

DR. KENNETH AND CAROLINE McDONALD ENG FOUNDATION SYMPOSIUM

Innovative Intensification in Cow-Calf Systems

Hosted by Texas A&M University

September 18-19, 2014

Embassy Suites

125 E. Houston St. • San Antonio, Texas 78205

210.226.9000



Dr. Kenneth & Caroline McDonald Eng Foundation



In recognition of Caroline Eng's deep love of the beef cattle industry, a symposium is held each year to explore strategies that foster the long-term sustainability of the industry. A critical element of sustaining the beef supply chain is the creation of technologies and strategies that support the primary production in the cow-calf sector. Through the generosity of the Dr. Kenneth and Caroline McDonald Eng Foundation, innovative strategies and technologies are being developed and evaluated that will:

- Further reduce land use requirements to produce a pound of beef;
- Optimize biological, resource, and economic efficiency through innovative strategies and technologies;
- Improve the stability of the global supply of high quality protein.

*Dr. Kenneth and Caroline
McDonald Eng*



-C- -K-
CAROLINE AND KENNETH

AGENDA

Innovative Intensification in Cow-Calf Systems

Thursday, September 18, 2014

- 1:00 pm *Welcome and Introductions* — H. Russell Cross, Texas A&M University; Larry L. Berger, University of Nebraska; Clint Rusk, Oklahoma State University
Moderator — Jason Sawyer, Texas A&M University
- 1:15 pm *Opening Remarks* — Kenneth S. Eng
- 1:30 pm *Managing Energy Requirements in Confined Cows* — Tryon Wickersham, Texas A&M University
- 2:15 pm *Limit Feeding Production Cows in Confinement* — Karla Jenkins, University of Nebraska
- 3:00 pm *Break*
- 3:15 pm *Cow Efficiency: Implications for Beef Sustainability* — Sara Place, Oklahoma State University
- 4:00 pm *Nutritional and Management Considerations when Merging Cow-Calf and Feedlot Operations* — Bill Dicke, Consultant-Lincoln, NE; Dave McClellan, Consultant-Fremont, NE; Jim Simpson, Consultant-Canyon, TX; Ron Crocker, Rancher-Mason County, TX; Paul Defoor, Cactus Feeders; Roberto Eizmendi, Cactus Feeders; *Moderator*: Kenneth Eng, Cattleman-NE & MS
- 5:00 pm *Concluding Remarks for Session*
- 5:30 pm *Open House and Reception*
- 7:00 pm *Adjourn*

Friday, September 19, 2014

- 7:30 am *Coffee and Pastries*
- 8:15 am *Welcome and Introductions*
Moderator — Tryon Wickersham, Texas A&M University
- 8:30 am *Fetal Programming: Implications and Opportunities in Confinement Systems* — Carey Satterfield, Texas A&M University
- 9:15 am *Intensified Cow/Calf Production in the Southern Great Plains Using Wheat Pasture, Semi-Confinement and Cover Crops* — David Lalman, Oklahoma State University
- 10:00 am *Break*
- 10:15 am *Herd Health Observations in Nebraska Intensive Cow-Calf Systems Project* — Jason Warner, University of Nebraska
- 11:00 am *Does Intensification Improve Sustainability?* — Jason Sawyer, Texas A&M University
- 11:45 am *Questions & Answers*
- 12:00 pm *Concluding Statements and Looking Ahead* — Kenneth S. Eng

TABLE OF CONTENTS

Kenneth Eng, Ph.D.	6
Welcome	8
Speaker Bios	13
Managing Energy Requirements in Confined Cows	17
Limit Feeding Production Cows in Confinement	27
Cow Efficiency: Implications for Beef Sustainability	35
Nutritional and Management Considerations when Merging Cow-Calf and Feedlot Operations	41
Fetal Programming: Implications and Opportunities in Confinement Systems	47
Intensified Cow/Calf Production in the Southern Great Plains Using Wheat Pasture, Semi-Confinement and Cover Crops	59
Herd Health Observations in Nebraska Intensive Cow-Calf Systems Project	69
Does Intensification Improve Sustainability?	79
Advertisements	
ABS.....	91
Biolite.....	92
Elanco	93
Merck.....	94
American Akaushi Association	95
Micronutrients	95
The Plains Nutrition Council.....	96
Prince Agri Products.....	97
Dijaide.....	97
Multimin.....	98
Westway Feed Products.....	98
Temple Tag.....	99
Tru Max	100
Zinpro	101
Animal Health International.....	101
Notes	102



KENNETH ENG, PH.D.

I'm pleased that the second symposium will be held in San Antonio and hosted by Texas A&M University and assisted by University of Nebraska and Oklahoma State University. I have an emotional tie to Texas A&M as they gave me my first job after I received my Ph.D. That was in 1962 and it paid a whopping \$7,200 per year. In truth, it was the only job offer I had but, it turned into a great start. Later, around 1970, I designed and lectured the first classes at A&M in the feedlot Management master's degree program. Department Head O. D. Butler arranged the classes for 7:30 a.m. Monday, Tuesday and Wednesday mornings so I could continue with my consulting work later in the week. What a great set of mentors Butler, Riggs, Pope, Riewe, etc. were. Also, Caroline and her family are from the Brazos County area and at one time, she was vice president of the Bank of A&M. Her father trained and showed Quarter Horses for the Animal Science department in the 1950s. For me, the symposium and the Foundation are about Caroline and her love for the industry. She would be proud.

It's apparent based on the calls and conversations that the interest in intensive cow production is increasing. This plus the incredible profits and markets we've enjoyed, (the events dreams are made of) makes this a great time for a San Antonio symposium.

Kenneth Eng & The Dr. Kenneth & Caroline McDonald Eng Foundation

I was born on a farm in Boone County, Neb. approximately 50 miles west of Norfolk. Following graduation from high school at Newman Grove I attended college at Wayne State, received a bachelor's degree and master's degree from the University of Nebraska and Ph.D. in animal nutrition from Oklahoma State. I then joined the staff at Texas A&M doing Animal Nutrition research and later returned to Texas A&M ('69 & '70) on a consulting basis. In 1965, I became Ralston-Purina's first feedlot technical feedlot consultant mainly in the Western area of the United States. Three years later I entered the independent feedlot consulting business and was active in research and consulting in the late 60s, 70s, and 80s. In 1968, I designed one of the first feedlot performance and profit projection programs based on the University of California net energy system. Many of these programs are still used.

In 1990, I began downsizing my consulting business and focused on personal yearling operations in the 90s and cow-calf operations beginning in 2000. Beginning in 1988, Caroline was a constant companion, business partner and soul mate until she drowned in 2010. Since Caroline's death I have further limited my research and consulting and have concentrated on the cow, ranch and farmland investments in Texas, Oklahoma and

Nebraska. In early 2012, I shifted my agricultural investments to South Mississippi along the Pearl River approximately 80 miles east of Natchez and 90 miles north of New Orleans. My staff and I are concentrating on timber, cattle, recreational (hunting and fishing) and educational events.

Following Caroline's death, the Dr. Kenneth & Caroline McDonald Eng Foundation was initiated to fund research and education in the areas of cow-calf efficiency and production. The Foundation is in recognition of Caroline's love for the cattle business and cattle people and a partial payment for my good fortune in the industry. The Foundation is funding approximately \$2 million in research in the area of beef cow efficiency including dry lot cow production to University of Nebraska, Oklahoma State University and Texas A&M. (A portion of these funds will go towards annual cow-calf efficiency symposiums.) Grants are also awarded to Wayne State College building projects and Plains Nutrition Council for Research Poster Session awards.

I have authored over 600 articles including Feed Stuffs Beef Bottom Line article for 30 years and seven books of poetry and 10 calendars. In recent years I have received the Oklahoma State Graduate Student of Distinction Honor, Plains Nutrition Industry Service Award, Feedlot Achievement Industry Award and most recently, the Beef Magazine Trail Blazer Award Honoree. Whatever successes I've been fortunate to achieve are due to Caroline, good friends, good clients, good luck and good timing.

I have just completed a book titled "Started Small and Just Got Lucky." It's an autobiographical and historical account of a country boys 50 plus year journey through the cattle industry. We hope to have it available at this symposium and all profits will go to the Dr. Kenneth & Caroline McDonald Eng Foundation.

