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Enteric methane emissions and nitrogen utilisation efficiency for two genotype of hill hoggets offered fresh, ensiled and pelleted ryegrass

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ABSTRACT

Thirty-six 12-month-old hill hoggets were used in a 2 genotype (18 Scottish Blackface vs. 18 Swaledale × Scottish Blackface) × 3 diet (fresh vs. ensiled vs. pelleted ryegrass) factorial design experiment to evaluate the effects of hogget genotype and forage type on enteric methane (CH_4) emissions and nitrogen (N) utilisation. The hoggets were offered 3 diets ad libitum with no concentrate supplementation in a single period study with 6 hoggets for each of the 6 genotype × diet combinations (n = 6). Fresh ryegrass was harvested daily in the morning. Pelleted ryegrass was sourced from a commercial supplier (Aylescott Driers & Feeds, Burrington, UK) and the ryegrass silage was ensiled with Ecosyl (*Lactobacillus plantarum*, Volac International Limited, Hertfordshire, UK) as an additive. The hoggets were housed in individual pens for at least 14 d before being transferred to individual respiration chambers for a further 4 d with feed intake, faeces and urine outputs and CH_4 emissions measured. There was no significant interaction between genotype and forage type on any parameter evaluated. Sheep offered pelleted grass had greater feed intake (e.g. DM, energy and N) but less energy and nutrient apparent digestibility (e.g. DM, N and neutral detergent fibre (NDF)) than those given fresh grass or grass silage ($P < 0.001$). Feeding pelleted grass, rather than fresh grass or grass silage, reduced enteric CH_4 emissions as a proportion of DM intake and gross energy (GE) intake ($P < 0.01$). Sheep offered fresh grass had a significantly lower acid detergent fibre (ADF) apparent digestibility, and CH_4 energy output (CH_4-E) as a proportion of GE intake than those offered grass silage ($P < 0.001$). There was no significant difference, in CH_4 emission rate or N utilisation efficiency when compared between Scottish Blackface and Swaledale × Scottish Blackface. Linear and multiple regression techniques were used to develop relationships between CH_4 emissions or N excretion and dietary and animal variables using data from sheep offered fresh ryegrass and grass silage. The equation relating CH_4-E (MJ/d) to GE intake (GEI, MJ/d), energy apparent digestibility (DE/GE) and metabolisability (ME/GE) resulted in a high r^2 ($CH_4\text{-E} = 0.074\ \text{GEI} + 9.2\ \text{DE/GE} - 10.2\ \text{ME/GE} - 0.37$, $r^2 = 0.93$). N intake (NI) was the best predictor for manure N excretion ($\text{Manure N} = 0.66\ \text{NI} + 0.96$, $r^2 = 0.85$). The use of these relationships can potentially improve the precision and decrease the uncertainty in predicting CH_4 emissions and N excretion for sheep production systems managed under the current feeding conditions.

1. Introduction

Within the UK sheep production systems, approximately 43% breeding hoggets are hill breed types. The UK hill sheep sector is dominated by the Scottish Blackface (BF) breed with its outstanding qualities of survivability, adaptability and versatility. Being excellent feeders, of strong constitution and lamb rearers, the Swaledale is a bold hardy sheep, well fitted to endure the hardships of exposed and high lying situations. Research undertaken on hill farms around Northern Ireland has demonstrated that crossing BF ewes with Swaledale rams to produce crossbred hoggets can increase flock output compared with the pure BF. However there is limited data on the CH_4 emissions from crossbred hill hoggets in comparison to pure BF hoggets. CH_4 is produced in ruminants as an unavoidable by-product of enteric fermentation, a digestive process by which nutrients are broken down by micro-organisms into simple molecules for absorption into the bloodstream in the rumen. CH_4 is formed by CH_4-producing archaea, known as methanogens. Methanogens use a limited range of substrates, including CO_2/H_2, formate, acetate, and methyl compounds. The type of carbohydrate fermented regulates the amount of H_2 available for CH_4 formation through

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the ratio of volatile fatty acids (VFAs), which are the major end products of carbohydrate digestion in the rumen (Johnson and Johnson, 1995). Increased structural carbohydrates in the diet shift the stoichiometry of the fermentation towards production of acetic and butyric acids, which leads to an increase in CH_4 production (Wilkerson et al., 1995). Increasing the proportion of non-structural in the diet lowers the amount of CH_4 produced, due to a shift in the fermentation pathways towards propionate, and a decline in the ruminal pH (Lovett et al., 2003). Pacheco et al. (2014) reported a range of 18.0–27.0 g CH_4 per kg dry matter intake from several experiments using respiration chambers to measure CH_4 emissions from sheep offered fresh perennial ryegrass. The Intergovernmental Panel on Climate Change (IPCC) Tier 2 methodology (IPCC, 2006), currently uses GEI, which is calculated from standard models, and a standard CH_4 conversion factor (CH_4-E/GE=6.5%) to calculate CH_4 emissions. This conversion factor which was developed using data irrespective of the influence of different animal production levels and dietary factors is also applied to hill hoggets. Hill hoggets typically have lower body weights than lowland breeds. They are thus expected to have lower feed intakes theoretically and subsequently lower CH_4 emissions. It is also possible that physiological and/or behavioural differences between different breed types may lead to differences in amounts of CH_4 emitted. There is therefore an urgent need to develop more accurate CH_4 conversion factors specific to hill hoggets and representative of the breeds and rearing systems employed in the UK sheep production systems.

