). [6] Polyunsaturated fatty acid (C18:2 *n*-6; C18:3 *n*-3; C20:4 *n*-6; C20:5 *n*-3; C22:5 *n*-3; C22:6 *n*-3). [7] Conjugated linoleic acid (C18:2 c9 *t*11; C18:2 *t*10 *c*12). [8] *trans*-FA (C18:1*t*9; C18:1*t*11; C18:2).

Table 39. Effect of silage type and concentrate feed level on individual fatty acids (FA) from the *longissimus dorsi* (mg FA/g tissue) of finished heifers and steers.

	Silage (S)				Concentrate level (kg/day) (C)			Significance[1]	
	PGS[c]	FGS[d]	RC	sed	1.5	4	sed	S	C
C12:0	0.0212	0.0303	0.0359	0.01500	0.0288	0.0295	0.01230	NS	NS
C14:0	1.47	2.04	2.04	0.640	1.55	2.15	0.525	NS	NS
C15:0	0.254	0.356	0.355	0.0946	0.291	0.352	0.0775	NS	NS
C15:1*c*10	0.095	0.152	0.135	0.0427	0.108	0.147	0.0350	NS	NS
C16:0	17.3	21.8	20.6	4.44	18.0	21.8	3.64	NS	NS
C16:1*t*9	0.109	0.148	0.122	0.0306	0.117	0.137	0.0251	NS	NS
C16:1*c*9	2.19	2.39	2.42	0.534	2.11	2.56	0.438	NS	NS
C17:0	0.662	0.889	0.847	0.2134	0.721	0.878	0.1749	NS	NS
C17:1*c*10	0.520	0.589	0.588	0.1059	0.529	0.602	0.0868	NS	NS
C18:0	9.9	13.0	11.7	2.73	10.7	12.4	2.24	NS	NS
C18:1*t*9	0.206	0.272	0.206	0.0494	0.207	0.249	0.0405	NS	NS
C18:1*t*11	0.842	1.125	0.922	0.2453	0.829	1.097	0.2010	NS	NS
C18:1*c*9	25.4	28.8	24.9	26.68	23.8	29.0	4.23	NS	NS
C18:1*c*11	0.753	0.829	0.783	0.1415	0.701	0.876	0.1160	NS	NS
C18:2*t*9*t*12	0.205	0.264	0.262	0.0674	0.209	0.278	0.0552	NS	NS
C18:2*n*-6	1.82	2.17	1.95	0.195	1.82	2.14	0.160	NS	*
C18:3*n*-3	0.671	0.678	0.834	0.1100	0.656	0.799	0.0902	NS	NS
CLA *c*9*t*11	0.152	0.187	0.231	0.0708	0.193	0.186	0.0580	NS	NS
CLA *t*10*c*12	0.109	0.111	0.096	0.0280	0.096	0.115	0.0230	NS	NS
C20:4*n*-6	0.622	0.639	0.615	0.0442	0.644	0.607	0.0362	NS	NS
C20:5*n*-3	0.252	0.245	0.269	0.0147	0.265	0.246	0.0120	NS	NS
C22:5*n*-3	0.333	0.324	0.358	0.0243	0.345	0.331	0.0199	NS	NS

PGS Perennial based grass silage. FGS Fescue based grass silage RC Red clover. [1] No significant interaction between silage and concentrate supplementation.

Table 40 Effect of silage type and concentrate feed level on fatty acid groups from the longissimus dorsi (mg FA/g tissue)

	Silage (S)				Concentrate level (kg/day) (C)			Significance[1]	
	PGS[c]	FGS[d]	RC	sed	1.5	4	sed	S	C
TOTAL FA	67.1	80.9	74.2	15.07	67.3	80.9	12.35	NS	NS
Total SFA[2]	29.5	38.2	35.7	7.96	31.2	37.7	6.52	NS	NS
Total MUFA[3]	29.2	33.2	29.3	6.02	27.5	33.7	4.94	NS	NS
n-3[4]	1.27	1.26	1.47	0.138	1.28	1.39	0.113	NS	NS
n-6[5]	2.45	2.81	2.57	0.222	2.46	2.75	0.182	NS	NS
n-6:*n*-3 ratio	2.02[a]	2.38[b]	1.87[a]	0.119	2.06	2.13	0.098	***	NS
Total PUFA[6]	3.72	4.07	4.03	0.341	3.74	4.14	0.280	NS	NS
PUFA:SFA ratio	0.153	0.130	0.165	0.0262	0.136	0.162	0.0214	NS	NS
Total CLA[7]	0.261	0.298	0.326	0.0932	0.289	0.301	0.0764	NS	NS
Total *trans*-FA[8]	1.25	1.66	1.39	0.342	1.25	1.63	0.280	NS	NS