Sincerely,



Kenneth S. Eng

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WELCOME!

On behalf of Texas A&M University and the Department of Animal Science, it is my pleasure to welcome you to the Innovative Intensification in Cow-Calf Systems Symposium. This annual symposium is the result of Dr. Kenneth Eng's visionary leadership in the beef industry and his ability to recognize and address the challenges it faces. The main issue is, "not only have cow numbers declined but also the cow habitat has also declined due to the drought and alternative uses for ranch land such as grain production, subdivisions, recreational use, etc," said Dr. Eng. Through the Dr. Kenneth and Caroline McDonald Eng Foundation, Dr. Eng has committed nearly \$2 million to address timely and relevant beef industry issues by supporting research initiatives at Texas A&M University, Oklahoma State University and the University of Nebraska-Lincoln. Dr. Eng has set a fabulous example for future generations of what one person can do to impact an entire industry.

The mission of the Department of Animal Science is to improve lives through discovery, integration, dissemination and application of science based knowledge and animal products. We are dedicated to serving the beef industry through our teaching, research and extension programs.

The Department of Animal Science offers dynamic and challenging undergraduate and graduate programs that cover a broad variety of fields including animal behavior, animal biotechnology, beef cattle, dairy science, equine science, food science and technology, meat science, physiology of reproduction, sheep and goats, and swine. Our ever-increasing undergraduate enrollment is testimony that we continue to attract outstanding students who benefit from hands-on experiences, judging teams, internships and study abroad programs that help them better understand the world of agriculture and prepare them to be industry leaders.

Many Animal Science faculty hold joint appointments with Texas A&M AgriLife Research and collaborate with others in the College of Agriculture and Life Sciences and Texas A&M AgriLife Extension. Research programs focus on both applied science, which has an immediate application to Texas animal agriculture, and basic science, which provides the foundation for scientific information to impact further research discoveries. Areas of research include animal behavior, animal genomics, animal nutrition, beef cattle, equine science, meat science, molecular endocrinology, physiology of reproduction, food safety, bacteriophage and microbiology.



The Texas A&M AgriLife Extension Service Animal Science unit is composed of faculty helping Texans learn about animal science through teaching research-based technologies throughout the state and nation. These specialists are based in eight different regions of the state and work to educate our citizens about beef cattle, dairy cattle, goats, horses, meat and other foods, sheep and swine. Extension faculty also provide on-going support by providing information and technical expertise to commodity groups, consultants and allied industry partners. Programs led by Animal Science Extension faculty include: Beef Cattle Short Course, Grass-fed Beef Conference, Southwest Beef Symposium, Rebuilding Beef Herd, Horsemanship School Program, Mare/Foal Workshop, Beef 101, Beef 706 and Pork 101, HACCP Training Courses, Center of the Plate Workshop, Southwest Dairy Day, drought and disaster education, animal handling and youth programs.

The challenges and opportunities facing the beef industry are ever increasing. It is important to the Texas A&M University Department of Animal Science that we stay on the forefront of these changes and do our part to impact and improve this vital industry. Thanks to the generous funding by the Dr. Kenneth and Caroline McDonald Eng Foundation, we are better able to do just that. I would like to personally thank you for participating in this symposium that has the potential to impact the entire beef industry. Your attendance does make a difference.



H. Russell Cross, Ph.D.
Professor and Head
Department of Animal Science
Texas A&M University



INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Speaker Bios





Ron Crocker

Mason County, Texas

Ron Crocker is the managing partner for CA Cattle Company, an intensively managed cow/calf herd located in Mason County, TX.

He has spent the last 40 plus years operating ranches and feed yards in Ariz., Australia, New Mexico, Kansas and Texas. Crocker attended Dartmouth College and the University of Arizona with a degree in animal science and business.



Paul Defoor

Cactus Feeders

Dr. Defoor is Senior Vice President and the Chief Operating Officer at Cactus Feeders, Inc., where he oversees all Feedyard Operations, Environment and Safety, Cattle Procurement and Sales, Business Analysis,

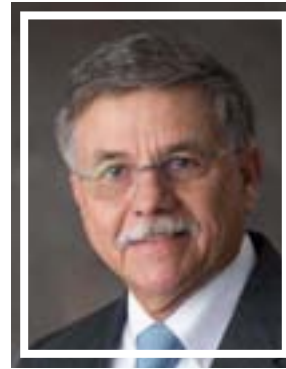
and Cactus Research; an industry leader in beef production-science, and applied research. He also serves on the Company's Board of Directors where he sits on the Audit and Executive Compensation Committees. Prior to his current role, Dr. Defoor led Business Analysis and Strategy Development for the Company.

Dr. Defoor serves on the NCBA's Beef Foresight Advisory Group, the TCFA Research Committee, and is a past president of the Plain's Nutrition Council.

He graduated Summa Cumma Laude from Texas Tech with a bachelor's degree in animal science, followed by a Ph.D. in Ruminant Nutrition from Texas Tech, and an MBA from West Texas A&M. He has 16 published manuscripts in peer reviewed journals, including the Journal of Animal Science where he has served on the Editorial Board. Dr. Defoor recently received the Vance Publishing "40 Under 40 in Agriculture" award, and has received the Texas Tech University Animal and Food Science Hall of Fame Award.

Prior to Cactus Feeders, he worked as a Technical Services Manager in the animal pharmaceutical

industry, as a Feedyard Nutrition Consultant, and served on the faculty of New Mexico State University. Dr. Defoor's "why" is to improve standards of living through advancements in food production.



Bill Dicke

Lincoln, Nebraska

Bill was raised on a crop and livestock farm in Southwest Nebraska. He attended the University of Nebraska-Lincoln where he obtained a B.S. degree in Animal Science and Agricultural Economics, and a M.S. degree in Ruminant

Nutrition. In the early 1980's, he formed Cattlemen's Nutrition Services, LLC. Today the firm consults for feedlot and ranch clients in the Northern Plains, Central Plains, and surrounding areas. Cattlemen's Nutrition Services, LLC also conducts large pen commercial research trials.



Roberto Eizmendi

Cactus Feeders

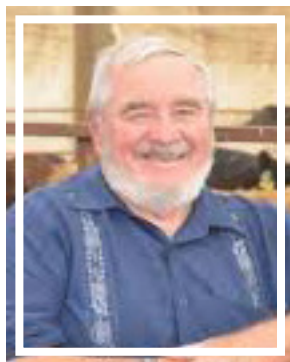
Roberto E. Eizmendi is the General Manager of the Cow-Calf Division of Cactus Feeders, with responsibilities over the development of a confined cow calf operation, including facilities design and construction, acquisition of replacement

heifers, safety, health, nutrition, genetic and reproductive programs, risk management, personnel development and cattle marketing.

Roberto E. Eizmendi was born in Argentina and graduated from Universidad Nacional del Litoral with a degree on Veterinary Medicine, followed by a Master of Agriculture in Beef Cattle Science from Texas A&M University. Roberto was the recipient of the San Antonio Livestock Show and Exposition Scholarship, the International Good Neighbors Scholarship, and an Academic Excellence Scholarship from Texas A&M University.

Roberto E. Eizmendi moved back to the United States in April 2011 joining Cactus Feeders as Assistant Manager of one of Cactus feedyards. Prior to moving to USA, Roberto was the General Manager of Cactus Argentina, a subsidiary

of Cactus Feeders in Argentina with responsibilities over the operation of a feedyard and a packing plant owned by Cactus Feeders in association with Tyson and Cresud (Publicly owned largest argentine agricultural company). Previously he worked as the General Manager of Establecimiento Forestagro, an agricultural company in the north part of the country, with activities on farming, cow – calf, stockers and grass finishing steers.



Kenneth Eng

Eng Foundation

Dr. Kenneth Eng was born on a farm in Boone County, Nebraska. He received a B.S. from Wayne State, M.S. from the University of Nebraska and Ph.D. in animal nutrition from Oklahoma State University. In

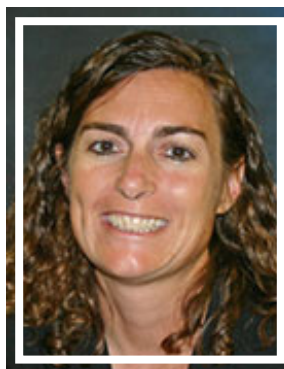
1962 he joined staff at Texas A&M University for animal nutrition research and later returned to Texas A&M ('69 & '70) on a consulting basis. He soon met Caroline who was born and raised in the Brazos County area and had close family ties to Texas A&M.

