Small Ruminant Research 130 (2015) 108–116

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Relationship between energy intake and chewing index of diets fed to pregnant ewes

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ARTICLE INFO

Article history:
Received 21 January 2015
Received in revised form 3 June 2015
Accepted 7 June 2015
Available online 14 June 2015

Keywords:
Energy intake
Grass silage
Linear model
Neutral detergent fibre
Sheep

ABSTRACT

The objective was to determine whether a linear relationship exists between the metabolizable energy (ME) intake of pregnant ewes and a dietary chewing index (CI). The relationship was studied using five feeding trials with intake data from 108 pregnant ewes, 4 to 1 weeks before lambing, giving a total of 324 observations. All ewes were fed grass silage *ad libitum*, supplemented with concentrates either separately or in a total mixed ration (TMR). The ewes were of different breeds, were between 2 and 7 years old, had a mean body weight (BW) in the 4th week before lambing of 95.1 kg (SD = 9.64), and gave birth to an average of 2.2 lambs (SD = 0.37). The average daily ME intake was 29.4 MJ/d (SD = 5.26). The NorFor CI (min/MJ ME) of the feeds was estimated from the neutral detergent fibre (NDF) (g/kg DM), indigestible NDF (g/kg NDF) and the theoretical chopping length (mm) of the forage. The CI values were adjusted for the BW of the ewes and for NDF intake higher than 0.7% of forage NDF per kg of BW. The mean corrected CI (CI_{cor}) was 27.2 min/MJ ME (SD = 5.10). The relationship between ME intake (MEI) and CI_{cor} was analysed using nonlinear mixed effects modelling, using the equation $MEI = ME_0 - k \times ME_0^2 \times CI_{cor}$, where MEI is the daily metabolizable energy intake, ME_0 is considered the theoretical maximum intake capacity of the animal in a theoretical situation with no physical constraint on intake, and parameter k represents the decline in MEI with the increasing CI_{cor} of the ration. The model includes random variation of week within experiment on the intercept and linear fixed effect of week before lambing on parameter k. The maximum daily chewing time, CT_{max}, for the pregnant ewes was predicted to be $1/(4 \times k)$. The MEI declined linearly with increasing dietary CI ($P < 0.001$), with different within-experiment intercepts in relation to week before lambing ($P < 0.001$), supporting the existence of a linear relationship between MEI and CI_{cor} for pregnant ewes in the last 4 weeks before lambing. CT_{max} could be calculated for the ewes and had a mean of 1066 min/d. The model appears to have a potential for predicting MEI in pregnant ewes fed forages *ad libitum* with concentrates restrictively or TMR diets, based on BW, energy value of feeds, NDF and iNDF concentration of forage.

1. Introduction

1.1. Background

Energy intake in late pregnancy directly affects the body condition of pregnant ewes, amount of colostrum produced by the ewe, and birth weight of lambs (Robinson et al., 1999). Energy intake in late pregnancy is therefore important when optimizing lamb performance (Avondo et al., 2002). Each individual sheep is considered to have a maximum production capacity (Illius and Jessop, 1996). This capacity depends on the genetic potential and varies during the course of the sheep's life according to stage of growth and reproduction (Illius and Jessop, 1996). For the pregnant ewe, the maximum production capacity further depends on the number and size of the foeti, as growing foeti compromise abdominal space and limit daily feed intake, especially in late pregnancy (Forbes, 1970; Bermudez et al., 1989; Robinson et al., 1999). Feed intake in late pregnancy reflects the nutritional challenge of meeting increased nutritional

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http://dx.doi.org/10.1016/j.smallrumres.2015.06.004
0921-4488/

requirements given the reduced digestive capacity of the rumen. During this physiological state of the ewe, highly digestible feed becomes increasingly important over time to supply both the ewe and the growing foeti with sufficient energy (Robinson et al., 1999). Increasing forage maturity at harvest, results in increasing neutral detergent fibre (NDF) concentration and lignification of the NDF (Jung, 1997); this reduces forage digestibility resulting in increased rumen fill and time spent chewing per kg of dry matter (DM), which results in decreased voluntary feed intake (Roche et al., 2008). According to Mertens (1994), the dietary constraint on DM intake in sheep and cattle is related to the dietary NDF concentration. In diets with high forage NDF concentration, the intake is constrained by a physical fill effect, whereas intake is constrained by the energy demands of the animal when diets have low forage NDF concentration (Mertens, 1994). Supplementing with concentrates can reduce forage intake, depending on the forage quality and amount and type of concentrate (Mertens, 1994; Robinson et al., 1999).

Low voluntary feed intake by sheep can be partly explained by insufficient degradation when chewing forage (Blaxter et al., 1966). Daily chewing time has been found to be closely related to the intake of forage NDF (Nørgaard et al., 2011a). According to Jalali et al. (2012a), the mean rumination time per kg of NDF increases with increased lignification of forage NDF. The Nordic Feed Evaluation system (NorFor; Volden, 2011a) introduced a parameter to describe the diet of dairy cows based on the eating and ruminating times, *i.e.* the chewing index (Nørgaard et al., 2011b). Nørgaard and Mølbak (2001) found a linearly decreasing net energy intake (NEI) with increasing dietary chewing index (CI) value. This relationship held when forage NDF intakes were below the maximum capacity for NDF intake of 12–14 g NDF per kg of body weight (BW) in cattle (Mertens, 1994). The NorFor CI value for dairy cattle depends on theoretical cutting length, NDF concentration, and the proportion of indigestible NDF, creating a value suitable for the prediction of energy intake.