PGS Perennial based grass silage. FGS Fescue based grass silage RC Red clover. [1] No significant interaction between silage and concentrate supplementation. [2] Saturated fatty acid (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0). [3] Monounsaturated fatty acid (C14:1*c*9; C15:1*c*10; C16:1*t*9; C16:1*c*9; C17:1*c*10; C18:1*c*9; C18:1*c*11). [4] *n*-3 (C18:3*n*-3; C20:5*n*-3;). [5] *n*-6 (C18:2*n*-6; C20:4*n*-6). [6] Polyunsaturated fatty acid (C18:2 *n*-6; C18:3 *n*-3; C20:4 *n*-6; C20:5 *n*-3; C22:5 *n*-3; C22:6 *n*-3). [7] Conjugated linoleic acid (C18:2 c9 *t*11; C18:2 *t*10 *c*12). [8] *trans*-FA (C18:1*t*9; C18:1*t*11; C18:2).

DISCUSSION

Silage yield

A summary of the DM yield of each the forages from experiments 1 to 4 is presented in Table 41. Average DM yield ranged from 6.6 tonnes DM/ha for vetch/barley to 8.9 tonnes DM/ha for lupins/wheat wholecrop silage. These DM yields are considerably lower than the yield of 14.4 tonnes DM/ha reported for a 2-cut silage system and 10.4 to 13 tonnes DM/ha reported for wholecrop wheat (O'Kiely and Moloney, 2002; Keady, 2005 and Walsh *et al*, 2008).

Table 41 Yield of legume/cereal whole crop silages and red clover silage.

Legume	Cereal	Yield (t DM/ha)
Lupins	Triticale	7.6
Vetch	Barley	6.6
Lupins	Wheat	8.9
Peas	Oat	7.3
Red clover	-	8.2

Relatively low yields have been reported for white lupin wholecrop silage (Fraser *et al*, (2005) (6.1 tonnes DM/ha) although the yields ranged from 4.6 to 8.0 tonnes DM/ha depending on stage of maturity and variety. While similar information is not available for lupins/cereal wholecrop silages, Ghanbari-bonjar and Lee, (2002) and Caballero et al, (1995) recorded low DM yields for beans and vetch wholecrop silages of 6.4 and 3.1 tonnes DM/ha, respectively. It is also important to note that in the current experiments, the lupins used were yellow lupins which are lower yielding than white lupin used by Fraser et al (2005).

Based on samples of the lupins/cereal wholecrop taken at harvest in the current experiments, approximately 13% (Experiment 1) and 29% (Experiment 2) of the wholecrop consisted of lupins. Using this figure to estimate an average lupin yield in the lupins/cereal wholecrop silages over Experiment 1 and 2, the estimated yield of lupins would 1.6 t DM/ha. This yield is much lower for lupins grown and harvested as the sole forage. As the relative growth rates of clover plants decrease rapidly in response to shading (Kendall and Stringer 1985) it is likely that this lower yield is due to competition for light and nutrients by the cereal crop. This finding is supported by Caballero et al, (1995) who recorded a 52% decrease in DM yield when oats were sown in combination with vetch (60:40 DM ratio) compared to oats sown as the sole forage.

Silage chemical composition.

A summary of the chemical composition of the silage offered in experiments 1 to 4 is presented in Table 42.

Table 42. Effect of silage type on chemical composition of ensiled forages.

	PGS	FGS	Lupins/ triticale	Vetch/ barley	Lupins/ wheat	Peas/ oats	Red clover
Dry matter (g/kg fresh)	291	230	350	304	354	293	310
pH	3.96	4.05	4.6	4.68	4.90	4.70	4.58
Composition of DM (g/kg unless otherwise stated).							
Crude protein	128	120	142	147	182	102	165
Ammonia N (g/kg N)	81	101	149	140	142	109	170
Acetic acid	13.0	17.7	25.3	41.8	34.4	46.6	15.4
Butyric acid	2.21	8.95	1.85	0.66	0.57	0.52	2.4
Lactic acid	97.6	76.6	22.6	6.4	4.2	2.7	62.2
Acid detergent fibre	333	344	350	320	409	349	318
Neutral detergent fibre	579	584	571	594	628	578	467
Ash	95	96	75	122	92	99	110
Starch	4.7	6.8	121	101.3	108	145	24.6
Gross energy (MJ/kg DM)	20.4	19.5	18.7	18.4	19.1	20.2	18.7

