Livestock Science 158 (2013) 74–83

Contents lists available at ScienceDirect

Livestock Science

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

The development of a model to predict feed intake by growing cattle

Arto Huuskonen [a,*], Pekka Huhtanen [b], Erkki Joki-Tokola [a]

[a] MTT Agrifood Research Finland, Animal Production Research, Tutkimusasemantie 15, FI-92400 Ruukki, Finland
[b] Swedish University of Agricultural Sciences (SLU), Department of Agriculture for Northern Sweden, S-90183 Umeå, Sweden

ARTICLE INFO

Article history:
Received 6 June 2013
Received in revised form
1 October 2013
Accepted 3 October 2013

Keywords:
Intake
Growing cattle
Modelling
Diet factors
Animal factors

ABSTRACT

The objective of this work was to develop total dry matter intake (TDMI) prediction models for growing cattle. The Finnish dataset of 1006 experimental period treatment means from 17 feeding trials in growing bulls was collected for developing TDMI prediction models. The diets were mainly based on grass silage or grass silage partly or completely replaced by whole-crop silages or straw. The concentrate feeds consisted mainly of cereal grains, fibrous by-products and various protein supplements. The following non-linear equation for the relationship between TDMI and body weight (BW) (kg) was defined: TDMI (kg/d) = 0.191 × $BW^{0.627}$ (Adj. RMSE = 0.451). The model was improved when both the constant and exponent were adjusted for dietary variables. Dietary neutral detergent fibre (NDF) concentration (kg/kg DM) generated a greater improvement in the model than other variables investigated (dietary concentrations of forage NDF and ME, and the proportion of concentrate). The constant decreased and the exponent increased with increasing dietary NDF concentration. The following equation was defined: TDMI (kg/d) = (0.209–0.489 × NDF) × $BW^{(0.614+0.397\times NDF)}$ (Adj. RMSE = 0.438). In the model NDF concentration was centred to the mean concentration of 0.40 kg/kg DM. The model was marginally improved when the constant was adjusted for silage DMI (SDMI)-index that was centred to 100 units and dietary concentration of volatile fatty acids (VFA). The effects of SDMI-index and VFA were highly significant ($P < 0.01$): TDMI (kg/d) = (0.199–0.380 × NDF + 0.000348 × SDMI-index − 0.00044 × VFA) × $BW^{(0.624+0.348\times NDF)}$ (Adj. RMSE = 0.433). A complete dataset was used for the evaluation of models developed from the Finnish dataset. The complete dataset was collected from growing cattle feeding experiments, in which total mixed rations or forages were fed ad libitum. Overall, the complete dataset comprised 135 feeding experiments and 687 treatment means. The following relationship between observed and predicted TDMI was derived with a non-linear model including SDMI-index and dietary VFA concentration as adjustment factors for the constant: Observed TDMI = −0.35(±0.40) + 1.01 (±0.051) × Predicted TDMI ($n = 421$; Adj. RMSE = 0.243). The developed models can be used to estimate the intake responses to BW and diet changes. They provide an improved basis for practical ration formulation systems and economic evaluation.

1. Introduction

Voluntary feed intake in cattle has a great impact on the performance. Variation in the performance is more closely related to feed intake than to diet digestibility or efficiency of converting digestible energy to metabolisable or net energy (Mertens, 1994). Therefore, in order to plan a feeding programme or to optimise a ration to meet the requirements under conditions of ad libitum feeding, it is necessary to predict feed intake accurately and precisely. Regulation of feed intake in ruminants involves multiple

* Corresponding author. Tel.: +358 40 808 425.
E-mail address: arto.huuskonen@mtt.fi (A. Huuskonen).

1871-1413/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.livsci.2013.10.005

mechanisms related to dietary and animal factors that are poorly understood (Ingvartsen, 1994; Mertens, 1994). Interactions between these two factors further complicate predictions. Despite extensive research efforts over the past 30–40 years, no generally accepted model for intake prediction has been developed.