Mathematical models have been proven to be powerful tools for improving animal performance (Tedeschi et al., 2005). Currently, several models can predict feed intake in pregnant ewes (ARC, 1980; INRA, 2007; NRC, 2007). The ARC (1980) model classifies forage types as coarse forages, fine forages, and silage and uses a specific prediction equation for each forage type. For silage, the ARC model predicts DM intake based on BW and metabolic BW. The ARC model was built on data from sheep breeds and feeds commonly used in the UK (ARC, 1980). The NRC (2007) intake model, developed from data on grazing sheep, predicts DM intake from animal characteristics, mature BW, and actual BW/mature BW. The INRA (2007) model defines a feed fill value and an animal intake capacity, using these values to predict optimal ration formulation. The same system can be used to predict forage DM intake when concentrate DM intake is known. The INRA model for non-dairy sheep is based on *ad libitum* intake by barn-fed wethers 1 to 2 years old.

Empirical models of feed intake cannot be expected to give accurate predictions in situations outside those for which the models were specifically adjusted (Elsen et al., 1988). Even models built on a wide range of data cannot be considered universally valid (Elsen et al., 1988). None of the above mentioned intake models have been validated specifically for late pregnancy or ewes fed grass silage. A new model for predicting feed intake under these conditions could help optimize animal performance and improve profitability and sustainability in the production.

1.2. Background of the model

Nørgaard and Mølbak (2001) presented a linear model describing the net energy intake (NEI), relative to the metabolic BW, as a linear function of the dietary CI of diets fed to lactating dairy cows, non-lactating dairy cows, growing bulls, and growing steers. The model was built on data from 13 experiments using a range of forage qualities and various amounts of concentrates distributed over 31 treatments. The model presented by Nørgaard and Mølbak (2001) is replicated, in an expanded version in the following equation:

$$\mathrm{NEI} = \mathrm{NE_0}\text{-}b \times \mathrm{CI} \times \left(\frac{625}{\mathrm{BW}}\right) \tag{1a}$$

where NEI is expressed in MJ NE/kg $\mathrm{BW}^{0.75}$, $\mathrm{NE_0}$ in MJ NE/kg $\mathrm{BW}^{0.75}$, b in $(\mathrm{MJ\,NE})^2/(\min \times \mathrm{kgBW}^{0.75})$, CI in min/(MJ NE) and BW in (kg).

The intercept value ($\mathrm{NE_0}$) was considered to be the theoretical maximum intake capacity of NE for the specific group of cattle, where the feed intake was not constrained by rumen fill. The slope, b, represented the decreasing NEI with increasing CI of the ration.

The estimated slope values were found to be directly proportional to the squared $\mathrm{NE_0}$ values for each group of animals within experiments (R^2 = 0.89). This relationship implies a close link between the theoretical maximum NEI capacity and the decreasing intake with increasing CI values.

1.3. Objectives

The objective was to examine and modify the linear relationship between metabolizable energy intake and the CI of the rations as described by Nørgaard and Mølbak (2001), for application to ewes in late pregnancy. The hypotheses are that the metabolizable energy intake (MEI) of similar groups of pregnant ewes fed different types of forage can be described as a linear function of the CI of the ration, and that the predicted intercepts of the linear function vary with the experiment and week before lambing. It is further hypothesized that the resulting model can be used to predict a maximum daily chewing time ($\mathrm{CT_{max}}$) and to evaluate how the $\mathrm{CT_{max}}$ varies with week before lambing.

2. Materials and methods

2.1. Animals and feeds used in the model

The investigation was based on daily individual intake data from 108 pregnant ewes during the last 4 weeks of pregnancy, distributed over 14 dietary treatments in four Swedish experiments, experiment 1 through 4 (Nadeau and Arnesson, 2008; Jalali et al., 2012a; Helander et al., 2014a,b; Nadeau pers. comm., 2014), and one Norwegian, experiment 5 (Eknæs et al., 2009). Ewes were pregnant with two foeti in experiments 1 to 4 and two to three foeti in experiment 5. Pregnancy status was identified by ultrasonography. Ewes were divided into groups according to age, BW, body condition score and number of foeti. The treatments were allocated randomly to these groups of ewes, within each experiment. The experiments were conducted as continuous trials. The dietary treatments in experiment 1 included grass silage of two stages of maturity at harvest supplemented daily with 0.8 kg concentrate. The treatments in both experiments 2 and 3 included unchopped and chopped grass silage supplemented with 0.8 kg concentrate daily, and a totally mixed ration (TMR) of chopped grass silage and concentrate. Experiment 4 included grass silage treated with a salt-based additive, formic acid based additive or no additive, supplemented with 0.5 kg concentrate daily. The treatments in experiment 5 included grass silage of three stages of maturity at harvest, supplemented with different levels of concentrate.

The average weekly intake by individual ewes was used. Due to missing registrations of components needed to calculate CI, a total of 324 observations were used of a total of 432. The ewes were adults between 2 and 7 years old with a mean BW of 95 kg (SD = 9.64) 4 weeks before lambing. In the Swedish experiments, experiments 1 to 4, the breeds were Finewool–Dorset crosses and