PGS – perennial ryegrass silage (Experiments 1, 2, 3 and 4); FGS – fescue based grass silage (Experiments 3 and 4),

In general the legume/cereal silages and red clover silage fed in experiments 1 to 4 were of poor quality with low levels of lactic acid, high ammonia concentration and high pH. Although there is no comparative information in the literature on the fermentation characteristics of lupins/triticale wholecrop silage, lupins and peas/oats have produced good quality silages in studies by Fraser et al (2005) and Rondahl et al (2007). However, poor fermentation quality has been observed in red clover and lucerne silages (Fraser et al 2000) and this is attributed to the low DM and sugar content which increase the chance of a clostridial fermentation occurring. The protein concentration the lupins/triticale, vetch/barley and peas/oats silages are similar to other published values. Rondahl et al (2007) reported that peas/oats wholecrop silage had a CP content of 144 g/kg DM and Salawu et al (2001) observed a value of 103 g/kg DM for peas/wheat silage. As the crude protein concentration of ensiled white lupins have been shown to range from 212 to 248 g/kg DM (Fraser et al 2005) it was expected that the CP concentration of legume/cereal wholecrop silages in the current studies would have been greater than the average value of 143 g/kg DM obtained. However, view of the yield and composition results discussed previously, the low level of establishment of lupins in LT2 in particular accounted for the low CP levels achieved.

In experiments 2 and 3 the legume:cereal crops were harvested a different time intervals post-sowing which may have had an effect on resultant silage quality. However, it is important to recognize that the experiments were not designed to assess the effect of stage of harvest or harvest date post-sowing on chemical composition of the legume/cereal wholecrop. Consequently caution should be taken when comparing the effect of harvest date of legume:cereal wholecrop silages. Nevertheless, in Experiment 2 lupins/triticale wholecrop silage was harvested 117 days post sowing at a dry matter of 291 g/kg and a crude protein of 97 g/kg DM in contrast to Experiment 2 where lupins/triticale wholecrop silage was harvested 167 days post sowing at a dry matter of 457 g/kg and a crude protein of 233 g/kg DM. In Experiment 1 lupins was established as a separate crop to triticale within the same field, but were harvested together in an attempt to reduce the likelihood of triticale outcompeting lupins. The silage was harvested, 121 days post sowing and a low CP concentration (120 g/kg DM) similar to Experiment 2 was still obtained. These results seem to indicate that as time interval from sowing to harvest increases, silage DM and protein contents increases. Previous studies with wholecrop barley have indicated a negative correlation between harvested DM and CP concentration (O'Kiely and Moloney, 1995). However, Fraser *et al*, (2005) did not observe a relationship between plant maturity and CP concentration and Fraser et al (2005) also recorded a higher wholecrop silage CP concentration than Sheldrick *et al*, (1980) in which the harvest date of the two studies were similar at 130 and 133 days post sowing. Fraser *et al*, (2005) concluded that white lupin was not suited to being harvested as a wholecrop silage due to the low CP concentration of the silage in comparison to grain production.

In agreement with previous studies (Dewhurst *et al*, 2003; Lee *et al*, 2009), red clover silage in experiment 4 had a higher CP concentration and lower NDF concentration relative to grass silage (PGS and FGS) as seen in Table 42. However, in experiment 4, the red clover silage had a lower CP concentration and poorer fermentation characteristics compared to red clover silage in studies by Lee *et al*, 2009; Grabber, 2009. The latter authors wilted the silage for 48 hours and used a silage additive while in experiment 4, an extended wilting period of 65 hours was adopted and no silage additive was used.

The PGS ensiled and offered in all experiments was of good quality, as indicated by a pH of below 4, high lactic acid concentration and a low concentration of butyric acid. The PGS was of superior quality (DOMD of 685 g/kg DM) relative to silages produced on beef farms in Northern Ireland (Lively *et al*, 2009). Perennial ryegrass is widely sown on commercial farms due to its high yield, nutrient value and ability to be ensiled successfully. As seen in Table 42 PGS had more successful fermentations than FGS, with a lower pH, ammonia N concentration and a higher lactic:acetic acid concentration. These results are in agreement with previous studies Optiz *et al*, (2004) and Chestnut *et al*, (1988) who ensiled a fescue-based grass silage. The latter authors attributed the poorer fermentation characteristics to a lower WSC concentration and a higher WSC:buffering capacity ratio in the fescue-based grass.