For estimating factors affecting the intake of grass silage in growing cattle Steen et al. (1998) determined the intakes of 136 silages from commercial farms in Northern Ireland. They concluded that silage intake is more closely related to factors influencing in vivo apparent digestibility and rumen degradability than to the end-products of silage fermentation such as lactic and volatile fatty acids (Steen et al., 1998). It was also concluded that the intake potential of silages can be predicted with a high degree of accuracy by the near infrared reflectance spectrometry (NIRS) from both dried and fresh samples of silage (Gordon et al., 1998; Offer et al., 1998; Steen et al., 1998). To overcome the problems related to variation in animal and environmental factors in estimating the effects of feed factors on intake, Huhtanen et al. (2002) presented a relative silage dry matter (DM) intake (SDMI)-index based on treatment mean data from milk production studies using a mixed-model regression analysis. This model estimates the effects of silage characteristics (*D*-value, fermentation parameters) on SDMI potential when the animal and other dietary factors (e.g. concentrate supplementation and feeding management) are constant. The model was updated and extended to include additional silage variables, such as grass harvest (primary growth vs. regrowth), herbage species and silage DM and neutral detergent fibre (NDF) concentration (Huhtanen et al., 2007). In addition to forage characteristics, total DM intake (TDMI) is greatly influenced by the amount and composition of concentrate supplements, and possible interactions between concentrate supplementation and forage intake potential (Dulphy et al., 1989; Keady et al., 2004). Therefore, Huhtanen et al. (2008) developed a relative total diet DM intake index model to extend the relative SDMI index to account for the effects of concentrate supplementation on silage and TDMI of dairy cows.

Different models for prediction of voluntary intake have been compared for growing cattle (e.g. AFRC, 1991; Ingvartsen, 1994; Neal et al., 1988; NRC, 2000; Pittroff and Kothmann, 2001; Rook et al., 1990). Ingvartsen (1994) concluded that feed intake models should at least include important animal and feed factors, and models assuming constant intake per kg $W^{0.75}$ may result in serious lack of fit. The Finnish models mentioned earlier (Huhtanen et al., 2002, 2007, 2008) were developed for predicting feed intake of dairy cows. On this basis it was concluded that the effects of animal and dietary factors on TDMI of growing cattle are possible to predict from a dataset of beef production experiments. Therefore, the objective of this study was to develop a DMI prediction model for growing cattle. The aim was to estimate the effects of animal and feed factors on intake by taking these factors into account independently. The model factors were restricted to those that would be available at the time of ration formulation.

2. Materials and methods

2.1. Dataset – Finnish data with experimental period treatment means

Data were collected from feeding trials with growing bulls fed ad libitum of total mixed ration (TMR) or ad libitum of grass silage, or whole-crop silages (barley, oats or wheat) or straw partly or completely substituted for grass silage fed with fixed amounts of concentrates. About 70% of the studies were conducted with pure dairy breeds (Ayrshire, Friesian, Holstein) and the remainder with beef breeds. The list of references used to collect the Finnish dataset is provided in Appendix A. The forages were supplemented with concentrate feeds, fed either in TMR or separately, differing both in the amounts and composition between and within the experiments. The concentrate feeds consisted mainly of cereal grains, fibrous by-products and various protein supplements. The minimum prerequisite for an experiment to be included in the dataset was that forage and total DM intakes and initial and final body weights (BW) were available for each experimental feeding period (average feeding period 29 days) and adequate forage characterisation (plant species, DM concentration, in vivo or in vitro digestibility and fermentation quality) and adequate concentrate characterisation [proportion of ingredients, DM, crude protein (CP) concentration] were available. The Finnish dataset comprised 257 forage analyses and 1006 experimental period dietary treatment means from 17 feeding trials.

2.2. Dataset – complete data with experimental treatment means

A complete dataset was collected from feeding experiments conducted with growing cattle (bulls, steers, heifers) using ad libitum feeding of TMR or forages (grass silage, or grass silage partly or completely replaced with whole-crop silages, legume silages, hay or straw). The concentrate feeds consisted mainly of cereal grains, fibrous by-products and various protein supplements. About 55% of the studies were conducted with pure dairy breeds (Ayrshire, Friesian, Holstein, and Nordic Red) and the remainder with beef breeds or dairy × beef crossbred animals. In the complete dataset 47% of the experiments were conducted in the UK and Ireland, 46% in the Nordic countries and 7% in other countries (e.g. Belgium, Canada, and Israel). For the Finnish experiments, unpublished data were also used. Variation in the design of experiments, animal performance, feeding routines, etc. between the experiments was substantial, i.e. it covered most practical on-farm feeding situations. The complete dataset included concentrate supplementation studies (54 feeding experiments/270 treatment means), protein supplementation studies (49/188), silage additive studies (20/63), silage harvest maturity studies (25/86), silage wilting studies (11/35), whole-crop studies (15/43) and legume studies (3/15). The minimum prerequisites for an experiment to be included in the complete dataset were the same as for the Finnish dataset. Overall, the complete dataset comprised 135 feeding experiments and 687 treatment means by