In 1965 he became Ralston-Purina's first feedlot Technical Feedlot consultant mainly in the Western United States. Three years later he entered the independent feedlot consulting business and was active in research and consulting in the late 60's, 70's, and 80's. In 1990 Eng began downsizing his consulting business and focused on personal yearling and cow-calf operations. Since Caroline's death in 2010, he has concentrated on the cow, ranch and farmland investments in Texas, Oklahoma and Nebraska. In early 2012, he shifted his agricultural investments to South Mississippi and Louisiana.

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completed an autobiographical and historical account book titled Started Small and Just Got Lucky. In recent years Eng received the Oklahoma State Graduate Student of Distinction Honor, Plains Nutrition Industry Service Award, Feedlot Achievement Industry Award and most recently, the Beef Magazine Trail Blazer Award Honoree.



Karla Jenkins

University of Nebraska-Lincoln

Dr. Karla Jenkins received her bachelor's degree from Texas A&M and her master's degree and Ph.D. from the University of Nebraska. She is the Cow/Calf Range Management Specialist for UNL at the Panhandle Research and

Extension Center in Scottsbluff. Her research program includes finding more efficient and economical ways to produce beef cattle while sustaining the range resource. This research often includes evaluating annual forage crops and alternative uses for grain crops, such as field peas, as components in beef cattle diets to improve sustainability and efficiency of cattle operations in western Nebraska.

Since 2009 she has been studying limit feeding energy dense by-products mixed with crop residues to maintain beef cows in confinement to provide grazing deferment for range, maintain a core herd from liquidation, or as part of a system to reduce dependency on pasture. Her extension program involves working with producers to explain and implement practices found to be beneficial through research.



David Lalman

Oklahoma State University

Dr. David Lalman is a professor in the Animal Science Department at Oklahoma State University. His position is Extension Beef Cattle Specialist with primary responsibilities in cow/calf and stocker cattle

nutrition and management. Dr. Lalman's extension and research program emphasis is on increasing profitability and/or reducing cost of production

forage utilization, defining optimal supplementation practices and evaluating beef production systems and alternatives.



Dave McClellan

Fremont, Nebraska

Dave McClellan is the Owner/Operator of McClellan Consulting Service, Inc. since 1991 servicing 27 feedlot and cow/calf operations in seven states. McClellan was born June 6, 1946. He received a bachelors degree from

Westmar College LeMars, Iowa. McClellan earned his masters degree from the University of Iowa in Iowa City, Iowa.

McClellan entered the industry in 1981 as a Territory Manager with Hubbard Milling Co. Mankato, Minnesota. He was in the Presidents Club for Sales Growth in 1982, 1983, and 1984. McClellan was promoted to Regional Manager of Nebraska in 1984.

In 1985, McClellan moved to Farr Better Feeds in Duncan, Nebraska to work as a feed nutritionist. He was named the Nutritionist of the Year in 1989 and 1990.

He founded McClellan Consulting Service, Inc. as an Independent beef cattle nutritional and management service in 1991 and continues in that capacity today.



Sara Place

Oklahoma State University

Dr. Sara Place is an assistant professor of Sustainable Beef Cattle Systems in the Department of Animal Science at Oklahoma State since February 2013. Her research program focuses on the intersection of management

and production practices that optimize animal well-being, nutrient-use efficiency, and the business sustainability of animal agricultural operations.

Prior to Oklahoma State, she worked with the Innovation Center for US Dairy and Winrock International as a Livestock Production Consultant. She received her

Ph.D. in June 2012 from University of California, Davis in animal biology where her work focused on measurement and mitigation of greenhouse gas emissions from cattle. She earned a bachelor's degree in Animal Science from Cornell University in 2008 and an associate's degree in agriculture business from Morrisville State College in 2006. Place is originally from Upstate New York where she grew up on her family's dairy farm.



Carey Satterfield

Texas A&M University

Dr. Carey Satterfield is an assistant professor in physiology of reproduction in the Department of Animal Science at Texas A&M University.

Dr. Satterfield received a bachelor's degree in animal science in 1999 followed by a master's degree and Ph.D. in physiology of reproduction in 2005 and 2008, respectively, all from Texas A&M University. Satterfield then completed postdoctoral studies in growth and nutrition at Texas A&M University in 2009.

Dr. Satterfield's research interests are focused on the long-term consequences of maternal nutrition on fetal and postnatal growth and development using sheep as his primary animal model. In addition, Dr. Satterfield studies the role of nutraceuticals in fetal brown adipose tissue development and the ability of offspring to regulate their core body temperature during periods of cold stress.



Jason Sawyer

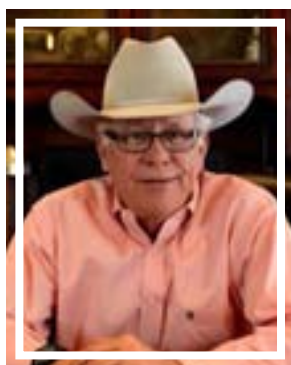
Texas A&M University

Dr. Jason Sawyer is an associate professor of beef cattle science in the Department of Animal Science and holds a joint appointment with Texas AgriLife Research. He also serves as associate head for operations for the department

and superintendent of the McGregor Research Center. He received a bachelor's degree in rangeland ecology and management from Texas A&M, and master's

degree and Ph.D. in beef cattle nutrition and management from New Mexico State University. Dr. Sawyer teaches undergraduate and graduate courses in beef cattle science, Stocker and Feeder Cattle Management, Advancements in Beef Production, and Beef Cattle Management, as well as a course in research methods for animal science. Dr. Sawyer's research interests revolve around beef cattle production systems, with a special emphasis on stocker cattle production systems and upstream and downstream impacts of management inputs.

In addition to teaching and research commitments, Dr. Sawyer has managerial responsibility for the department's AgriLife Research Center at McGregor, Texas, and for a number of other research, teaching, and extension facilities located in and around College Station.



Jim Simpson

Canyon, Texas

Jim Simpson is an independent consulting nutritionist headquartered in the Panhandle region of Texas. He currently services approximately 400,000 head of feedlot cattle in the Southern Great Plains and abroad. Prior to forming Simpson Nutrition Services, LLC in 1994, he was the Director of Nutrition for the Friona Industries Feedlot Division and Nutritionist for Hi Pro Feeds in Friona, Texas.

Jim managed the University of Nebraska Research Facility at Mead, Nebraska in the early 1980's and the Texas A&M Research Feedlot in the late 1970's. He is an Individual Sustaining Member of the American Society of Animal Science, past President of the Plains Nutrition Council, past Secretary of the Ruminant Nutrition Research Council and a former member of the Salmonella Task Force in Washington, D.C.

Jim currently serves on the Cattle Health and Well Being Committee with NCBA and the Legislative and Regulatory Committee of the Texas Cattle Feeders Association. Jim received his bachelor's degree and master's degree from Texas A&M University. He makes his home in Canyon, Texas.



Jason Warner

University of Nebraska-Lincoln

Jason M. Warner is pursuing a Ph.D. in ruminant nutrition in the Department of Animal Science at the University of Nebraska-Lincoln under the direction of Drs. Rick Rasby and Terry Klopfenstein. He holds a bachelor's degree (Animal Science & Grazing Livestock Systems) and a master's degree (Animal Science), both from UNL.

Throughout his graduate career, Warner's research has focused primarily on nutrition and management for the cow-calf sector of the beef industry. His work has included the utilization and storage of ethanol co-products for the cowherd, supplementation programs for gestating cows, and most recently the evaluation of alternative (confinement) cow-calf production systems. Warner is a native of southwest Nebraska, and was raised on his family's cow-calf and diversified dryland farming operation.



