ABSTRACT: Twenty-nine presentations by 28 speakers at the California Net Energy System (CNES) 50th Anniversary Symposium provided an informative overview of the past, present, and future of the CNES. The Symposium was divided into eight sessions, with each one or two sessions followed by a lively discussion period. This article provides a summary of key points made by the speakers in each session as provided at the conclusion of the Symposium. Additional thoughts about future directions for research related to the CNES are offered.

Key words: beef cattle, conference summary, net energy

INTRODUCTION

The California Net Energy System (CNES) 50th Anniversary Symposium is a testament to the significance and enduring importance of the research on beef cattle energetics and body composition conducted by faculty members at the University of California, Davis, between the late 1950s and early to mid-1960s. This work culminated in the publication of the classic article by Lofgreen and Garrett (1968). The CNES quickly became the basis for energy requirements and feed energy values for growing and finishing cattle in the National Research Council's Nutrient Requirements of Beef Cattle series. Although the CNES has been updated and modified to address changes in the beef industry, the fundamental principles and components of the system described in the original publication remain in place five decades later.

The Symposium included 29 presentations by speakers from around the globe on topics that covered the history, current status, and future of the CNES, ranging from practical applications to in-depth considerations of factors affecting metabolic efficiency. It was my honor to provide a brief summary of the conference presentations. What follows is a bullet-point listing of the key points made by speakers in each the eight sessions as presented at the conference.

KEY POINTS BY CONFERENCE SESSION

Session 1
- The fundamentals of any nutrient requirement system include 1) a system for expressing animal requirements for nutrients and 2) a system for expressing the ability of feeds to meet requirements.
- The laws of thermodynamics were fundamental to development of the CNES, as were
developments in indirect calorimetry, as well as the comparative slaughter technique.

- Industry input, specifically recognition of the failure of the total digestible nutrients (TDN) system to discriminate among the ability of feeds to support performance, was a key component in development of the CNES.
- The 1968 article was rejected twice!

**Session 2**

- The strong linear relationship between net energy for maintenance (NEm) and net energy for gain concentrations of feeds is fundamental to determining net energy (NE) values from animal performance.
- “Back-calculated” values seem to be affected by initial body weight (BW), and variation in these values across seasons is high.
- Intake patterns in feedlot cattle could be a factor in variability of NE values calculated from animal performance.
- The CNES is useful for programmed feeding, comparative pricing, evaluating feeding programs, and determining energy values for novel feeds.
- More work is needed on environmental effects relative to energetics and the relationship between BW and carcass weight.
- The CNES works with a wide variety of cattle types and feeding situations, but more research is needed on other cattle breeds and genotypes, as well as on how growth-enhancing technologies such as implants and beta-agonists affect results.
- Digestible energy (DE) x 0.82 works well to estimate metabolizable energy (ME) for lower energy, forage-based diets, but adjustments are needed for higher-energy, processed grain diets. Newly published and proposed equations seem to provide good options for adjustments.
- A biological maximum for conversion of DE to ME seems to occur at approximately 3.5 Mcal/kg of ME, but confirmation of this value is needed.
- TDN is a fundamental problem with current energy systems—it does not account for variation in conversion of gross energy (GE) to DE. Also, GE is more variable among feeds than the TDN system suggests.
- Corn silage is a variable feed!
- Better predictions of DE and ME should help decrease variation in ultimate NE estimates.

**Session 3**

- NEm can be used effectively for beef cows as a single unit for maintenance, pregnancy, and lactation, but more work is needed on the ME-use efficiency coefficients for these functions.
- Maintenance of beef cows is a moving target because of variation in nutrient supply, environmental conditions, etc.
- Fetal programming effects on maintenance requirements, energetic efficiency, and milk production are highly likely, but more work is needed to predict and quantify these effects.

**Session 4**

- Principles of the CNES have been applied effectively to develop a “CNES-equivalent” system (BR-CORTE) for Nelore cattle in Brazil.
- The BR-CORTE system seems to work well for other Bos indicus cattle besides Nelore cattle.
- Maintenance requirements are about 10% lower for Nelore cattle than for British breeds.
- Will sensors and computerized feeding records replace the CNES and similar systems and allow for individual animal management? Do we have the technology to do this but not the skilled labor?
- The CNES principles work effectively to describe energy requirements of goats; final BW differences accounted for most of the variation associated with sex and genotype of goats in Brazil.