Another environmental concern for the sheep production systems is N excretion. Livestock urine and faeces are important components of the N cycle in pastures, where the microbial processes in the soil produce nitrate and nitrous oxide which are responsible for groundwater pollution and global warming, respectively. Therefore, the accurate prediction of N output is essential for developing mitigation strategies to reduce the environmental impact of sheep production systems. However, only a few models to predict the N excretion have been reported in sheep offered legumes or foliages (Molle et al., 2009; Patra, 2010). Molle et al., (2009) recorded a range of 0.28–0.50 for faecal N/manure N in milked sheep grazing grass-legume binary mixtures differing in the legume component. Patra (2010) presented a mean value of 0.64 for faecal N/manure N in sheep of different breeds with foliages incorporated in the diets. These results may not be suitable for the grass-based diets in hill sheep due to the different diets and breeds. Most of the available CH_4 prediction equations are either based on lowland sheep data or on a collection of datasets from the literature without distinguishing the specific characteristics of hill sheep which are small and hardy breeds adapted to survive on low-quality forage in exposed upland conditions (Pelchen and Peters, 1998; Hammond, et al., 2013). The lack of such information can impact the development of appropriate mitigation strategies to reduce the environmental footprint for hill sheep production. Therefore, the objects of the present study were to investigate the effects of breed and forage types on enteric CH_4 emissions and the efficiency of N utilisation, and to use these data to develop prediction equations for CH_4 production and N excretion in hill hoggets.

2. Materials and methods

The present study was conducted under the regulations of Department of Health, Social Services and Public Safety of Northern Ireland in accordance with the Animals (Scientific Procedures) Act 1986 (Home Office, 1986).

2.1. Animals, experimental design, and diets

Thirty-six hill hoggets aged 12 months and weighed 42 ± 4.0 (mean ± SD) kg were used in a 2 genotype (18 Scottish Blackface and 18 Swaledale × Scottish Blackface) × 3 diet (fresh grass, dried and pelleted grass and grass silage) factorial design in the present study. Sheep within each genotype were offered 3 ryegrass only diets ad libitum in a single period study with 6 hoggets for each of the 6 genotype × diet combinations (n=6): fresh grass, dried and pelleted grass and grass silage. Dried and pelleted grass was sourced from a commercial supplier (Aylescott Driers & Feeds, Burrington, UK) and pelletized from dried and ground perennial ryegrass. Fresh grass was harvested daily in the morning (from 02 May to 14 Jun, 2012) from a primary growth sward with perennial ryegrass, and the grass silage was made from the secondary growth (harvested on 30 June and 1 July 2011) perennial ryegrass which was ensiled with Ecosyl (*Lactobacillus plantarum,* Volac International Limited, Hertfordshire, UK) as an additive. Deworming of the sheep was carried out before the beginning of the experiment using Cydectin (Zoetis, Surrey, UK). The 36 animals were individually housed at the same time in the commencement of the study for at least 14 d in pens before being transferred to individual respiration chambers for a further 4 d with feed intake, faecal and urine output and CH_4 emissions measured. The sheep were blocked in 6 groups in time with 6 animals per group balanced with genotype and diet to enter the 6 individual chambers with one sheep per chamber. The sheep were housed in metabolic crates which were individually placed in chambers. Each crate contained a feed bin, drinking water container and separate trays to collect faeces and urine. The chambers were opened once daily at 0900 h to deliver diet and water and collect faeces and urine. The amount of feed offered was adjusted based on average feed intake of the previous two days to ensure a 10% refusal. The chemical composition of the experimental diets is shown in Table 1.

2.2. Measurements

Body weight (BW) was measured at the beginning of the study at the same time when the 36 sheep were moved in the individual pens. Sheep were then gradually transferred to chambers in 6 groups with 6 animals in each group and weighted before entering and after leaving the chamber. Quantities of feed offered

Table 1
Chemical composition of the experimental diets[a].

Item	Pelleted Grass	Fresh Grass	Grass Silage
DM (g/kg)	893	203	312
Ash (g/kg DM)	64	67	87
CP (g/kg DM)	152	114	100
NDF (g/kg DM)	584	526	556
ADF (g/kg DM)	277	254	324
GE (MJ/kg DM)	19.0	18.4	18.1
ME (MJ/kg DM)	9.7	13.3	11.4
pH			3.7
NH_3-N /Total N (g/kg)			77.3
Acetic Acid (g/kg FM)			5.8
Propionic Acid (g/kg FM)			0.05
n-Butyric Acid (g/kg FM)			0.16
i-Valeric Acid (g/kg FM)			0.02
Lactic Acid (g/kg FM)			44.6

ME was based on the in vivo chamber data; ME = Gross energy – Faecal energy – Urine energy – Methane energy. NDF and ADF were assayed without a heat stable amylase and expressed inclusive of residual ash.

[a] DM of Grass Silage was volatile corrected oven dry matter (VCODM); VCODM=$DM_{(85\ ^{\circ}C)}$+0.716 × (Acetic Acid+Propionic Acid+n-Butyric Acid+i-Valeric Acid)+0.224 × Lactic Acid+ NH_3/N × N+0.97 × (Ethanol+Propanol) (Porter and Murray, 2001); FM = fresh matter.