Dry matter intake

Offering alternative forages to grass silage such as legume silage or cereal wholecrop silages to beef and dairy cattle have been shown to increase in silage and total dry matter intakes (Thomas *et al*, 1981; Keady et al, 2005; Niderkorn and Baumont, 2009). The increase in dry matter intake of animals offered legume silages such as red clover is often attributed to the faster rate of passage of the feed through the digestive tract (Dewhurst et al, 2003). Contrary to this and other studies (Thomas *et al*, 1981; Niderkorn and Baumont, 2009) animals offered red clover silage in experiment 4 had a lower silage and total dry matter intake compared to PGS. The lower intakes observed in experiment 4 could in part be explained by the poor silage fermentation characteristics and low fibre digestibilility of red clover silage. Limited research studies have examined the dry matter intake of beef cattle offered legume/cereal wholecrop silage. Therefore it is not possible to compare the results of the currents studies with those reported in the literature. Overall, results from experiments 1, 2 and 3 show legume:cereal wholecrop silage to have a similar total dry matter intake compared to PGS. The lack of significant effect particulalry in experiment 2 may be due to the high concentrate levels offered (550g concentrate/kg total DMI).

Animal performance

Averaged over experiments 1, 2 and 3 animals offered legume/cereal wholecrop silage as a sole silage or in combination with grass silage had 15% lower liveweight gain and carcass gain compared to animals offered PGS. The superiority of PGS relative to the legume:cereal wholecrop silages was greater when concentration supplementation level was less than 7 kg/head/day. At the high levels of concentrate supplementation (>7kg/head/day (Experiment 2)), any silage type effect was removed due to the low forage intake (450 g silage/kg total DMI) of which only 0.5 of silage DM intake was legume:cereal wholecrop silage.

In the current studies the performance of animals offered the legume:cereal wholecrop silages were lower than the performance of animals offered other alternative forages such as wholecrop cereals or maize silage reported in the literature (Walsh *et al*, 2008; Keady 2005; Walsh *et al*, 2005 and O'Kiely and Moloney, 1995). Walsh *et al* (2008) and O'Kiely and Moloney (1995) observed carcass gains of 736 and 629 g/day respectively for cattle offered wholecrop barley silage while Walsh et al, (2005) observed carcass gains of 780 g/day for cattle offered maize silage.

Ensiling red clover as either a monoculture or in combination with grass silage has had variable effects on animal performance with positive (Steen and McIlmoyle, 1982) and negative effects (Stewart and McCullough, 1985) observed when compared to animals offered solely grass silage. In the current study no difference in either animal performance or feed efficiencies were observed. Liveweight gain and carcass gain values were low in comparison to previous research on silage of similar digestibility and similar levels of concentrate (Steen and Kilpatrick. 2000). Animals offered 1.5 and 4 kg concentrate/head/day produced carcass gains of 0.24 kg/day and 0.35 kg/day with the proportion of concentrates making up 241 and 453 g/kg DM, respectively of the total diet. These gains are lower than the carcass gain values of 0.53 kg/day and 0.61 kg/day reported by Steen and Kilpatrick (2000) where concentrates contributed 240 and 360 g/kg DM of the total diet. Differences can be attributed to the higher metabolisable energy of total diet (12.5 MJ/kg DM) in the study by Steen and Kilpatrick (2000) compared with a value of 11.9 MJ/kg DM in the current study. The inclusion of dairy cross heifers in the current experiment is also likely to have reduced the overall animal performance when compared to continental steers (Steen, 1995).

Meat quality

The current studies demonstrate that generally legume/cereal wholecrop silage and red clover silage had no or limited effect on carcass characteristics, instrumental meat quality parameters or fatty acid composition compared with PGS. While, there is no known published data on the effect of legume/cereal wholecrop silages on instrumental meat quality or fatty acid composition a considerable amount of research has investigated the effect of red clover (and white clover) on meat quality albeit in terms of fatty acid composition rather than instrumental meat quality (Dewhurst 2009). Previous studies have demonstrated that the inclusion of legumes as a protein supplement and as a forage crop have increased long chain unsaturated fatty acids (C18:1 – C18:3) in milk of dairy cows and lean meat from beef cattle (White *et al*, 2007; Waghorn *et al* 1998, respectively). Generally including red clover in the diets of beef cattle has beneficial effects on fatty acid composition (Scollan et al 2006) and experiment 4 did observe a beneficial effect of feeding red clover on linolenic acid concentrations. However in a review of the effect of forage legumes, Dewhurst (2009) noted that there is little evidence that forage type influences meat quality when expressed in terms of tenderness when other confounding factors are removed. With regard to other wholecrop silages, Keady et al 2007 failed to observe a significant effect on instrumental meat quality when wholecrop wheat was included with grass silage (40:60 ratio on a DM basis) in the diet of finishing beef cattle. Offering solely maize silage or inclusion of maize silage in a grass silage diet has been shown to improve meat colour and tenderness in some studies (O'Sullivan et al 2002; Hoving-Bolink et al 1999). However in agreement with the current study, no effect on tenderness or sensory meat quality parameters has been observed in other studies (Keady et al 2007, Brennan et al 1987).

