

Effect of forage to concentrate ratio and duration of feeding on growth and feed conversion efficiency of male lambs

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ABSTRACT: Rations (DM basis) for spring-born male lambs consisting of concentrates ad libitum (CON), 50:50 (50% concentrate:50% forage), and forage ad libitum (FORG) were evaluated across feeding periods of three durations (36, 54, and 72 d). Lambs on CON diets were offered ad libitum access to concentrate along with 400 g of fresh weight silage (daily), while 50:50 diets were offered 0.9 and 3.0 kg of concentrate and silage, respectively. Lambs on FORG were offered ad libitum access to 25.5% DM silage. These rations were fed to 99 spring-born male Texel cross Scottish Blackface lambs which were assigned to a 3 × 3 factorial arrangement. Lambs were slaughtered

following completion of their respective treatments. Lambs fed CON diets had greater ADG, FCE, and carcass weight ($P < 0.001$) and carcasses with greater conformation score ($P < 0.001$) than lambs fed 50:50 or FORG diets. Duration of feeding had no effect on production variables across all three concentrate inclusion levels. It was concluded that the inclusion of concentrates is needed to adequately finish lambs fed indoors. Feeding lamb's 50:50 diets resulted in modest responses and may be a viable option for finishing lambs or to maintain growth in lambs when the cost of concentrate feed is high relative to the financial return on the lamb meat.

Key words: carcass, concentrate feeding level, lamb, performance

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INTRODUCTION

Recent studies have outlined the superior growth rate and feed conversion of Texel cross Scottish Blackface (SB) (TXSB) ram and wether lambs compared with purebred SB ram and wether lambs (Claffey et al., 2017). In Ireland, hill lambs (lambs from mountain regions) require an intensive feeding period to achieve 16- to 22-kg

carcasses required for current market specification (Diskin et al., 2016). However, little research has been conducted on the effects of concentrate feeding level and duration of feeding on the performance of lambs from hill systems. The research presented in this paper is applicable to hill sheep finishing systems. In hill lamb production systems, it is becoming increasingly common for lambs to be housed in the final quarter of the year in order to reach target slaughter weight. This occurs predominantly as a management tool to help to build grass supplies for priority stock such as breeding females or for early springtime grazing.

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Approximately, 75% of male lambs from hill production systems are offered for sale as lambs for further finishing or as lambs for slaughter between August and December each year. Feeding strategies for these lambs consist of grass silage supplemented with varying levels of concentrate depending on lamb weight at housing as well as the market outlook. Silage quality and quantity will also determine the level of concentrate feeding required. Heavier lambs (>38 kg at housing) may potentially reach target slaughter weight when fed on a combination of forage and concentrate, although lighter lambs (25–30 kg at housing) generally require a period of ad libitum concentrate feeding to reach required slaughter weights (42 kg). Lambs fed ad libitum concentrates compared with diets with a forage component have been shown to produce meat with higher fat content when both groups are slaughtered at a constant weight (Fisher et al., 2000; Archimède et al., 2008; Resconi et al., 2009). The increasing demand for healthier and environmentally sustainable meat products is stimulating market interest in more extensive systems as outlined by the review of Siro et al. (2008), due to the lower fat content of meat from animals produced from extensive systems as well reduced greenhouse gas emissions of animals fed from forage diets compared with diets high in concentrate. The inclusion of higher levels of forage in the lamb's diet over the finishing period could be useful to achieve the high-quality meat desired by consumers. However, it is pertinent to first establish the effects of concentrate:forage ratio on lamb performance and carcass traits, particularly the ability to produce carcasses which are deemed suitable by commercial standards.

Therefore, the objective of this study was to examine the effects of concentrate:forage feeding levels and duration of feeding on lamb performance and carcass traits.

MATERIALS AND METHODS

All animal procedures used in this study were conducted under experimental license from the Health Products Regulatory Authority (HPRA) in accordance with the European Union protection of animals used for scientific purposes regulations 2012 (S.I. No. 543 of 2012).

