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The effect of changing cow production and fitness traits on net income and greenhouse gas emissions from Australian dairy systems

M. J. Bell,* R. J. Eckard,* M. Haile-Mariam,†‡ and J. E. Pryce†‡[1]
*Melbourne School of Land and Environment, University of Melbourne, Victoria 3010, Australia
†Biosciences Research Division, Department of Environment and Primary Industries, Agribio, 5 Ringroad, Bundoora, Victoria 3083, Australia
‡Dairy Futures Cooperative Research Centre, Bundoora, Victoria 3083, Australia

ABSTRACT

The aim of this study was to compare the effect of changing a range of biological traits on farm net income and greenhouse gas emissions (expressed in carbon dioxide equivalents, CO_2-eq.) in the Australian dairy cow population. An average cow was modeled, using breed-average information for Holsteins and Jerseys from the Australian Dairy Herd Improvement Scheme. A Markov chain approach was used to describe the steady-state herd structure, as well as estimate the CO_2-eq. emissions per cow and per kilogram of milk solids. The effects of a single unit change in herd milk volume, fat and protein yields, live weight, survival, dry matter intake, somatic cell count, and calving interval were assessed. With the traits studied, the only single-unit change that would bring about a desirable increase in both net income and reduced emissions intensity per cow and per kilogram of milk solids in Australian dairy herds would be an increase in survival and reductions in milk volume, live weight, DMI, SCC, and calving interval. The models developed can be used to assess lifetime dairy system abatement options by breeding, feeding, and management. Selective breeding and appropriate management can both improve health, fertility, and feed utilization of Australian dairy systems and reduce its environmental impact.

Key words: biological variation, methane, nitrous oxide, abatement

INTRODUCTION

Dairy production has made large advances in efficiencies over the past 60 yr as a result of changes in breeding, nutrition, and management (Capper et al., 2009). However, losses of dietary energy in the form of methane (CH_4), as well as nitrogen (N) in manure, are significant inefficiencies and sources of pollution in the form of CH_4 and nitrous oxide (N_2O) (FAO, 2010). Given the effect of greenhouse gas (**GHG**) emission levels on climate change, mitigation of these gases has gained importance in recent years.

In Australia, dairy systems are predominantly seasonal calving in the southeastern region of the country, with year-round calving in other areas (Haile-Mariam et al., 2008), and rely on pasture as an affordable source of nutrients. Supplementation of the diet with grain is carried out to optimize the achievement of the genetic potential of the cow for milk production. About 83% of cows are of Holstein genetic background and 17% have Jersey genetic background (ADHIS, 2012).

Although diet manipulation can alter the potential production of CH_4 and N_2O emissions, selective breeding could offer a cost-effective means of abating emissions in the medium to long term (Moran et al., 2007). The effect of selective breeding is also permanent and cumulative. Sufficient phenotypic records of enteric CH_4 emissions from dairy cows are not yet available to allow selection on this trait within national populations; however, reductions in enteric CH_4 could be made through selection on DMI or residual feed intake, both of which are highly correlated with enteric CH_4 emissions (de Haas et al., 2011). Genomic predictions for DMI or residual feed intake (i.e., an estimate of feed efficiency) allow their inclusion in a multiple trait selection index (de Haas et al., 2012), which takes into account the correlations between traits of interest (Pryce et al., 2009).

Production traits such as milk yield and DMI are moderately heritable in dairy cows at about 0.30 (Koenen and Veerkamp, 1998; Veerkamp, 1998) compared with low heritabilities for health and fertility traits (Pryce et al., 1999). Therefore, coupled with existing genetic variation (shown in this study), improvement is easier to achieve in DMI and milk production traits than in health and fertility. As a result, and given that production is a significant part of the selection goal, the GHG produced per unit of feed eaten are likely to reduce because of improvements in gross efficiency and a dilution of maintenance energy and protein required. Bell et al. (2011) modeled an experimental herd using a Markov

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[1]Corresponding author: jennie.pryce@depi.vic.gov.au

chain approach to describe different dairy production systems. That study also assessed the effect of a phenotypic and genetic standard deviation improvement in a range of biological traits. One limitation of the study by Bell et al. (2011) was that the experimental design did not allow full expression of variation in cow survival. In the current study, we develop a more comprehensive model to assess variation in biological traits, including survival, in a national dairy population.