Tryon Wickersham

Texas A&M University

Dr. Tryon Wickersham is an associate professor in animal nutrition in the Department of Animal Science at Texas A&M University. He received his bachelor's degree in animal science from Texas A&M University and his master's degree and Ph.D. in ruminant nutrition from Kansas State University. Dr. Wickersham teaches graduate level courses and laboratories in animal nutrition. He also directs research in ruminant nutrition with an interest in forage utilization and nitrogen metabolism. His previous research has focused on protein supplementation to cattle consuming low-quality forage and nitrogen metabolism in cattle consuming diets that are deficient in nitrogen. Future research goals include determining optimum supplementation strategies for ruminants consuming forages of divergent nutritive values and furthering our understanding of nitrogen metabolism in ruminants.

INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Managing Energy Requirements in Confined Cows

Tryon Wickersham, Ph.D.
Department of Animal Science
Texas A&M University



MANAGING ENERGY REQUIREMENTS IN CONFINED COWS

*Levi A. Trubenbach, Tryon A. Wickersham, Gordon E. Carstens, and Jason E. Sawyer
Department of Animal Science and McGregor Research Center
Texas A&M University, College Station, TX*

INTRODUCTION

The United States beef cattle sector has experienced a contraction in cows since 2007; in 2014 there are signs that some expansion may occur. Despite record high prices, however, the anticipated pace of expansion is still very low, and even a minor perturbation in weather, input prices, or calf prices could easily cause producers to revert to liquidation. Ironically, this continued liquidation has occurred despite high prices and positive cash margins for cow-calf operators for several years.

One explanation for this apparent contradiction is the significant capital requirement for cow-calf operators to expand. The largest portion of this requirement is an investment in land required to support expansion. While land can be, and often is leased or rented to support cow-calf enterprises, competition for land in a local geography is often a significant limit. The competition for land for alternate uses (non-agricultural, alternate agriculture, energy, recreation, etc.) and the values placed upon these ventures often make land purchase to support expansion a difficult investment decision. So while cash margins may have been positive, they have not been large enough to incent producers to compete for high-value land in order to expand.

Expansion is important to the continuance of the industry. While cow liquidation and improvements in beef production efficiency have, to some degree, supported beef output, recent trends suggest declines in total beef production that are anticipated to accelerate in the near term. More cattle are required to sustain industry infrastructure and the viability of beef as a staple protein source through price moderation. Moderation in prices, while positive from a consumer perspective, will require increased

economic efficiency of production operations in order to preserve cash margins. It would also appear that these margins must be expanded, as they currently may not be sufficient to maintain reinvestment rates in the industry.

Clearly, many of these constraints are interlinked. A high leverage point appears to be the development of production solutions that increase beef production per unit area (acre) of land as a mitigation strategy to the capital constraint faced by cow-calf operators. Identifying mechanisms to make these solutions cost-efficient are also required, such that cash margins and operating profits can be sustained to incent reinvestment and further rebuilding of the beef industry.

Intensification (increasing output per unit area) is not a new concept; however, it has historically been viewed that intensification of cow-calf systems could not be competitive with ‘cheap’ grazing from rangeland or improved pastureland.

Our primary aim is to develop solutions that enhance the economic, ecological, and social sustainability of the beef industry. Innovation in intensification of beef systems is one area in which we believe solutions exist, and with the generous investment of the Kenneth and Caroline McDonald Eng Foundation, and the Texas Beef and Distillers’ Grains Initiatives, we are pursuing these objectives.

CHALLENGES

Intensification has costs. The most obvious is the cost of purchasing exogenous calories and delivering them to cows during the appropriate periods. The optimization of this cost with associated returns is a key objective to enhance economic sustainability. Costs include the direct

purchase of calories (feed), the operating costs associated with delivery, and the capital costs of pens and other infrastructure and equipment required to manufacture and/or deliver feed.

Strategies which minimize the energetic cost of maintaining cows during this time period may result in enhanced economic efficiency (sustain output at reduced total cost), making this system more feasible. Thus a critical question was identified: Can the maintenance requirements and costs for cows in a strategically intensified system be reduced sufficiently to make the system economically viable?

THE EXPERIMENT

Thirty-two $\frac{3}{4}$ British X $\frac{1}{4}$ Bos indicus cows were used to examine the effects of dietary energy concentration and intake level on energy metabolism. Cows were blocked by day of gestation, stratified by BW and randomly assigned to treatment. A 2 x 2 factorial arrangement was used. A high-energy (H; 2.45 Mcal ME/kg) or low-energy (L; 1.94 Mcal ME/kg) ration was fed at either 80% of estimated NRC maintenance requirements (80) or 120% NRC requirements (120; see Tables 1 and 2). Energy requirements were calculated using the mean BW of treatment cows prior to treatment application. Four cows (1 per treatment) were randomly assigned to each pen and fed individually at approximately 0700 h and 1300 h daily using Calan gates. Orts (if present) were collected weekly.

At both the beginning and end of the feeding period (56 d), animals were subjected to a series of measurements including: weight, hip height, heart girth, and body condition score (BCS); ultrasound measurements of rib (between 12th and 13th rib) fat thickness, rump fat thickness, intramuscular fat and ribeye area for both direct comparison and estimation of body energy reserves. A calculated BCS was estimated at both the beginning and end of the trial using a regression equation derived from data reported by Herd and Sprott (1998; see Figure 1). Cow BW was measured daily for the first seven days on to

identify a point of fill equilibration, and BW was also measured every two weeks following the start of the trial.

Fecal samples (2 per day) were collected and immediately frozen on d 14, 28, 42, and 56. Samples of TMR were taken daily and composited weekly. Samples were dried in a forced-air oven for at least 96 h at 55°C and allowed to air equilibrate for determination of partial DM. Samples were ground through a 1-mm screen using a Wiley mill and dried at 105°C for determination of DM. Organic matter was determined as the loss in dry weight upon combustion in a muffle furnace for 8 h at 450°C. ADF analysis was performed using an Ankom Fiber Analyzer (Ankom Technology Corp., Macedon, NY), and ADIA was determined by loss in ADF DM weight upon combustion in a muffle furnace at 450°C.

A series of equations published in the Beef Cattle NRC (2000) were used to quantify empty body energy.

Body composition was estimated using the following equations:

$$AF = 3.768 \times CS$$

$$AP = 20.09 - 0.668 \times CS$$

Where:

AF = proportion of empty body fat

AP = proportion of empty body protein

CS = body condition score

Body components were calculated as:

$$TF = AF \times EBW$$

$$TP = AP \times EBW$$

Figure 1. Regression of cow body condition score on ultrasound backfat thickness. Adapted from Herd and Sprott (1998).

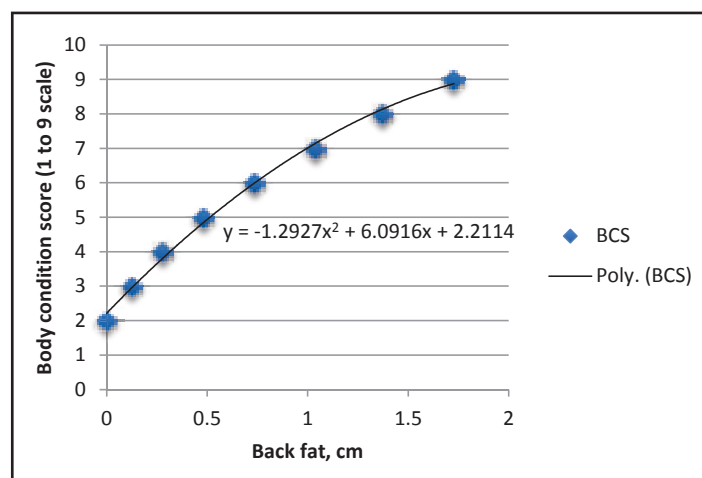


Table 1. Composition and nutrient analysis of diets.

Ingredient	High Energy	Low Energy
	% As fed	
Wheat straw	34.52	64.08
Corn	29.46	0.00
Distillers grain	27.46	27.36
Urea	1.10	1.10
Molasses	5.00	5.00
Mineral	2.46	2.46
Ingredient Cost	\$157.33	\$129.52
Nutrient composition	% of DM ^a	
CP	13.7	11.1
ADF	36.7	49.2
Ash	90.4	89..3
ME ^b	2.54	1.96
NEm ^c	1.64	1.12

^aDry matter contents: high energy, 89.7%; low energy, 90.8%.
^{b,c}Mcal/kg as fed, estimated using NRC

Table 2. Daily treatment diet intake.