The lack of a significant effect of forage type on meat quality parameters observed in these studies may have been due to a number of factors. Firstly relatively high levels of concentrate were offered (Experiment 3) and combined with the fact that the legume/cereal wholecrop forages were offered along with PGS at a ratio of 50:50 on a DM basis which likely reduced silage type effect on instrumental meat quality. Secondly, in the carcasses were all hung by the tenderstretch method post slaughter. As Lively *et al.* (2005) observed that differences in shear force between Charolais and Holstein genotypes when the carcasses were suspended from the aitch bone disappeared when the carcasses were suspended from the achilles tendon (tenderstretch method) it is also likely that the tenderstretch hanging method reduced likely differences in meat quality parameters in the current study .

General considerations

Overall, the results of the experiments reported demonstrate that finishing beef cattle offered legume/cereal wholecrop forages had 15% lower liveweight gain and carcass gain relative to offering high quality (DOMD of 685 g/kg DM) grass silage. This was mainly attributed to the poor fermentation characteristics of the legume:cereal wholecrop silage. A summary of the input costs associated with each of the legume/cereal forages is presented in Table 43. The total costs of producing legume/cereal wholecrop silage are on average 15% lower than for a 2-cut grass silage system. However, when costs are expressed per tonne utilisable DM yield, legume/cereal wholecrop silages have higher (52% higher) costs due to their low yields. Combined with poor animal performance this would produce a significantly lower gross margin. These results demonstrate that beef producers should place increased emphasis on making good quality grass silage rather than legume:cereal wholecrop silages in order to optimise performance and reduce feed costs in finishing beef systems.

Table 43. Inputs and costs/ha legume/cereal wholecrop silages relative to grass silage

	Grass silage[8]	Lupins/ triticale	Lupins/ wheat	Vetch/ barley	Peas/ oats
Establishment costs[1]					
Ploughing	55	55	55	55	55
Power harrowing	27	27	27	27	27
Drilling	40	19	19	19	19
Seed[2]	95	106.5	122.83	57.35	96.2
Lime[3]	75	8	8	8	8
Inorganic fertiliser[4]	50	82	60	60	60
Sprays[5]	20	24.75	24.75	24.75	24.75
Total establishment costs	**51.7[9]**	**101**	**101**	**101**	**101**
Other variable costs					
Inorganic fertiliser[4]	262	-	-	-	-
Sprays[5]	7	-	-	-	-
Contractor charges[6]					
Fertiliser applications	22.5	7.5	7.5	7.5	7.5
Spray applications	4	16	16	16	16
Slurry spreading	19	19	19	19	19
Harvesting	300	181	181	181	181
Polythene		5	5	5	5
Additive[7]	102	42.4	38.4	55.2	52.1
Total variable costs	**717**	**492**	**482**	**434**	**470**
Land charge (£/ha)	200	250	250	250	250
Total costs	**968**	**843**	**833**	**785**	**821**
Yield (t DM/ha)	14.42	7.6	8.9	6.6	7.3
Post harvest loss (%)	16	15	15	15	15
Utilisable DM yield (t UDM/ha)	12.1	6.5	7.6	5.6	6.2
Cost (£/tonne UDM)	**80[9]**	**131**	**110**	**140**	**132**

[1] Establishment costs based on contractor charges as per Farm Business Data 2009
[2] Grass 35 kg @£2.70/kg,Lupins/triticale 142 kg/ha @ £0.75/kg; Vetch/barley 185 kg/ha @ 0.31/kg, Lupins/wheat 173 kg/ha @ £0.71/kg, Peas/oats 185 kg/ha @ £0.52 /kg
[3] Grass - lime 5 tonnes @£15/tonne; legume/cereals 0.5 tonnes @£15/tonne
[4] Grass 179 kg/ha 0:0:60, 763 kg/ha 27%N, 50 kg urea Lupins/triticale 340 kg/ha 17:17:17 (Experiment 1), 247 kg/ha 22:0:12 (Experiment 2), Lupins/wheat, vetch/barley, peas/oats 247 kg/ha 22:0:12
[5] Grass for establishment sward kill + herbicide ; Legume/cereal - pre-emergent herbicide 4.5 litres/ha @ £5.50/litre
[6] Contractor charges as per Farm Business Data 2009
[7] Additive costs £2/tonne
[7] Grass silage – assume 2 –cut silage system.
[9] Assume 7 year life; [10] includes feed out charge of £12/tonne

