The Professional Animal Scientist 33:393–400
https://doi.org/10.15232/pas.2017-01624

Review: Advantages and limitations of dairy efficiency measures and the effects of nutrition and feeding management interventions

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ABSTRACT

Economists, nutritionists, and geneticists have attempted to describe dairy cattle efficiency in simple, quantifiable terms. On-farm measures of dairy efficiency include physical feed efficiency, efficiency of nutrient usage, economic feed efficiency, total dairy enterprise efficiency, and lifetime efficiency. Each calculated measure of dairy efficiency has its own advantages and limitations. Each measure has merit for describing a segment of dairy efficiency, yet no one measure can sufficiently describe dairy efficiency or be applicable across all farms. Use of multiple dairy efficiency metrics, each with a moving target specific to the individual dairy enterprise, should be considered. Nutrition and nutrient management interventions can improve the use of dairy resources, increasing both economic and environmental sustainability. With greater DMI and milk yield, a smaller proportion of dietary nutrients are used for maintenance functions, improving productive efficiency and reducing the environmental impact of the dairy cow. Nutritional factors independent of cow genetic merit affect energetic losses in the form of feces, heat of digestion and metabolism, or methane. Improvements in nutrient retention can occur with increases in rate of digestion and decreases in rate of passage of feed ingredients. Forage and grain losses, feed ingredient options, and forage and feed ingredient targeting according to cow potential need to be considered. Consistency of delivery and consumption of the formulated ration without high feed refusal rates typically improves dairy efficiency. Cow grouping affects social behavior, cow well-being, nutrient wastage, milk yield, and expenses, with optimum strategies being farm specific.

Key words: sustainability, milk production, nutrient waste, economic viability

INTRODUCTION

Sustainable dairy production must return a profit for the dairy enterprise and produce quality milk for consumers while maintaining optimal cow well-being and practicing environmental stewardship (von Keyserlingk et al., 2013). Feed typically accounts for 50 to 60% of the operating expenses on a dairy farm, making it a logical focal point when trying to increase efficiency (Knoblauch et al., 2012). Yet, high milk production, which requires proper nutrition, typically generates more profit than low feed cost (Dunklee et al., 1994; VandeHaar and St-Pierre, 2006). The economic objective of the farm is generally to maximize net economic returns while converting a greater percentage of feed nutrients into milk with little nutrient wastage. Fortunately, Place and Mitloehner (2010) concluded that increasing productive efficiency also results in fewer air emissions per unit of milk.

In today's marketplace, sustainability is a new indicator of quality. It can be tempting to use dairy efficiency metrics to address consumer and retailer questions about sustainability. However, although each measure has merit for describing a segment of dairy efficiency, no one measure can entirely describe a dairy's efficiency or be applicable across all farms. Each calculated measure of dairy efficiency has its own advantages and limitations. Dairy efficiency goals should be considered to be moving targets that are specific for the current situation of individual dairy enterprises with the focus placed on continuous progress. The objectives of this review are to discuss the advantages and limitations of current measures of dairy efficiency and to describe the effects of nutrition and feeding management on dairy efficiency regardless of genotype. Actions that herd managers and nutritionists can immediately implement to increase dairy efficiency in their operations are discussed.

REVIEW AND DISCUSSION

Dairy Efficiency Measures—Description, Advantages, and Limitations

Physical Feed Efficiency. The most well-known and used measure of dairy efficiency is the amount of milk produced, expressed as 3.5% FCM, 4% FCM, or energy-corrected milk, per unit of DMI or "physical feed efficiency" (physical **FE**). This is a measure of gross feeding efficiency

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Table 1. Advantages and limitations of various dairy and feed efficiency measures