Intake	High Energy Diet		Low Energy Diet	
	<u>80</u>	<u>120</u>	<u>80</u>	<u>120</u>
As fed, kg	4.40	6.39	6.49	9.52
Dry matter, kg	3.95	5.73	5.89	8.65
Crude protein, g	540	785	656	963
Digestible energy, Mcal	13.63	19.81	15.50	22.76
Metabolizable energy, Mcal	11.17	16.24	12.71	18.67

$$EBW = BW - FL$$

$$FL = SBW * x$$

$$SBW = BW * 0.96$$

Where:

TF = total fat, kg

TP = total protein, kg

FL = fill, kg

x = % SBW (estimated for each treatment by measuring proportional ruminal contents in cannulated steers fed the same treatment diets via rumen evacuation.

Total body energy was calculated as:

$$TBE \text{ (Mcal)} = 9.4 * TF + 5.7 * TP$$

RE and HE were calculated as:

$$RE = TBE_f - TBE_i$$

$$HE = ME - RE$$

Where:

TBE_f = total body energy on d 0, Mcal

TBE_i = total body energy on d 56, Mcal

RE = retained energy, Mcal

HE = heat energy, Mcal

ME = metabolizable energy, Mcal.

All response data were analyzed as a 2X2 factorial in a completely randomized design.

RESULTS

Both diet formulation and level of intake influenced outcomes of interest in this study; no interactions were observed between diet formulation and level of intake (Table 3).

Apparent organic matter digestibility was increased for the high energy density ration, as anticipated. Restricting intake appeared to increase OM digestibility across both diets by a mean of 4.5 percentage units. While modest, the improvement in digestibility is effectively an increase in DE intake, and thus translates to an increase in ME or NEm intake at a given level of DMI. This increase, therefore, results in an increase in efficiency of the system, and would be expected to reduce the total quantity of feed required to achieve maintenance regardless of diet fed. An alternate view is that this effect reduces the cost per calorie of a given diet by approximately 7.5% when feed intake is restricted.

Regressing the logarithm of heat energy (HE) on ME intake allows a solution to be estimated for HE at ME intake = 0; i.e., an estimate of fasting heat production, or NEm, requirement. Back transformation allows expression of the requirement on a metabolic BW basis (BW^{0.75}). The accepted estimate of NEm requirement for beef cattle is 0.077 Mcal/EBW^{0.75}. When the NRC is used to predict the requirements for crossbred cows similar to those used in this study, under similar environmental conditions, the maintenance requirement estimated increases slightly from 0.077 to 0.082 Mcal/EBW^{0.75}. When data from this study are utilized in a regression as described, the estimated

maintenance requirement for cows fed the Low energy density diet is 0.081 Mcal/EBW^{0.75}; the estimated requirement for the cows fed the High energy density diet is 0.062 Mcal/EBW^{0.75}, suggesting that diet formulations applied in this manner resulted in a substantial reduction in apparent energy requirements, and thus an increase in the energetic efficiency of the system. When expressed as the daily requirement for a 1,200 lb cow, this difference results in a 23.5% reduction in daily NEm requirement when feeding the High density diet (8.12 vs. 6.21 Mcal/d, respectively). The reduction in caloric requirement coupled with the increased energy density of the High density diet result in a substantial reduction in the estimated DM required to maintain the animal during a confinement feeding period.

Because the High energy diet is based on somewhat more expensive ingredient combinations, it is more expensive per ton as fed (ingredient cost of 129.52 vs 157.33 \$/ton as fed for Low and High, respectively); however, the proportionally greater density results in a lower cost per calorie delivered.

APPLICATION IN THE MODEL SYSTEM

Conceptual foundations have been described previously (Sawyer et al., 2013). Briefly, the basis for comparison is a ranch which is stocked in such a manner as to be energetically neutral – in other words, the ranch produces a given quantity of caloric energy yearlong, and is stocked such that the energetic demand of the cow herd is perfectly balanced with the caloric production of the ranch.

Table 3. Effects of high and low energy diets fed at 80 or 120% of NRC energy requirement on key responses in crossbred cows.

Intake	High Energy Diet		Low Energy Diet		Probability		
	Low Intake	High Intake	Low Intake	High Intake	Diet	Intake	Diet x Intake
OM Digestibility, %	67.12	62.08	62.79	58.85	0.03	0.01	0.74
HE, per NRC (Mcal/d)	10.29	14.17	12.61	17.05	<0.01	<0.01	0.52
RE, per NRC (Mcal/d)	1.43	1.43	-0.13	0.79	0.10	0.02	0.95

In this conceptual scenario, produced calories are transferrable within a year; i.e., stockpiled forage or hay produced within the boundaries of the system can be utilized at a different point in the year to remain in balance. No exogenous (purchased from outside the system) calories are utilized, although some allowance in the budget is made for other supplements (protein, mineral).

Energy requirements for a 1,200 lb Brangus cow were estimated using the NRC (2000) on a monthly basis for a 12-month production cycle, assuming a daily activity requirement of 2.2 Mcal NEm/d (Figure 2). Total requirements across the year are estimated at 5,277 Mcal NEm/cow. Thus, a ranch 'in balance' in this framework has a net primary production of calories of 5,277 Mcal NEm per cow per year.

The intensification strategy in this system is to place cows into a confined feeding system for 4 months per year. Cows are placed into the intensified system immediately following weaning, and returned to pasture 30 d prior to calving. This results in a minimization of the caloric demand for any 4-month period during the production cycle that must be supplied with calories purchased externally to the ranch. Additionally, this simplifies management by avoiding calving and/or breeding during the confinement period. Other advantages, including strategies to dilute

capital deployment or eliminate idling facilities also accrue, but will not be discussed in this article.

The requirement estimated for cows during the 4 months immediately post weaning in this model is 1,490 Mcal NEm, and includes requirements for maintenance, conceptus growth and activity. Because it was assumed that the ranch was 'in balance' energetically, the removal from grazing for this period reduces energy demand from the ranch by an amount equivalent to the forecast requirement ($5277 - 1490 = 3787$ Mcal per cow). Effectively, the ranch is now surfeit forage by 1490 Mcal, and the surplus energy can be reallocated to additional cows. In this case, for every cow placed into the confinement system, and additional 0.39 cows can be added for the remaining 8 months of the year. This increase in total cow numbers brings the ranch back into balance, such that total cow energy demand from the ranch is equal to 5277 Mcal.

Feed must be purchased or supplied exogenously in order to meet cow requirements while in the intensified system. Based on the data presented above, the energy required to maintain the cows during the 4 month feeding period is not equivalent to the caloric demand of cattle grazing, and the magnitude of the difference is dependent upon the feeding strategy selected. Using the High energy diet from the reported study results

in a reduction in maintenance requirements and thus reduces the caloric demand, while adjustments in digestibility due to restricted feeding result in more efficient utilization of both diets and thus reduce the quantity of diet required to supply required energy.

Incorporating observed diet and intake effects into a model that adjusts energy requirements appropriately, and then into an enterprise budget framework, allows assessment of the economic efficiency of each system (see Table 4). Due to high calf prices, all scenarios appear

Figure 2. Energy requirements (NEm, Mcal/d) for a 1,200 lb. Brangus cow, grazing.

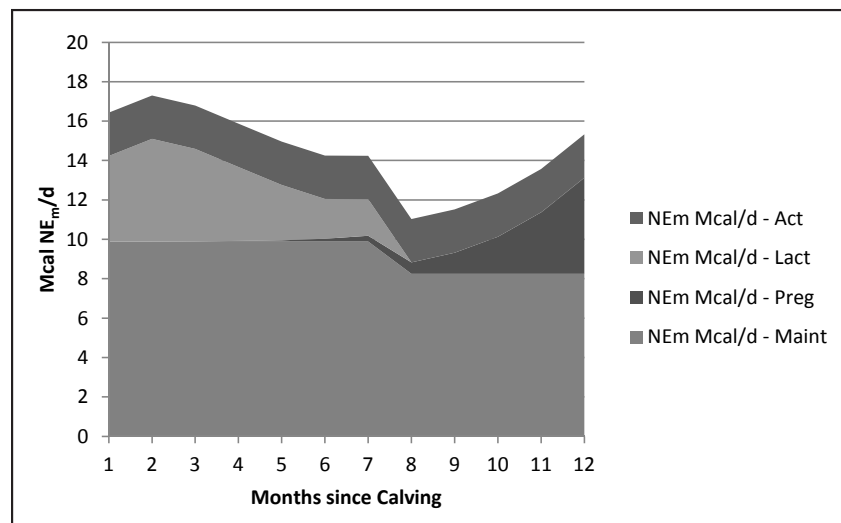


Table 4. Enterprise budget estimates comparing 3 cow calf systems.