CONCLUSIONS

The low DM yield/ha of the legume/cereal wholecrop silages obtained in these studies relative to a typical two-cut silage systems resulted in legume/cereal wholecrop silages having a higher production cost per tonne utilisable DM relative to grass silage. On average, when offered as the sole forage or in combination with grass silage, legume/cereal wholecrop silages produced 15% lower liveweight gain and higher feed cost per kg carcass gain relative to grass silage. These results demonstrate that beef producers should place increased emphasis on making good quality grass silage rather than legume/cereal wholecrop forages.

References

Agriculture Research Council, 1965. Recommended Procedures for Use in the Measurement of Beef Cattle and Carcasses. Agricultural Research Council, London, UK.

Bligh, E.G., Dwyer, W.J., 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 37, 911–917.

Brennan, R.W., Hoffman, M.P., Parrish, F.C., Epplin, F., Bhide, S., Heady, E.O. 1987. Effects of differing rations of corn silage and corn grain on feedlot performance, carcass characteristics and projected economic returns. J. Anim. Sci. 64, 23-31.

Caballero, R., Goicoechea, E.L., Hernaiz, P.J. 1995. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. Field Crop Res. 41, 135-140

Dewhurst, R.J., Fisher, W.J., Tweed, J.K.S., Wilkins, R.J. 2003. Comparison of grass and legume silages for milk production. 1. Production responses with different levels of concentrate. J. Dairy Sci. 86, 2598-2611

Dewhurst, R.J., Delaby, L., Moloney, A., Boland, T., Lewis, E. 2009. Nutritive value of forage legumes used for grazing and silage. Irish J. Agric. Food Res. 48, 167-187

Ferris, C.F., Patterson, D.C., McCoy, M.A., Kilpatrick, D.J. 2010. Effect of offering dairy cows diets differing in phosphorus concentration over four successive lactations: 1. Food intake, milk production , tissue changes and blood metabolites. Animal 4, 545-559

Fraser, M.D., Fychan, R. Jones, R. 2000. Voluntary intake, digestibility and nitrogen utilization by sheep fed ensiled forage legumes. Grass Forage Sci. 55, 271-279

Fraser, M.D., Fychan, R., Jones, R. 2005. The effect of harvest date and inoculation on the yield and fermentation characteristics of two varieties of white lupin (Lupinus albus) when ensiled as a whole-crop. Anim. Feed Sci. Technol. 119, 370–322

Ghanbari-bonjar, A. Lee, H.C. 2002. Intercropped field beans (Vicia faba) and wheat (Triticum aestivum) for whole crop forage: effect of nitrogen on forage yield and quality. Crops and Soils 138, 311-315

Grabber, J. 2009. Forage management effects on protein and fiber fractions, protein degradability and dry matter yield of red clover conserved as silage. Anim. Feed Sci. Technol. 154, 284-291

Hoving-Bolink HA, Hanekamp WJA and Walstra P 1999. Effects of diet on carcass, meat and eating quality of once to bred Piemontese x Friesian heifers. Livest. Prod. Sci. 57, 267-272.

Keady, T.W.J. 2005. Ensiled maize and whole crop wheat forages for beef and dairy cattle: effects on animal performance. In Park, R.S., Stronge, M.D. (Eds.). Proceed. XIVth Inter. Silage Conf. a satellite workshop of the XXth Inter. Grass. Congr., July 2005, Belfast, Northern Ireland pp. 65-82

Keady, T.W.J., Kilpatrick, D.J. 2005. Prediction of carcass weight from live weight in beef animals. Proceedings of the British Society of Animal Science, 2005, pp 179

Keady, T.W.J., Lively, F.O., Kilpatrick, D.J., Moss, B.W. 2007. Effects of replacing grass silage with either maize or whole-crop wheat silages on the performance and meat quality of cattle offered two levels of concentrates. Animal. 1, 613-623

Kempster, A.J., Cuthbertson, A., Harrington, G. 1982. Beef carcase grading and classification. In: Carcase Evaluation in Livestock Breeding Production and Marketing, Granada, London, UK, pp. 163-201

Kendal, W.A., Stringer, W.C. 1985. Physiologocal aspects of clover. In: N.L. Taylor (Ed.). Clover Science and Technology, Madiaon, WI: American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, pp. 111-159

Lee, M.R.F., Evans, P.R., Nute, G.R., Richardson, R.I., Scollan, N.D. 2009. A comparison between red clover silage and grass silage feeding on fatty acid composition, meat stability and sensory quality of the *M. longissimus* muscle of dairy cull cows. Meat Sci. 738-744

Lively, F.O., Keady, T.W.J., Moss, B.W., Patterson, D.C., Kilpatrick, D.J. 2005. Effect of genotype, carcass weight and fat classification and pelvic hanging technique on meat quality. Proceedings of the British Society of Animal Science pp 59.

