Computers and Electronics in Agriculture 125 (2016) 29–38

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

Original papers

A stochastic farm model to simulate dairy farms and the segregation of cows to produce milk with different concentrations of unsaturated fatty acids

D. Silva-Villacorta [a,*], N. Lopez-Villalobos [a], H.T. Blair [a], R.E. Hickson [a], A.K. MacGibbon [b]

[a] Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand
[b] Fonterra Co-operative Group, Palmerston North, New Zealand

ARTICLE INFO

Article history:
Received 4 May 2015
Received in revised form 19 April 2016
Accepted 22 April 2016
Available online 4 May 2016

Keywords:
Unsaturated fatty acids
Milk fat
Stochastic farm model
Operating profit
Segregation of cows

ABSTRACT

The objective of this study was to develop a model for the simulation of milk production, milk composition (including milk fat UFA concentration), the segregation of dairy cows and the economic performance of dairy farms under New Zealand farming conditions. The model developed was used to investigate the effect on farm production and profit of the phenotypic segregation of cows for the production of milk fat with high UFA concentration. The model used the Cholesky decomposition algorithm of (co)variance matrices to simulate the performance of Holstein–Friesian cows for milk yield (MY), fat percentage (F%), protein percentage (P%), fat UFA concentration and live weight (LW). The mean performance of cows and farms simulated by the model were very close to national average statistics for New Zealand dairy farms.

The model was used to simulate: (1) a population of 1,820,000 cows in 5600 farms (AVE farms), and (2) the establishment of a farm (120 ha) for the production of milk high in UFA through the segregation into a herd of the top 325 (2.71 cows/ha) or 353 (2.94 cows/ha) cows for fat UFA concentration ($UFA_{2.71}$ farm and $UFA_{2.94}$, farm, respectively). The simulations were repeated 1000 times and 95% confidence intervals were estimated by bootstrapping methodology. On average, the $UFA_{2.71}$ and $UFA_{2.94}$ farms produced milk with 23.6% more UFA than AVE farms. However, cows on the $UFA_{2.71}$ and $UFA_{2.94}$ farms had significantly lower yields of fat (both −48 kg, $P < 0.05$), protein (−24 and −23 kg, respectively, $P < 0.05$) and milksolids (−73 and −72 kg, respectively, $P < 0.05$) than cows on AVE farms. Under a milk payment system that pays for yields of fat ($3.80/kg) and protein ($9.67/kg), and penalises milk volume (−$0.03/l), the $UFA_{2.71}$ and $UFA_{2.94}$ farms had significantly lower operating profit (−$872/ha and $946/ha, respectively, $P < 0.05$) than AVE farms. These results indicate that farm profit would be adversely affected unless there is a premium for fat UFA concentration.

1. Introduction

In recent years there has been a trend towards both healthy and convenient foods (Bermudez et al., 2010; IFICF, 2012). Increasing the concentration of unsaturated fatty acids (UFA) in milk fat improves the spreadability of butter (MacGibbon et al., 2002) and may have health benefits if it is associated to increases in c9, t11 conjugated linoleic acid and n-3 polyunsaturated fatty acids (Givens, 2009; Butler, 2014).

Since the late 1960s, several studies have examined the feasibility of increasing the milk fat UFA concentration at the farm level, through dietary manipulation (Scott et al., 1970; Kalac and Samkova, 2010; Shingfield et al., 2013). More recently, some studies have investigated the feasibility of using genetic selection (Bastin et al., 2013; Lopez-Villalobos et al., 2014) and the segregation of dairy cows to produce milk with high UFA concentration (Thomson et al., 2003a; Bobe et al., 2007). Some studies reported that increasing the UFA concentration of milk fat at the farm level may adversely affect the production of other milk components and farm profit (Chilliard et al., 2001; Hurtaud and Peyraud, 2007; Stoop et al., 2008; Silva-Villacorta et al., 2011). However, at present, little is known about the impact of increasing the fat UFA concentration on the physical and financial performance of dairy farms.

* Corresponding author.
E-mail address: d.silvavillacorta@massey.ac.nz (D. Silva-Villacorta).

http://dx.doi.org/10.1016/j.compag.2016.04.021
0168-1699/

The objective of the present study was to develop a stochastic bio-economic farm model that simulates milk production, milk composition (including fat UFA concentration), and the economic performance of dairy farms under New Zealand conditions (seasonal pasture-based system). The farm model developed was used to examine the effect on farm production and profit of segregating cows that produce milk fat with high UFA concentration.

2. Materials and methods

2.1. Outline of the model

An empirical stochastic farm model that accounts for all the inputs and outputs in a typical New Zealand dairy farm was developed in SAS Version 9.2 (SAS, 2009). Key model inputs are farm size (milking platform effective hectares, ha), start of calving date and calving pattern, drying-off date, replacement rate, herd structure, feed supply, milk payment, stock prices and farm expenses (Fig. 1).