				Base System - 500 cow		Low Energy - 697 cow		High Energy - 697 cow	
Revenue	Head	Qty	\$/Unit	\$/Cow	Total	\$/cow	Ent. Total	\$/cow	Ent. Total
Steer	0.43	5.25	\$210.00	\$474.08	\$237,037.50	474.08	330,330.00	474.08	330,330.33
Heifer	0.27	4.75	\$188.00	\$241.11	\$120,555.00	241.11	168,002.84	241.11	168,002.84
Cull Cow	0.15	12	\$115.00	\$207.00	\$103,500.00	207.00	144,235.36	207.00	144,235.36
Cull Bull	0.01	18	\$120.00	\$21.60	\$10,800.00	21.60	15,050.65	21.60	15,050.65
Total Revenue									
				\$943.79	\$471,892.50	943.79	657,619.17	943.79	657,619.17
Variable Costs									
Supplies		1	\$18.35	\$18.35	\$9,175.00	18.35	12,786.08	18.35	12,786.08
Marketing Expenses		1	\$33.03	\$33.03	\$16,516.24	33.03	23,016.67	33.03	23,016.67
Supplements		1	\$78.00	\$78.00	\$39,000.00	55.97	39,000.00	55.97	39,000.00
Vet. Supplies		1	\$16.50	\$16.50	\$8,250.00	16.50	11,497.02	16.50	11,497.02
Fuel		1	\$67.00	\$67.00	\$33,500.00	67.00	46,684.87	67.00	46,684.87
Repairs		1	\$47.50	\$47.50	\$23,750.00	47.50	33,097.49	47.50	33,097.49
Labor		1	\$63.00	\$63.00	\$31,500.00	55.54	38,700.00	55.54	38,700.00
Utilities		1	\$24.00	\$24.00	\$12,000.00	24.00	16,722.94	24.00	16,722.94
Interest		1	\$13.03	\$13.03	\$6,513.42	13.03	9,076.96	13.03	9,076.96
Livestock Depreciation		1	\$13.20	\$13.20	\$6,600.00	13.20	9,197.62	13.20	9,197.62
Purchased Energy						207.00	144,235.36	146.00	101,731.22
Total Variable Costs									
				\$373.61	\$186,804.66	551.12	384,015.01	490.12	341,510.87
Fixed Costs									
Brush Control		1	\$6.67	\$6.67	\$3,335.00	4.79	3,335.00	4.79	3,335.00
Depreciation		1	\$52.18	\$52.18	\$26,090.00	45.31	31,574.00	45.31	31,574.00
Insurance		1	\$27.00	\$27.00	\$15,500.00	19.37	13,500.00	19.37	13,500.00
Land Costs		1	\$120.00	\$120.00	\$60,000.00	86.11	60,000.00	86.11	60,000.00
Total Fixed Costs									
				\$205.85	102,925.00	155.58	108,409.00	155.58	108,409.00
Total Costs									
				579.46	289,729.66	706.70	492,424.01	645.70	449,919.87
Returns									
				364.33	182,162.84	237.08	165,195.15	298.08	207,699.29

to be profitable. Adopting either diet in this intensification strategy allows an increase from 500 cows (base case) to 696 cows. The increase in cow numbers results in increases in total costs, but reduces the per cow cost for many fixed cost items. Total depreciation expense is increased due to the requirement for additional equipment. Most of these changes are similar for either intensification alternative.

The increased efficiency observed with the High energy diet, fed at estimated maintenance requirements using observed adjustments, requires less total monetary expenditure per cow for purchased calories than the low energy strategy, despite the lower cost per ton of the Low energy diet. With the pricing structures utilized in this example, the Low energy strategy did not increase profitability compared to the base case. Alternately, the high energy strategy increased total returns to the ranch compared to the base case. Both strategies increase the output per unit of land area, as the additional acres utilized for farming off-site (to supply feed) are low relative the grazing acres required per animal unit.

Overall, this study and the application of its results indicate that strategic intensification is a feasible option to enhance the aspects of sustainability of ranching systems. Additional opportunities to enhance the efficiency of the system exist by deploying additional technologies and quantifying additional effects. An appropriate adjustment to the activity requirement should be identified. Inclusions of diet enhancements, such as ionophores, are likely to add additional efficiencies. Known variance in the energetic efficiency of individual animals offers a complimentary technology to capitalize upon both genetic and management tools to improve the viability of beef cow systems.

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INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Limit Feeding Production Cows in Confinement

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LIMIT FEEDING PRODUCTION COWS IN CONFINEMENT

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INTRODUCTION

The available forage supply for maintaining beef cow herds continues to be threatened by several factors. High commodity prices encourage the conversion of pasture land into crop ground, cities and towns continue to sprawl out into rural areas creating subdivisions where historically cattle grazed, and drought, fires, hail, and insects continue to periodically deplete forage supplies. When forage supplies cannot be located or are not affordably priced; cattle producers must either sell their cattle or feed the cattle in confinement.

Feeding beef cows in confinement is not a new concept. However, limit feeding them (less than 2% of body weight on a DM basis) an energy dense diet, with the intent of keeping the cows in the production cycle, rather than finishing them out, needs to be thoroughly evaluated. Keeping cows in confinement 12 months out of the year may not be the most economical scenario, but partial confinement when pastures need deferment or forage is not available, may keep at least a core group of cows from being marketed, or provide a means of maintaining a cowherd where pastures is simply limited. Producers will need to know how and what to feed the cows while in confinement to make it feasible. Crop residues, poor quality hays such as those from the conservation reserve program (CRP), and by-products tend to be the most economical ingredients to include in confinement diets.

NUTRIENT REQUIREMENTS OF THE COW

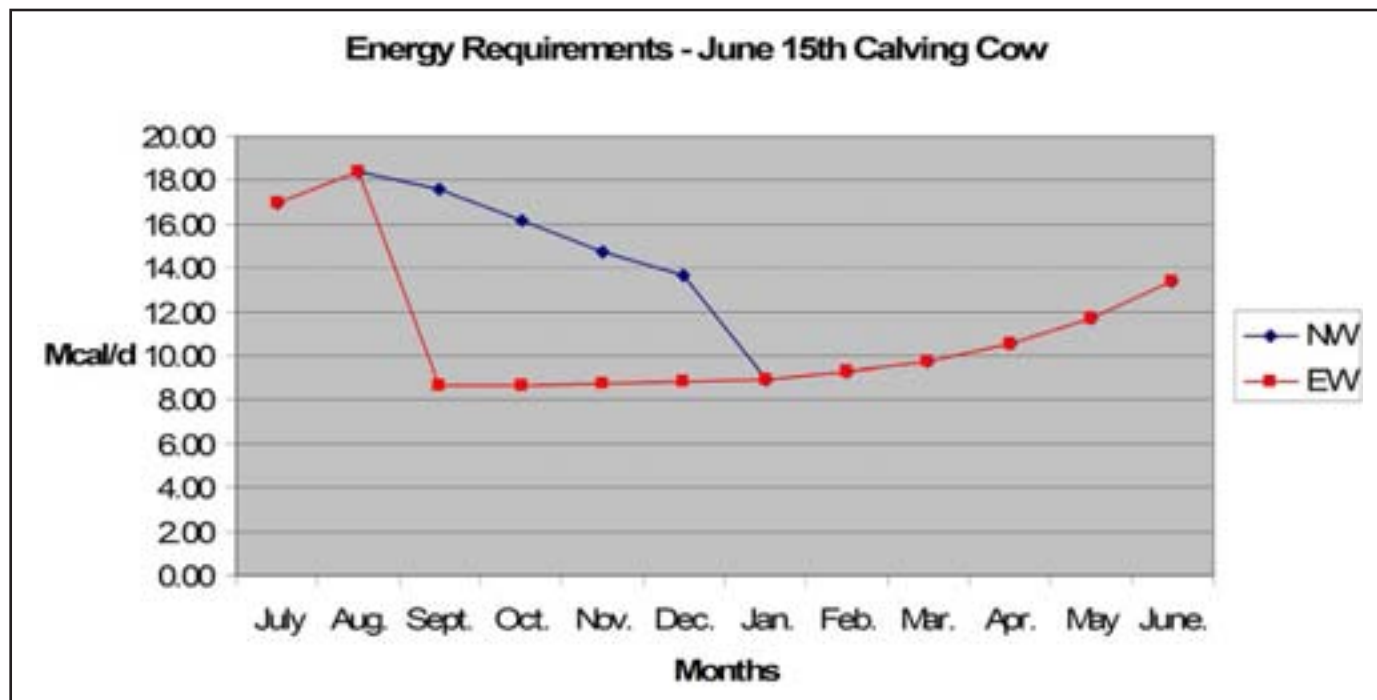
When producers decide to limit feed cows in confinement there are three concepts that become key to successful feeding. The first concept to understand is the cow's nutrient requirements. The cow's nutrient requirements