Prestudy Management

The study was undertaken at the Teagasc Sheep Research Centre, Mellows Campus Athenry, Co. Galway, Ireland. A total of 99 spring-born male

TXSB lambs were assigned to a 3 × 3 factorial arrangement which was made up of three concentrate:forage feeding ratios: ad libitum concentrate (CON) which also received 400 g of fresh weight silage daily (to help maintain rumen function and minimize the chance of digestive upset), 50% concentrate and 50% forage (50:50), ad libitum grass silage (FORG) with each treatment being fed for three feeding durations (36, 54, and 72 d); these treatments were named as CON36, CON54, CON72, 50:5036, 50:5054, 50:5073, FORG36, FORG54, and FORG72. Lambs were sourced from six commercial farms in the west of Ireland. At 5 mo of age, lambs were weighed and inspected visually to confirm sex and disease-free status before being transported to the research centre. On arrival at the research centre, lambs completed a strict bio-security protocol and were treated for internal and external parasites. Following completion of the bio-security protocol, lambs were placed on grass pasture until selected for commencement of the indoor intensive finishing period. The silage was harvested in early June from a perennial ryegrass sward and ensiled in round bales until the trial commenced. Lambs were assigned to treatment by BW with the aim of producing a 21-kg carcass across all treatments. Therefore, lighter lambs were placed on diets which were expected to produce higher weight gains, and heavier lambs were placed on diets predicted to deliver slower growth rates. This system of allocation to experimental treatments is consistent with commercial practice and ensured that each treatment had the opportunity to produce carcasses which were reflective of what is required at industry level.

Finishing Period

Lambs were individually accommodated on expanded metal floored feeding pens (182 cm L × 122 cm W) for the indoor finishing period. During the finishing period, lambs were allowed tactile, olfactory, and visual contact with each other through the pen partitions. Lambs were allowed a 12-d pre-experimental acclimatization period to adapt to their respective diets. Relative to commencement of ad libitum concentrate feeding (day 0), lambs were offered 150-g/d fresh weight of concentrate feed on days -12, -11, and -10 increasing by 100-g/d fresh weight concentrate on each day from days -9 to -1 to minimize the risk of digestive upsets. For the duration of the finishing period, lambs were offered 100-g/d DM of silage and had ad libitum access to concentrates. Concentrate and

silage samples were collected weekly and dried overnight at 55 °C and pooled for determination of CP, ADF, NDF, and ash (AOAC.942.05, 2005). Concentrate and silage were offered daily with individual lamb refusals recorded twice weekly. These intakes were used to calculate daily feed intake and feed conversion efficiency (FCE). The concentrate used was a 60% cereal-based lamb ration with 15% CP and an energy value of 1-UFL/kg fresh weight (Table 1). For lambs fed on 50:50 diets, a DMI of 1.5-kg DM was assumed so these lambs received 0.9 kg of concentrate daily (85% DM) and 3.0-kg silage (25.5% DM). The silage and concentrate feed were fed to lambs at the same time each morning, with each placed in containers in front of the lambs.

Animal Measurements

On day 0 (start of each feeding period) lambs were weighed and ultrasonically scanned (Dynamic Imaging, Livingstone, UK) for muscle depth and fat thickness as described by Davis (2010). Muscle depth was measured as the deepest point of the eye muscle on the 12th rib; subcutaneous back fat thickness was measured directly above the eye muscle at this point; lambs were ultrasonically scanned again on the final day of the experimental period which was the day prior to slaughter.

Post Slaughter

Lambs were transported to the slaughter facility on the morning of slaughter. A captive bolt

pistol was used to stun each lamb (Grandin, 1994). Immediately after stunning, lambs were exsanguinated, eviscerated, and the fleece removed. Cold carcass weight was recorded 24 h after slaughter and used to calculate kill out percentage (KO) as dressed carcass weight divided by preslaughter live weight multiplied by 100.

Carcasses were graded by an experienced grader for conformation using the EUROP scale (Commission Regulation (EC) No 22/2008), which was coded 5, 4, 3, 2, and 1, respectively, for data analysis and classified for fat cover using 1 to 5 scale (1 = low fat cover, 5 = excess fat tissue).

Data Analysis

Data residuals were examined for normality using the UNIVARIATE procedure of SAS (version 9.1.3, SAS Institute Inc., 2006). Production and carcass data were analyzed and generated using the MIXED procedure of SAS. The model included fixed effects of concentrate forage ratio, duration of feeding as well as all appropriate interactions with lamb considered as the random effect. Pairwise comparisons were determined using the Bonferroni adjustment to evaluate pairwise comparisons between treatment means. Mean values were considered to be statistically significantly different when $P < 0.05$ and considered a tendency when $P < 0.10$ but > 0.05 . Least square means are reported with pooled SEMs. Relevant covariates such as weight at onset of intensive feeding period were used where applicable.

