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Parameter estimation and sensitivity analysis of fat deposition models in beef steers using acslXtreme

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Abstract

The Davis Growth Model (a dynamic steer growth model encompassing 4 fat deposition models) is currently being used by the phenotypic prediction program of the Cooperative Research Centre (CRC) for Beef Genetic Technologies to predict P8 fat (mm) in beef cattle to assist beef producers meet market specifications. The concepts of cellular hyperplasia and hypertrophy are integral components of the Davis Growth Model. The net synthesis of total body fat (kg) is calculated from the net energy available after accounting for energy needs for maintenance and protein synthesis. Total body fat (kg) is then partitioned into 4 fat depots (intermuscular, intramuscular, subcutaneous, and visceral). This paper reports on the parameter estimation and sensitivity analysis of the DNA (deoxyribonucleic acid) logistic growth equations and the fat deposition first-order differential equations in the Davis Growth Model using acslXtreme (Hunstville, AL, USA, Xcellon). The DNA and fat deposition parameter coefficients were found to be important determinants of model function; the DNA parameter coefficients with days on feed >100 days and the fat deposition parameter coefficients for all days on feed. The generalized NL2SOL optimization algorithm had the fastest processing time and the minimum number of objective function evaluations when estimating the 4 fat deposition parameter coefficients with 2 observed values (initial and final fat). The subcutaneous fat parameter coefficient did indicate a metabolic difference for frame sizes. The results look promising and the prototype Davis Growth Model has the potential to assist the beef industry meet market specifications.

Keywords: Cattle; Fat deposition; Parameter estimation; Sensitivity analysis

1. Introduction

The Davis Growth Model, a dynamic steer growth model [9] that includes 4 fat deposition models [11] is currently being used by the phenotypic prediction program of the Cooperative Research Centre (CRC) for Beef Genetic Technologies to predict beef cattle fatness in the field [4]. Predicting beef cattle fatness will assist beef producers manage cattle to meet stringent market specifications that are related to both weight and fatness for domestic and international markets.

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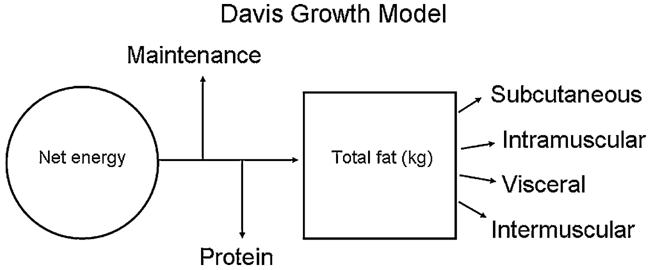

Fig. 1. Partitioning of net energy in the Davis Growth Model to total body fat and then the partitioning of total body fat to 4 fat depots.

The concepts of cellular hyperplasia and hypertrophy are integral components of the Davis Growth Model. The net synthesis of total body fat is calculated from the net energy available after accounting for energy needs for maintenance and protein synthesis. Total body fat (FAT) is then partitioned into 4 fat depots (intermuscular, intramuscular, subcutaneous, and visceral) (Fig. 1). Three of the fat depots are then converted to carcass characteristics: intramuscular fat (IMF, kg) to IMF as a percentage (%), subcutaneous fat (kg) to 12/13th rib fat (mm) and subsequently to P8 fat (B.J. Walmsley, unpublished results), and visceral fat (kg) to kidney, pelvic, and heart fat (KPH, %) [8]. The 4th fat depot, intermuscular fat, is not converted to any carcass characteristic. Each of the 4 fat depots is derived by a first-order differential equation. This paper describes the parameter estimation and sensitivity analysis of the DNA logistic growth equations and fat deposition first-order differential equations using acslXtreme (Hunstville, AL, USA, Xcellon). Data from Robelin [10] and Cianzio et al. [2] were used to parameterize the DNA equations and data from a meta-analysis study [7] were used to parameterize the fat deposition equations. The objectives of this study were: (1) describe the fat deposition models; (2) parameterize the DNA logistic growth equations and fat deposition first-order differential equations and; (3) conduct a sensitivity analysis of the parameters.

2. Notation and units

A number of symbols and special nomenclature are used throughout this paper. Table 1 outlines the notation with a description, units, and value where appropriate.

3. Method

The DNA logistic growth equations and fat deposition equations have been parameterized using acslXtreme (a tool for modelling and simulation of continuous dynamic systems and processes) and a sensitivity analysis was conducted using the sensitivity analysis routine in acslXtreme. Data reported by Robelin [10] and Cianzio et al. [2] were used to parameterize the DNA logistic growth equations and data from a meta-analysis study [7] were used to parameterize the fat deposition equations. The K_{syn} and K_{maint} parameters were initially parameterized against BW and FAT before the fat deposition parameters were estimated. It was assumed that fat was increasing in each of the depots therefore data with fat deposition parameter coefficients less than zero were removed. An evaluation of each of the acslXtreme optimization algorithms was conducted on 20 of the meta-analysis data sets. The carcass characteristics reported in the meta-analysis study [7] were converted to kilograms of fat using the equations described by McPhee et al. [8]. All BW values reported in this study are shrunk BW, i.e., the reported BW in the publications multiplied by 0.96. A summary of the inputs to initialize the Davis Growth Model simulations are shown in Tables 2 and 3 for non-implanted and implanted steers, respectively. A summary of the initial and final observed values to parameterize K_{syn} and K_{maint} against BW and FAT in the first instance and subsequently the fat deposition parameter coefficients ($kFAT_j$) for intermuscular, intramuscular, subcutaneous, and visceral fat are shown in Tables 4 and 5 for non-implanted and implanted steers, respectively.

3.1. Frame size

Frame size (1) was calculated based on the mean values of EBW reported in each of the publications in the meta-analysis study [7]. The industry scale of frame size is 1–9 corresponding to 550–950 kg MEBW, in steps of 50 kg