vary with age, size, and stage of production (NRC 1996). Two and three year old cows still have requirements for growth as well as gestation and/or lactation and should be fed separately from mature cows in a limit feeding situation to allow them to consume the feed needed to meet their requirements. More frequent sorting may be necessary when cows are limit fed to prevent very aggressive cows from over-consuming and timid cows from becoming too thin. When lactation starts, the cow's nutrient needs increase and peak at about 8 weeks of lactation (Figure 1). Producers need to either increase the energy density of the diet or increase the pounds of dry matter fed when lactation starts.

NUTRIENT CONTENT OF THE FEEDSTUFFS

Another important consideration is the nutrient content of the commodities used in the limit fed ration. Most producers are familiar with feeding low to medium quality forages to mid-gestation cows. They typically supplement with a protein source to improve forage digestion and the cows are allowed ad libitum access to the forage. The protein allows the cow to adequately digest the forage and if the forage is not restricted, the cow can usually meet her energy requirements. Limit feeding cows while maintaining body condition requires a mindset shift for producers. While the protein needs of the cow do need to be met, the first limiting nutrient, especially for the lactating cow, is energy. Typically, producers are always encouraged to send feed samples to a commercial laboratory for testing. The TDN value listed on commercial laboratory results is not from an analysis but is actually calculated from acid detergent fiber (ADF). In the case of forages, this is fairly similar to the digestibility and is an acceptable measure of forage energy. However, due to the oil content of some by-

Figure 1. Energy requirement for gestating and lactating cows calving June 15, early weaned calves weaned at 90 days (EW) and normal weaned (NW) at a traditional 205 d weaning



products, and the interaction of by-products in residue based diets, the University of Nebraska recommends using TDN values for by-products based on animal performance in feeding trials

Table 1. Total Digestible Nutrients of common by-products and commodities in forage based diets determined from feeding trials.

Ingredient ¹	TDN (% dry matter)
Corn distillers grains, wet, dry, modified	108
Corn condensed solubles	108
Sugar beet pulp	90
Soyhulls	70
Synergy	105
Corn gluten feed	100
Midds	75
Corn	83
Wheat straw/cornstalks	43
Meadow Hay	57

¹ Feeding trials from Blasi et al., 1998; Ham et al., 1993; Klopfenstein and Owens, 1988; Loy et al., 2003; Nuttelman et al., 2009; Oliveros et al., 1987.

(Table 1). Estimating too much energy for a commodity can result in poorer than expected cattle performance, while underestimating the energy value of a commodity would cause overfeeding, resulting in an increased expense for the confinement period.

FEED INTAKE OF THE NURSING CALF

The third important consideration is the feed intake of the calf. Nursing calves can be seen nibbling at forage within the first three weeks of life. By the time they are three months old, research indicates they are eating about 1% of BW in forage (Hollingsworth-Jenkins, et al. 1995). A 300 lb. calf would eat 3 lb. of DM in addition to nursing the cow. If calves are not weaned and in their own pen at this time, additional feed should be added to the bunk for them. Early weaning does not save feed energy but may be a good management practice in the confinement feeding situation. Research conducted at the University of Nebraska indicated that when nursing pairs were fed the same pounds of TDN as their weaned calf and dry cow counterparts, cow and calf performance was similar at the 205 d

weaning date (Tables 2,3, and 4). Table 5 depicts the common diets fed to the pairs and their weaned calf and dry cow counterparts. While not resulting in an advantage in feed energy savings, early weaning can be advantageous in other ways. Early weaning would allow the calves to be placed in a separate pen from the cows. Producers would then have the flexibility of feeding the calves a growing or a finishing diet, or even allowing them to graze forages if available. The cows then, without the demands of lactation, could be placed on a lower energy diet.

MANAGEMENT CONSIDERATIONS FOR YOUNG CALVES IN CONFINEMENT

A common misconception producers often have is that calves nursing cows do not need to drink very much water. In reality, they do need water, and especially so, when the temperatures are warm. A dairy calf study (Quigley, 2001) determined that calves less than 60 d old, consuming 0.8 gal/d of milk replacer, still consumed 0.66 gal/d of free choice water. These researchers also determined the relationship between temperature and free choice water intake was exponential rather than linear. At temperatures above 85° F, nursing calves may drink close to 1 gal/d of free choice water. Free choice water intake also promotes rumen development. Calves that begin eating early tend to thrive and gain weight better than those that don't. Young calves need to be able to reach the water tank and have access to sufficient water. In the UNL confinement feeding trial, calves as young as a couple of days drink water during July calving. Tanks need to be banked high enough that calves can reach the edge and water flow needs to be unrestricted enough that the tank can refill quickly after cows drink. The size of the tank needs to be big enough that on extremely hot days calves can access the water without cows pushing them away. In the research trial it was necessary to put small tubs of water out of reach of the cows but accessible to the calves. Feed access is also an issue as calves begin eating at a fairly young age. In the UNL confinement study, creep feeders were placed at the back of the feedlot pen to allow calves access to alfalfa pellets prior

to 90 days of age. Although consumption was low (0.37% BW), it probably served to initiate some rumen function. Calves begin eating at the bunk with cows at an early age and therefore would need to be able to access the feed bunk as well.

REPRODUCTION IN CONFINEMENT

Cows can be successfully bred in confinement consuming a high energy limit-fed diet (Table 3). The overall conception rate of moderate BCS cows is higher if they are on an increasing plane of nutrition just prior and during the breeding season. This can be done by increasing the DM fed, or increasing the energy density of the diet. Additionally, confinement improves the ease with which synchronization and artificial insemination protocols can be implemented (<http://beef.unl.edu/web/cattleproduction/breedingcowsinconfinement>). When bulls are confined with cows allow an additional 2 feet of bunk space for every bull and another 15-18 lb of TDN per bull/d depending on the condition of the bulls during breeding.

DEFINING CONFINEMENT FEEDING

Feeding in confinement does not necessarily have to be done in a feedlot setting. Although, the advantages of the feedlot often include feed trucks with scales and mixers, concrete bunks, good fences, and access to commodities not always available to ranchers. However, feeding cows in confinement can be achieved by setting up temporary feed bunks or feeding under a hot fence on harvested crop ground, pivot corners, a winter feed ground, or even, as a last resort, a sacrifice pasture. It is important to keep in mind that cattle limit fed a diet on a pasture will continue to consume the forage in the pasture and overgrazing can result if this is the option that has to be implemented. Regardless of location, cows will need a minimum of 2 ft. of bunk or feeding space and calves will need 1.5 ft.

Table 2. Daily DMI by weaning treatment and year.