**Session 5**

- HE = MEI − RE (Heat energy equals ME intake minus retained energy) is a critical CNES principle.
- The “difference trial” approach was fundamental to CNES calculations of feed NE values.
- Log HP (heat production) fit the existing bias for maintenance requirements; it was not chosen for theoretical reasons.
- All models are wrong, but some are useful! (attributed to British statistician, George Box, and quoted by Dr. Old).
- Predicting retained protein in the current National Academies of Sciences, Engineering, and Medicine (2016) model is challenging. Results seem to be related to the proportion of fat in gain as BW increases.
- Collinearity of protein and lipid deposition is a problem with univariate analyses. Multivariate models that include random effects might offer an alternative approach to address this problem.
Session 6

- Nutrient flux approaches (net portal appearance of nutrients) can yield similar results to traditional ME-based approaches; ultimately, this could lead to improved predictions (greater explained variation).
- In both live animals and dual-flow fermenters, dry matter (DM) intake is a key driver of nutrient flows and digestibility.
- Mineral status could affect energy requirements and retention but are effects likely longer term vs. shorter term?
- Dietary protein can affect digestion (e.g., low-crude-protein forages and effects of protein supply in the small intestine on amylase secretion in high-starch diets) and DM intake, which could influence energetics.
- Within practical ranges, feeding protein beyond requirements is not a major energy cost.

Session 7

- Differences in basal metabolic rate are the primary driver of differences in efficiency among individual animals, with body composition as the second most important factor.
- Mitochondrial proton leakage might be an important component of basal metabolic rate differences.
- Metabolic efficiency is important—what makes an animal efficient vs. inefficient is related to basal respiration and maximal respiration in mitochondria, protein turnover, and insulin signaling (and many other possible factors).
- We should think of cow–calf production as a nutrient transfer process—the ability of the cow to obtain and utilize nutrients and transfer nutrients to her calf—and design studies to evaluate transfer processes and coefficients.
- Management is an important part of efficiency and is likely a significant factor involved in the variation we see in energy metabolism of groups of cattle.
- Research questions for compensatory gain include how long is a compensatory gain period, what is the efficiency response, what are effects of length and severity of restriction, and how do we define nutritional and environmental stress as it relates to compensatory gain.
- How important is site of digestion in contributing to differences in efficiency?
- More math = fewer questions! (statement by Dr. Robbi Pritchard during the discussion session of Session 7).

Session 8

- Disease states affect maintenance requirements (fever, protein turnover, nutrient fluxes, inflammatory response, changes in body composition, etc.). How long do these effects persist? Do we simply insert a lag period in the pattern of intake and growth, or are there long-term differences at the same compositional endpoint?
- A better model might be a dynamic system with dynamic nutrient pools to address individual animal variation, but this must be aligned with a practical system that allows a pragmatic approach to addressing real-world problems.
- RFI (residual feed intake) data are variable—some animals are very efficient, and some are very inefficient, with a high proportion in the middle (like a normal distribution!)
- RFI is generally correlated with profit, but it is not a perfect relationship.
- Feeding behavior data seem to be repeatable, and technology for measurement is available. Feeding behavior data also seem to be sufficiently related to RFI that they might be useful for predictive purposes.
- The CNES was not designed to predict methane and greenhouse gases (GHG) and is not good at it! But, if we could predict feed DE and ME values more effectively, the CNES would work better to predict GHG.

WHAT IS NEXT? CONCLUSIONS AND RECOMMENDATIONS

The conference provided an excellent summary of the research to further develop and refine the CNES in the years since the publication of the article by Lofgreen and Garrett (1968). In addition, new research findings regarding factors affecting metabolic efficiency in individual animals also were highlighted. Certainly, research that encompasses efficiency at the whole-animal and cellular levels should continue in earnest, as these efforts will help to refine the system further and shed light on factors related to animal variability in efficiency.

Another clear, although somewhat indirect, message from the conference is that our ability to refine the system, particularly in terms of making practical adjustments for variation in body composition (e.g.,
retained energy and protein) associated with genotype, growth-enhancing technologies, management factors, environment, and physical activity (to name a few) is limited by the sheer paucity of data to parse out such sources of variation. Perhaps it is time to think on a large scale in terms of developing a new database to address such research questions. Much like the beef genome, genetics of bovine respiratory disease, food safety, and other major research projects that have been supported by a significant infusion of federal funding, is it time to carve out funding for an 8- to 10-yr federal grant program to create a new CNES database? A multi-institutional grant with common methodology for collection of body composition data and associated feed composition and digestibility data could provide the opportunity to directly and systematically consider the effects of numerous sources of variation. Funding to support the research that led to the development of CNES came largely through state and federal (Hatch) funding available to the California Agricultural Experiment Station, with strong support (although not likely financial support) from the California beef industry. At present, the ability of any single state to replicate the type of investment that was made by California in the late 1950s and early 1960s is virtually nonexistent. Given the significance of the CNES to the beef industry and its immeasurable return on the original investment—not only in the United States, but also abroad—a multimillion dollar national investment in such a project would pay immense dividends for another 50 yr.

Conflict of interest statement. None declared.

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