RESULTS

Table 2 summarizes the effects of concentrate:forage, duration, and the concentrate:forage ratio \times duration interaction on a range of dependent production and carcass variables. Concentrate:forage \times duration interactions were recorded for ADG, FCE, daily DMI, and ultrasound muscle depth. Lambs fed CON diets had greater ADG when compared with 50:50 and FORG lambs for each of the three feeding durations, 36, 54, and 72 d ($P < 0.001$). For carcass weight, CON diets fed for 36 d resulted in greater carcass weights than did 50:50 or FORG diets fed for the same duration ($P < 0.001$). When diets were fed for 54 and 72 d, CON and 50:50 diets had greater carcass weights than FORG ($P < 0.001$). Carcass conformation was greater in CON and 50:50 diets compared with FORG diets when fed for 36 d ($P < 0.05$), while no difference was observed between concentrate

Table 1. Ingredient and chemical composition of concentrate and silage fed to TXSB cross lambs during the finishing periods

Concentrate		Silage
Ingredient, kg/tonne		
Maize	300	—
Barley	300	—
Soya hulls	165	—
Soya bean meal	155	—
Molasses	50	—
Minerals	30	—
Chemical composition		
DM, g/kg	850	255
DMD	—	740
Composition of DM, g/kg		
CP	172.7	133.37
NDF	278.43	642.65
ADF	145.05	364.67
Ash	62.25	100

DMD = DM digestibility.

feeding levels on carcass conformation score for 54 d of feeding. There were no differences recorded for carcass fat score between CON, 50:50, and FORG when fed 36 d, while when feeding durations were increased to 54 and 72 d, greater carcass fat scores were recorded in CON and 50:50 lambs compared with FORG ($P < 0.001$). KO percentage was greater in CON and 50:50 than FORG diets when diets were fed for 54 and 72 d ($P < 0.001$). While for following feeding for 36 d, KO was higher in CON fed lambs compared with FORG ($P < 0.05$), but no differences were recorded between CON and 50:50 diets or between 50:50 and FORG. For FCE, CON and 50:50 diets had lower FCE values than FORG for all feeding durations ($P < 0.001$), while there was no difference between CON and 50:50 fed lambs across the three feeding durations. Daily DMI was greater in CON than in 50:50 and FORG following 36 d of feeding ($P < 0.05$); following feeding durations of 54 and 72 d, CON and 50:50 had greater daily DMI than FORG ($P < 0.05$) but did not differ from each other. No differences were seen between concentrate feeding levels for ultrasound fat.

Table 2 also demonstrates the effect of duration of feeding within concentrate feeding level; for ADG, CON 36 was greater than CON 72 ($P < 0.001$), while no difference was observed between CON 36 and CON 54 or CON 54 and CON 72. FCE was greater in FORG diets fed for 72 d compared with FORG diets fed for 36 and 54 d ($P < 0.05$), while no difference was observed between FORG 36 and FORG 54. Silage intake was greater in 50:50 and FORG diets when fed for 54 and 72 d compared with 36 d ($P < 0.001$). Increasing feeding duration from 36 to 72 d decreased ultrasonic muscle measurements in CON diets ($P < 0.001$), while in 50:50 and FORG, increased feeding duration increased ultrasound measurements ($P < 0.001$). Feeding duration did not affect any other variables. Lambs offered CON diets had greater ultrasound muscle depth than 50:50 and FORG fed lambs following 36 and 54 d of feeding ($P < 0.05$), while no other differences were observed for ultrasound muscle measurements between concentrate feeding levels.

DISCUSSION

This study evaluated interactive effects of three concentrate:forage ratio diets and three durations of feeding on the production and carcass trait performance of TXSB hill lambs. The feeding levels and durations explored in this experiment are representative of hill finishing systems in Ireland and the United Kingdom. The treatments were deliberately

chosen to measure the response to the three ranges of concentrate, ranging from zero to ad libitum. The silage used in the current experiment could be classed as good quality silage.