The loss of carbon and N that contribute to GHG emissions from a system can be evaluated by assessing the carbon dioxide-equivalent (**CO_2-eq.**) emissions associated with production. The amount of CO_2-eq. emissions are often expressed per animal or area and per unit product (Guinée et al., 2002). In Australia, agriculture contributes 15% (80 Mt of CO_2-eq.) of total emissions reported in the national inventory (DCCEE, 2012a). Agriculture is accountable for both CH_4 and N_2O emissions nationally, which are about 57 and 73%, respectively, of the net national emissions of these GHG (DCCEE, 2012a). In 2011, the Australian Government launched a Carbon Farming Initiative whereby farmers could claim credits for reducing their net GHG emissions (DCCEE, 2012b).

The objectives of the present study were (1) to describe a dynamic dairy system that encompassed differences in genotype, nutrition, and environment, and its effect on feed intake, growth, and body composition; and (2) to assess the effect of a unit change in herd milk volume, milk fat yield, milk protein yield, live weight, survival, DMI, SCC, and calving interval on farm net income, CO_2-eq. emissions per cow, and CO_2-eq. emissions per kilogram of milk solids for an average Holstein herd and an average Jersey herd in Australia.

MATERIALS AND METHODS

Data

This study further developed the Australian Profit Ranking (**APR**) index model that derives economic values for traits of importance to the Australian dairy industry (Valentine et al., 2000; Pryce et al., 2009) to dynamically describe a milking herd that includes heifer replacements and lactating cows over a maximum of 12 lactations.

The model was constructed in Microsoft Excel (Microsoft Corp., Redmond, WA) and, in addition to changes in net income per cow, it was adapted to include CO_2-eq. emissions per cow and per kilogram of milk solids caused by a management or genetic change by calculating the difference between the current state (baseline situation) and a positive or negative change in a biological trait (improved situation).

Herd Structure

The model predicts the response of a single animal and represents the mean performance of a Holstein or Jersey breed in Australia dynamically. A total of 12 lactations (referred to as age groups) were modeled, in addition to the period before replacement heifers entered the milking herd between birth and their first calving.

The number of milking herd replacements was calculated from the number of animals required to maintain the steady-state herd. Replacement animals were assumed to calve at 2 yr of age, with cows surviving for an average of 3.0 lactations (Table 1). It was also assumed that all calf births resulted in a single live calf being born, of which half were male and half female. The only animals to leave the system were cull cows, male calves, and surplus female calves. All calves sold were assumed to leave the system immediately after birth (and contribute no GHG emissions to the system). This assumption ignores the effect of calf mortality, which was assumed to be exactly the same in both the baseline and improved situations.

The model had a steady-state herd. Although the number of cows in the model herd does not matter, for simplicity, individual cow values were multiplied by 100 to represent a herd of 100 cows. The herd structure

Table 1. Production values included in the model for an average cow, average Holstein cow, and average Jersey cow in Australia

Item	Unit	Average	Holstein	Jersey
Age at first calving	d	730	730	730
Lactations	no.	3.0	2.9	3.0
Growth rate	kg of protein/d	0.0033	0.0033	0.0033
Empty BW	kg/d	500	550	400
Mature milk volume[1]	L/lactation	7,035	7,538	5,392
Milk protein[1]	%	3.33	3.27	3.73
Milk fat[1]	%	4.02	3.91	4.83
Gestation	d	283	283	283
Lactation length[1]	d	324	328	307

[1]From ADHIS (2012).