Lively, F.O., Dawson, L.E.R. and Kennedy, P. (2009). Recent research on nutrition of finishing suckler beef cattle. In: From Beef Production to Consumption – a seminar for specialists. Proceedings of an AgriSearch seminar held at the Agri-Food and Biosciences Institute Hillsborough, 21st October 2009 pp.35-62

MAFF 1994. Fertiliser recommendations for agricultural and horticultural crops. Minstry of Agriculture, Fisheries and Food, 6th Edition, London, HMSO.

Moss, B.R., Lin, J.C., Reeves, D.W., Kochapakdee, S., Mask, P.L., van Santen, E. 1999. Lupin in ruminant diets. Towards the 21st century. In: Proceedings of the Eighth International Lupin Conference, Asilomar, CA, USA, 11-16 May 1996. International Lupin Association, Canterbury, New Zealand, pp. 102-114

Niderkorn, V., Baumont, R. 2009. Associative effects between forages on feed intake and digestion in ruminants. Anim. 3, 951-960

O'Fallon, J.V., Busboom, J.R., Nelson, M.L., and Gaskins, C.T. 2007. A direct method for fatty acid methyl ester synthesis: Application to wet meat tissues, oils, and feedstuffs. J. Sci. 85, 1511–1521.

O'Kiely P and Moloney AP 1995. Performance of beef cattle offered different ratios of grass and maize silage. Irish Journal of Agriculture and Food Research 34, 76.

O'Kiely, P., Moloney, A.P. 2002. Nutritive value of whole crop wheat and grass silage for beef cattle when offered alone or in mixtures. Proc. Irish Grass. Anim Prod. Assoc, pp. 99-100

O'Sullivan A, O'Sullivan K, Galvin K, Moloney AP, Troy DJ and Kerry JP 2002. Grass silage versus maize silage effects on retail packaged beef quality. J. Anim. Sci. 80, 1556-1563.

Okeudo, N.J., Moss, B.W., 2004. Interrelationships amongst carcass and meat quality characteristics of sheep. Meat Sci. 69, 1–8.

Payne, R.W., Murray, D.A., Harding, S.A., Baird, D.B., Soutar, D.M., 2007. Genstat for Windows (10th Edition) Introduction. VSN International, Hemel Hempstead.

Petit, H.V., Rioux, R., Ouellet, D.R. 1997. Milk production and intake of lactating cows fed raw or extruded peas. J. Dairy Sci., 980, 3377-3385

Petterson, D.S., Sipsas, S., Mackintosh, J. B., 1997: The Chemical Composition and Nutritive Value of Australian pulses, 2nd ed. Grain research and development corporation, Canberra, Australia.

Rondahl, T., Bertilsson, J., Martinsson, K. 2007. Mixing whole-crop pea-oat silage and grass-clover silage; positive effects on intake and milk production of dairy cows. Grass Forage Sci. 62, 459-469

Ross, S.M., King, J.R., O'Donovan, J.T., Spaner, D. 2005. The productivity of oats and berseem clover intercrops. I. Primary growth characteristics and forage quality at four densities of oats. Grass Forage Sci. 60, 74 -86

Salawu, M.B., Adesogan, A.T., Weston, C.N., Williams, S.P. 2001. Dry matter yield and nutritive value of pea/wheat bi-crops differing in maturity at harvest, pea to wheat ratio and pea variety. Anim. Feed Sci. Technol. 94, 77-87

Schreurs, N.M., Lane, G.A., Tavendale, M.H., Barry, T.N., McNabb, W.C. 2008. Pastoral flavour in meat products from ruminants fed fresh forages and its amelioration by forage condensed tannins. Anim. Feed Sci. Technol. 146, 193-221

Scollan, N.D., Hocquette, J-F., Nuernberg, K., Dannenberger, D., Richardson, I., Moloney, A. 2006. Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. Meat Sci. 74, 17-33

Singh, V., Joshi, Y.P., Verma, S.S. 1989. Studies on the production of Egyptian clover and oats under intercropping. Exp. Agric. 25, 541-544

Steen, R.W.J. 1984. A comparison of two-cut and three-cut systems of silage making for beef cattle using two cultivars of perennial ryegrass. Anim. Prod. 38, 171-179