Measure	Abbreviation	Calculation	Advantages	Limitations
Physical feed efficiency	Physical FE	FCM or energy-corrected milk/DMI	Indicates digestibility	Ignores nutrient density, cost, and body reserves
Energy conversion efficiency	ECE	Milk energy/ME intake	Considers diverse nutrient efficiencies	Ignores body reserves
Residual energy intake	REI	ME intake − Energy requirement	Less influence of body reserves	Relies on prediction of energy requirements
Ration cost efficiency	FEvc	Fiscal milk value/Fiscal DMI value	Reflects profits	Ignores body reserves
Feed cost per hundredweight (45.4 kg)	Feed cost/cwt	Farm feed cost/45.4 kg of milk shipped	Includes cost of dry period and reproductive efficiency	Ignores heifer costs and fiscal value of milk
Milk income over feed cost	IOFC	Milk income − Feed costs	Helpful for short-term feeding decisions	Dependent on feed costs and milk value
Lifetime efficiency		Energy in lifetime milk, conceptus, and body/Lifetime GE intake	Includes heifer, reproductive, and longevity efficiencies	Difficult to calculate for individual farms

calculated as the ratio of total outputs divided by total inputs (Table 1). Physical FE indicates whether cows are digesting their ration according to expectations (St-Pierre, 2008) and influences both environmental and economic outcomes.

The simplicity of calculating physical FE as FCM/DMI incurs numerous limitations (Table 1). First, physical FE does not consider body tissue accretion and mobilization, the implication being that physical FE changes with DIM. Maximum physical FE occurs in early lactation when cows are in negative energy balance and mobilizing body tissue to support milk production. As lactation progresses, physical FE declines exponentially over the first 3 mo and eventually linearly until lactation finishes (St-Pierre, 2008). Based on field experience, Hutjens (2005) suggested goals for physical FE (3.5% FCM/DMI) as 1.6 to 1.8 for multiparous cows <90 DIM, 1.3 to 1.4 for multiparous cows >200 DIM, and 1.4 to 1.6 as a mean for all cows between 150 to 225 DIM. Erdman (2011) suggested assessment of 150-d physical FE to correct for the effects of DIM and evaluate nutrition and management changes on a dairy in year-on-year comparisons.

It is evident that physical FE as a benchmark for sustainable milk production has numerous limitations, making it necessary to evaluate other economic and efficiency measures concurrently. Primiparous heifers still using nutrients for growth will present lower physical FE values than mature cows (Hutjens, 2005). Physical FE also ignores environmental stressors such as heat or cold that depress efficiency (Britt et al., 2003; Hutjens, 2005). Physical FE gives no consideration to nutrient density and nutrient profile. For example, increasing dietary fat increases dietary energy density, also increasing physical FE by 0.03 to 0.10 units per percentage unit of fat addition (Erdman, 2011). Typically, supplemental dietary fat is more costly than other energy sources. Protein quality and cost play a role in dairy efficiency but are not considered with FCM/DMI. With ideal rumen function, digestion, and microbial protein synthesis, RDP can make up a greater proportion of dietary protein, reducing the need for RUP, which is typically more expensive. Grain and forage lost from shrink and feeding refusals are not considered in physical FE either but greatly influence environmental and economic outcomes.

Efficiency of Nutrient Usage. Efficiency of use of individual dietary nutrients may not be similar (Armentano and Weigel, 2013), and calculation of separate nutrient efficiencies such as energetic efficiency and N efficiency can be valuable. Gross nutrient efficiencies, based on the amount of nutrient consumed, are typically calculated. Digestive efficiencies can be informative for comparing genotypes but can also be useful for nutritionists and environmentalists if fecal nutrient losses are separately accounted (Owens et al., 2016). Differences in metabolic efficiency suggest divergence in nutrient partitioning between milk production and other nutrient uses such as body tissue accretion. Thus, metabolic efficiency is used more by geneticists rather than by nutritionists or environmentalists (Phuong et al., 2013).

Energy conversion efficiency is calculated as milk energy output divided by ME intake (Table 1). Unfortunately, as with physical FE, energy conversion efficiency will be improved with greater mobilization of body reserves (early lactation) and reduced during body tissue accretion (late lactation). Because of the negative effects of body reserve loss on reproduction and health, greater energy conversion efficiency is not always desirable. Residual energy intake (**REI**) is actual ME intake minus the predicted