Concentrate:Forage Ratio

Little research has been conducted examining the effect of concentrate feeding levels in hill sheep finishing systems using the breed of lambs used in this experiment; also there is a paucity of information on the performance of lambs when fed different levels of concentrate while using silage as a forage source. Much of the published literature details the effects of concentrate feeding levels on lamb performance but when grazed at pasture and using grazed grass as the forage source. To the author's knowledge, this is one of the first studies to explore the performance of TXSB lambs over the finishing period when fed differing levels of concentrate indoors with silage used as a forage source. The reported increase in DMI as the concentrate:forage ratio increased could be associated with the reduction of forage and therefore fibre content in the diet (McDonald et al., 2011). Fibre is however also important to maintain rumen function and is necessary to prevent rumen digestive problems such as acidosis; no rumen digestive upsets were recorded for lambs in the current study. The higher levels of NDF in FORG diets compared with CON diets may also explain the difference in DMI between treatment groups. Previous studies have reported increased DMI for forage-based diets as the levels of concentrate supplementation increased (Keady and Hanrahan 2010, 2015). Although the latter studies used silage as the forage source, these studies were conducted using lowland sheep and not sheep from hill origins such as those in the current study. As well as higher NDF content in FORG diets, reduced DMI and subsequently reduced performance may be that diets high in forage tend to be bulkier, and as a result of the increased bulkiness, lambs cannot consume large volumes of feed and the gastrointestinal tract becomes full, compared with the easily consumed and more digestible concentrate diets (Forbes, 2007). This is further highlighted by the study of Owens and Goetsch (1993) which attributed greater DMI in concentrate fed lambs to greater physical density and smaller particle size of food, which directly reflect passage through the digestive tract. Thus, the lambs were not able to take in enough energy supply to allow muscle growth to occur and instead could only meet maintenance requirements. Reduced lamb performance

for FORG compared with CON groups could also be attributed to lower protein intake (Tripathi et al., 2007). The additional 34% increase seen in DMI for CON compared with FORG groups in the current study is similar to an increase of 38%–43% reported by Carson et al. (2001). Black and Chestnutt (1992) reported a 26% increase in DMI when moving from high forage:concentrate ratio to medium or lower forage:concentrate ratio.

The increase in ADG as concentrate feeding level increases follows the same trend as the results reported by Borton et al. (2005). More recent studies have also highlighted that live weight gain is closely related to DMI, which is achieved by feeding higher levels of concentrate (Keady and Hanrahan, 2015). Fimbres et al. (2002) reiterated that an increase in live weight gain is associated with higher concentrate feeding levels and thus greater DMI. The study of Carvalho et al. (2007) reported that increasing levels of forage while decreasing the levels of concentrate had a negative effect on ADG of lambs fed on diets of 30:70, 40:60, 50:50, 60:40, and 70:30 forage:concentrate ratios; these results are likely explained by the effects of DMI intake and the inability of the ovine rumen to digest high amounts of bulky feed rapidly. As well as the longer time required to break down forages compared with concentrates and the reduced DMI, differences in ADG observed in this study could be explained by the lower energy density of the FORG diets in comparison with CON and thus altering the total energy intake between the dietary treatments (Murphy et al., 1994). Furthermore, the differences seen in the current study in ADG between concentrate feeding levels were a consequence of lower FCE and greater DMI of CON treatments. Lambs fed FORG diets were only able to consume sufficient levels of feedstuff to meet their maintenance requirements. Lambs fed on CON diets had excessive energy to partition for muscle and tissue development, ultimately resulting in weight gain. As a result of the increased ADG for CON and 50:50 diets compared with FORG groups, these treatment groups resulted in heavier lambs at slaughter. Lambs fed 50:50 in the current study resulted in moderate growth rates; at commercial level, these diets may be useful in scenarios when concentrate price is high relative to the price of lamb. The positive effects of concentrate were further highlighted by Keady and Hanrahan (2015) who stated that increasing level of concentrate offered would lead to increase carcass gains of 141 and 111 g per 1-kg increase in concentrate DMI for lambs offered medium- and high-value silage, respectively.

The additional performance and FCE of concentrate fed lambs in this study are consistent with previous work using TXSB lambs which noted that 20-kg carcass lambs fed concentrate reached slaughter 6.7 d earlier and where slaughtered at 2.7-kg lighter live weight compared with lambs fed concentrate and grass (Annett et al., 2011). Higher energy contents of the CON diets compared with FORG diets resulted in the energy intake of the lambs differing, and thus, CON treatments had increased energy supplies to use for growth while consuming lesser amounts of physical feed as the concentrate was easier to digest and breakdown than treatments with high amounts of forage. The rationale for this is that the lamb's maintenance must be filled, before any nutrients it takes into its body can be used for gain (Fluharty et al. 1996).

The superior KO of lambs fed higher levels of concentrate agrees with earlier studies (Black and Chestnutt, 1992; Chestnutt, 1994). Feeding lambs high levels of bulky forages which are slow to digest can lead to an increased digestive tract size/weight. As a result, the gastrointestinal tract is greater in mass and thus has a negative effect on the KO of lambs. Furthermore, Fluharty et al. (1999) reported that intestinal tract weights were greater in forage fed lambs than in concentrate fed lambs. In addition to increased digestive tract size, decreased levels of fat cover, which is commonly observed with lambs fed forages, will result in lower KO (Borton et al., 2005).