Steen, R.W.J. 1995. The effect of plane of nutrition and slaughter weight on growth and food efficiency in bulls, steers and heifers of three breed crosses. Livest. Prod. Sci. 42, 1-11

Steen, R.W.J., Kilpatrick, D.J. 2000. The effects of the ratio of grass silage to concentrates in the diet and restricted dry matter intake on the performance and carcass composition of beef cattle. Livestock Production Science 60, 181-192

Steen, R.W.J., McImoyle, W.A. 1982. An evaluation of red-clover silage for beef production. Animal Production. 34**:** 95-101

Thomas, C., Aston, K., Gibbs, B.G., Tayler, J.C. 1981. The voluntary intake and live-weight gain of beef-cattle given red clover silage. Anim. Prod. 32, 143-148.

Thorsted, M.D., Olesen, J.E., Weiner, J. 2006. Width of clover strips and wheat rows influence grain yield in winter wheat/white clover intercropping. Field Crops Res. 95, 280-290

Walsh, K., O'Kiely, P., Moloney, A.P., Boland, T.M. 2008. Intake, digestibility, rumen fermentation and performance of beef cattle fed diets based on whole-crop what or barley harvested at two cutting heights relative to maize silage of ad libitum concentrates. Anim. Feed Sci. Techno. 144, 257-278

Waghorn, G.C., Douglas, G.C., Niezen, J.H., McNabb, W.C. and Foote, A.G. 1998. Forages with condensed tannins – their management and nutrition value for ruminants. Proceed New Zealand Grass. Assoc. 60, 89–98.

White, C.L., Staines, V.E., Staines, M.V. 2007. A review of the nutritional value of lupins for dairy cows. Aust. J. Agric. Res. 58, 185-202

APPENDIX 1

OUTPUTS FROM THE PROJECT

PUBLICATIONS

Lively, F.O., Dawson, L.E.R. and Kennedy, P. (2009). Recent research on nutrition of finishing suckler beef cattle. In: From Beef Production to Consumption – a seminar for specialists. Proceedings of an AgriSearch seminar held at the Agri-Food and Biosciences Institute Hillsborough, 21st October 2009 pp.35-62

Dawson, L.E.R. and Moss, B.W. (2009). Comparison of the performance of finishing beef cattle offered grass silage, lupin/triticale silage or maize silage. Proceedings of the Irish Grassland and Animal Production Association, 2009 pp. 20

Kennedy, P. and Dawson, L.E.R. 2009. Comparison of the performance of finishing beef cattle offered grass silage and legume/cereal wholecrop silage either alone or in combination with grass silage. Proceedings of the British Society of Animal Science 2009 pp.77

Kennedy, P. and Dawson,. L.E.R. 2009. Comparison of the performance of finishing beef cattle offered grass silage alone or in combination with legume/cereal wholecrop silage. Proceedings of the 9th British Grassland Society Conference, 2009 pp. 11-12

Kennedy, P., Dawson, L.E.R., Moss, B.W., Fearon, A. (2009). Meat quality of beef cattle offered grass silage and legume/cereal silage either alone or in combination with grass silage. Proceedings of the British Society of Animal Science, 2009, pp. 53.

Dawson, L.E.R. 2010. The effect of inclusion of lupins/triticale wholecrop silage in the diet of winter finishing beef cattle on the performance and meat quality of beef cattle offered two levels of concentrates. Livestock Science (submitted).

PRESS RELEASES

Lively, F.O., Kennedy, P. and Dawson, L.E.R. (2009). AFBI evaluates role of legume/cereal wholecrop forages for finishing beef cattle. Farming Press, November 2009

Dawson, L.E.R. 2006. Options for feeding beef cattle this winter – key issue for Hillsborough beef open day. Farming Press, September 2006.

MEETINGS/OPEN DAYS/EVENTS/PRESENTATIONS

Beef Open Day, September 2006. Sustainable Beef Production, Charting the Way Forward

Carnlough and Glenarm Beef Group (January 2009). Presentation of current beef research

Presentation to FWAG Sustainable beef research programmes

Visit by Irish Farmers Association (September 2009) Overview of sustainable beef research programme.

AgriSearch Seminar (October 2009). From beef production to consumption – a seminar for specialists.

National Beef Association (March 2010) Dungannon Mart

CAFRE/AgriSearch/AFBI suckler event, July 2010, Greenmount Hill Farm.

British Grassland Society Visit 2009. Legume/cereal wholecrop forages for finishing beef cattle.

Presentation to Farm Wildlife and Advisory Group (FWAG), 2009. Sustainable beef research programmes