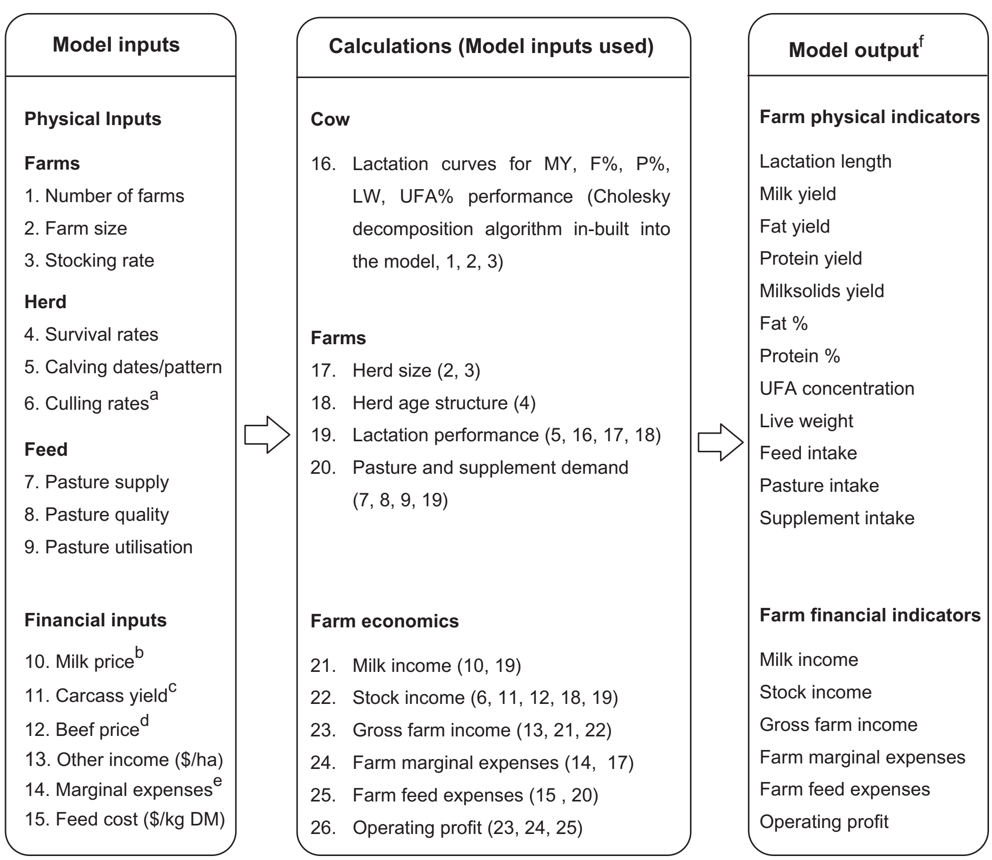
The model simulates the daily and annual performance of individual cows and farms for milk yield (MY), fat percentage (F%), protein percentage (P%), fat UFA concentration and live weight (LW). Key outputs of the model are data corresponding to milk production and composition, fat UFA concentration, cow live weight, feed demand, gross farm income and farm operating profit (per cow and per hectare).

2.2. Herd structure and replacement rate

The model considered 12 age classes: calves (female calves less than 2 months old), R1 (heifers less than 1 year old), R2 (heifers from 1 to less than 2 years old), and 2–10 years (cows in first to ninth lactation). The proportion of the herd in each age class was determined using the Leslie matrix model (Leslie, 1945), which takes into account the survival and fecundity (number of female offspring) rates for each age class. Survival rates used in the Leslie matrix for calves, R1, R2 and cows (age classes 2–10) were: 0.66 (percentage of female calves raised as replacement), 0.86, 0.86, 0.86, 0.87, 0.86, 0.81, 0.77, 0.71, 0.66, 0.64 and 0, respectively. Survival rate values were obtained from the dairy statistics of Livestock Improvement Corporation (LIC, 2011). Since it was assumed that 50% of calves born were females, the fecundity rate for cows in each age class was 0.5.

Farms simulated by the model had a 12 week spring calving period. Calving dates and pattern were derived from LIC (2011) and Holmes et al. (2002). The planned start of calving date was July 20. In each herd, 50% of the cows calved by August 11 (22 days after the start of calving), 90% of the cows calved by September 4, and the remaining cows calved between September 4 and October 10. All cows in each herd were dried off by May 10 the following year.

It was assumed that at the end of the mating period (October–December) 90% of the cows in the herd were pregnant and 94% of



[a] Due to age, death, disease, poor performance and unsatisfactory performance. [b] $/kg milk fat, $/kg protein, $/L milk (volume penalty), UFA premium (if any). [c] Carcass dressing out percentage for each age group. [d] $/kg carcass for each age group. [e] Farm expenses excluding feed costs ($/cow). [f] Per cow, per hectare and per kilogram of milksolids. The output also includes model input variables and calculations.

Fig. 1. Diagram of the parameters considered in the farm model and their relationship (MY = milk yield, F% = milk fat percentage, P% = protein percentage, LW = live weight, UFA% = concentration of unsaturated fatty acids in milk fat).