In many previous studies comparing different forage and concentrate ratios, grazed grass was used as the source of forage and lambs were at pasture for the duration of the study, and thus, as a result, lambs were more active in moving around to find and graze grass; in the current study, this was not an issue as lambs were stall fed and not exposed to as much physical exercise. McClure et al. (2000) reported that lambs from forage diets had greater intestinal weight and gut fill than lambs from concentrate diets, thus offering an explanation as to why KO was greater in CON than in FORG groups, while lambs on 50:50 diets were intermediate to both. Furthermore, in cattle, it has been shown that KO increases as the level of concentrate feeding increases (Gill et al., 1976).

The additional carcass weight reported for lambs from CON and 50:50 groups can be explained by the higher slaughter weight and greater KO. This difference observed in slaughter weight is likely due to higher energy intake and as a result increased growth rate, which from a commercial point of

view emphasizes the importance of finishing diets with low levels of indigestible fibre, to achieve maximum live weight gains and ultimately greater carcass weights.

Increasing the level of concentrate in the diet had a positive effect on fat cover of the carcass. Increased fat cover scores in the CON and 50:50 diets are most likely as a result of the higher metabolic energy and CP content of these diets. Although fat cover was higher in CON lambs, it must be noted that fat cover on FORG fed lambs from all feeding durations was still at an acceptable level from an industry perspective. Carcass fat scores for all treatments were above the industry-recommended guideline of 3 (1–5 scale, with 1 denoting a carcass with little or no fat cover and 5 representing excessive fat cover). If lambs had been grazed at pasture to supply a forage source, lower levels of fat cover may be expected as greater energy is expelled when lambs are at pasture, as metabolic requirements may increase as a result of exercise (Moron-Fuenmayor and Clavero, 1999). It could be suggested from the current results that housing lambs to finish from FORG diets is not a viable option. The difference observed in the current study between carcass fat and carcass conformation follows the same trends as found by Keady and Hanrahan (2013) for sheep and for beef cattle by Murphy and Loerch (1994). Increased fat cover from concentrate fed diets compared with forage fed lambs is consistent with previous studies (Kemp et al. 1970, 1972; Murphy and Loerch, 1994). These studies along with McClure et al. (1994) and Lloyd et al. (1980) also relate the increasing fat content to the increasing slaughter weight and carcass weight. Previous work has reported that as an animal gets heavier and approaches its mature weight, the levels of fat deposition increase (Owen et al., 1993); this theory could be applicable to lambs on CON and 50:50 diets as they grew at a higher rate and achieved a carcass weight than FORG lambs. The greater energy content of the diet as the levels of concentrate increase between FORG, 50:50, and CON may also help to explain the differing levels of fat cover. Energy is used by lambs firstly for maintenance, bone, muscle tissue development, and finally fat deposition (Owens et al., 1993). Past research has shown that a large proportion of an animals' maintenance energy requirement is attributed to visceral organs, specifically the liver, kidneys, and the gastrointestinal tract (Ferrell and Jenkins, 1985). The higher carcass fat scores reported for lambs finished on higher levels of concentrate

feeding are in agreement with the results reported by Chestnut et al. (1992).

Likewise, the carcass conformation scores reported in the current study agree with Borton et al. (2005) who reported that forage fed lambs have a reduced carcass conformation compared with lambs from concentrate diets. Dietary effects on carcass conformation score in the current study were similar to those reported by Speijers et al. (2009), Annett et al. (2011), and Carson et al. (2001); the superior carcass conformation of concentrate fed lambs could be mainly attributed to heavier carcass weights. In commercial practice, based on the results of this study, lambs fed FORG are likely to suffer a price penalization because of the lighter carcass weights produced for sale as well as the lower conformation of lambs in comparison with concentrate fed lambs, as producer payments within the EU are determined by carcass weight, conformation grade as well as fat cover.

CONCLUSION

This study was one of the first to examine the performance of TXSB lambs when fed differing levels of concentrate. The current study demonstrated the need for the inclusion of concentrates when finishing lambs indoors. This study demonstrates the superior ADG, FCE of concentrate fed lambs while producing carcasses with increased conformation. Responses from lambs fed CON diets suggest these diets may be useful for finishing lighter lambs, while the response to lambs fed the 50:50 diets were modest and may be an option for finishing lambs of heavier weights while producing sufficient fat cover and carcass conformation; this system may be useful when the cost of concentrates is high and moderate levels of growth performance and feed efficiency are required. The performance of lambs fed FORG in this study was only sufficient to meet the maintenance requirements and resulted in a poor KO, yielding light carcasses with poor conformation and likely to be deemed as undesirable in commercial practice.

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