Item	Year 1		Year 2	
	EW ¹	NW ²	EW ¹	NW ²
Cow	15.0	–	15.5	–
Calf	8.5	–	9.3	–
Cow-Calf Pair	–	22.8	–	24.9
Total	23.5	22.8	24.8	24.9

¹EW = early-weaned at 91 d of age.²NW = normal-weaned at 203 d of age.**Table 3. Performance of cows by location and weaning treatment.**

Item	ARDC		PREC		SEM	P-value		
	EW ⁴	NW ⁵	EW ⁴	NW ⁵		Weaning ¹	Location ²	WxL ³
Cow BW, lb								
October	1201	1180	1227	1212	114	0.26	0.08	0.85
January	1206	1166	1302	1232	104	0.02	<0.01	0.51
Cow BW change, lb	5	-14	74	20	23	<0.01	<0.01	0.15
Cow BCS ⁶								
October	5.5	5.5	5.2	5.2	0.3	1.00	<0.01	0.59
January	5.4	5.3	5.6	5.6	0.4	0.60	0.03	0.60
Cow BCS change ⁶	-0.1	-0.2	0.4	0.4	0.2	0.38	<0.01	0.38
Pregnancy, %	89.9	85.4	92.5	95.2	6	0.88	0.25	0.50

¹Fixed effect of calf age at weaning.²Fixed effect of location.³Calf age at weaning x location interaction.⁴EW = earle-weaning at 91 d of age.⁵NW = normal-weaned at 203 d of age.⁶BCS on a 1 (emaciated) to 9 (obese) scale.**Table 4. Performance of calves by location and weaning treatment.**

Item	ARDC		PREC		SEM	P-value		
	EW ⁴	NW ⁵	EW ⁴	NW ⁵		Weaning ¹	Location ²	WxL ³
Calf BW ⁶ , lb								
October	280	277	288	267	8	0.13	0.92	0.22
January	475 ^{b,c}	510 ^a	499 ^{a,b}	461 ^c	11	0.90	0.19	<0.01
Calf ADG, lb	1.73 ^{b,c}	2.06 ^a	1.86 ^b	1.70 ^c	0.18	0.09	0.02	<0.01

¹Fixed effect of calf age at weaning.²Fixed effect of location.³Calf age at weaning x location interaction.⁴EW = earle-weaning at 91 d of age.⁵NW = normal-weaned at 203 d of age.⁶Actual weights^{a-c}Within a row, least squares means without common superscripts differ at $P \leq 0.05$.

Table 5. Ingredient and nutrient composition of diets fed to all cows and calves from October to January by location and year¹.

Ingredient, %	Year 1		Year 2	
	ARDC	PREC	ARDC	PREC
Corn Silage	–	–	40.0	40.0
MDGS	56.5	–	36.5	–
WDGS	–	58.0	–	38.0
Cornstalks	40.0	–	20.0	–
Wheat Straw	–	40.0	–	20.0
Supplement ²	3.5	2.0	3.5	2.0
Calculated Composition				
CP, %	19.0	18.8	16.1	15.3
TDN, %	80.0	80.0	78.0	78.4
Ca, %	0.75	0.77	0.58	0.81
P, %	0.50	0.49	0.44	0.41

¹All values presented on a DM basis.

²Supplements contained limestone, trace minerals, vitamins and formulated to provide 200 mg/cow daily monensin sodium.

LIMIT FED DIET OPTIONS FOR CONFINED COWS OR PAIRS

Numerous commodities are acceptable in cow diets and their inclusion will depend on nutrient content, availability, and price. At least in Nebraska, there is large diversity in commodities available, particularly from the eastern to the western ends of the state. As a result, many diets have been formulated for producers. Some diets include ingredients unique to an area, while other ingredients are available in limited quantities in some areas and therefore cannot be included at

very high levels. Purchase price and trucking costs also impact commodity inclusion. The following example diets were formulated by UNL extension specialists for research trials or Nebraska producers (Table 6). These diets have been used to maintain body condition on cows and can be adapted for other regions with the help of a nutritionist or extension personnel. Handling characteristics should be considered as well when determining what ingredients to use. Research has indicated a diet containing 80% ground cornstalks and 20% wet distillers grains will result in some sorting. Ground wheat straw or low quality hay

Table 6. Example diets of by-products and residues for gestating, lactating, and lactating cows with 60 day old calves.

Diet (DM ratio)	Ingredients	Late Gestation Cow	Lactating Cow	Cow with 60 d old calf
		Dry matter intake, lb		
57:43	Distillers grains:straw	15.0	18.0	20.0
30:70	Distillers grains:straw	19.2	23.0	25.6
40:20:40	Distillers grains:straw:silage	15.4	18.5	20.6
20:35:45	Distillers grains:straw:beet pulp	14.6	17.5	19.4

may not result in the same degree of sorting. Corn wet distillers grains often results in less sorting than dry distillers. Unfortunately, many producers do not have access to the wet product. Mixing some water with the diet can reduce sorting or including silage or beet pulp can add enough moisture to reduce sorting. Rumensin can be added up to 200 mg/ton to improve efficiency and limestone should be added at 0.3 lb/cow to enhance the Ca:P ratio.

CONCLUSION

Limit feeding an energy dense diet to cows or pairs in confinement for a segment of the production cycle can be a viable alternative to herd liquidation. Producers choosing to limit feed cows or pairs in confinement must consider the nutrient needs of the cow, changes in nutrient requirements as production phase changes, nutrient content of available feeds, availability and associated costs of available feeds, as well as the increasing feed demands of the growing calf.

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INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Cow Efficiency: Implications for Beef Sustainability

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COW EFFICIENCY: IMPLICATIONS FOR BEEF SUSTAINABILITY

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INTRODUCTION

The world population is projected to reach 9.6 billion by 2050 with global animal protein demand in the same year expected to increase 70% over 2010 levels (Gerber et al., 2013). Most of the increase in demand will take place in developing nations where the highest population growth is projected to occur. However, much of the growth in demand will be due to increasing per capita incomes and corresponding per capita increases in animal protein consumption. Interest in beef sustainability has grown due to concerns of balancing the environmental impacts of beef production with the demands of a growing world population of increasing affluence while facing the constraints of finite resources (e.g. fossil fuels, freshwater) and climate change. The following paper will discuss the definitional issues surrounding sustainability, the role that ruminants play in sustainable food systems, and the implications of cow efficiency on beef sustainability.

SUSTAINABILITY: WHAT DOES IT MEAN?

While sustainability has often been equated to “environmentally friendly,” the term encompasses more than just environmental concerns. Often the concept is described as the “triple bottom line – people, profit, and planet” (Elkington, 2004) emphasizing that sustainability has economic, environmental, and social components that must be balanced to find a “sweet spot” of sustainability. Building on the triple bottom line concept, sustainable beef production can be defined as long-term business viability, stewardship of natural resources, and responsibility to the community, family, and animals. However, a one-size-fits-all “sweet spot” of sustainability for beef production

that cuts across production systems, climates, cattle breeds, etc. does not exist. Indeed, “solving” sustainability is an impossible task because sustainability is a wicked problem.

A wicked problem can be defined as a problem that cannot be solved, but rather can only be managed (Peterson, 2013). Peterson (2013) outlined four distinguishing characteristics that make problems wicked as the following: (1) no definitive formulation of the problem exists, (2) its solution is not true or false, but rather better or worse, (3) stakeholders have radically different frames of reference concerning the problem, (4) the underlying cause and effect relationships related to the problem are complex, systemic and either unknown or highly uncertain. In summary, the wickedness of sustainability stems from uncertainty surrounding the components of sustainability (e.g. greenhouse gas emissions from grazing cattle – few data exist), and the differences in perspectives and values across stakeholders. The stakeholders in the beef sustainability discussion are wide-ranging and can include producer groups, government regulatory agencies, and non-governmental organizations (e.g. The Nature Conservancy, World Wildlife Fund). While there are likely many commonalities across stakeholders, there are also many differences in how sustainability is defined and how components of sustainability are valued (e.g. an environmental stakeholder may place more emphasis on environmental impact, while a consumer group stakeholder may place more of an emphasis on food safety). As a consequence, stakeholders will have different visions for a sustainable path forward for beef. Despite its wickedness, continuous progress towards “better” sustainability in beef production is possible. Key components of that progress are research that can decrease uncertainties and improve our

understanding of the trade-offs across production systems, and subsequent communication of the trade-offs that exist.

A RUMINANT'S ROLE IN SUSTAINABLE FOOD SYSTEMS

Ruminants, such as cattle, do contribute to environmental concerns including water quality and greenhouse gas emissions. However, cattle also play a critical role in the food system by converting human inedible feedstuffs and by-products into human edible and useable products. Fundamentally, animal agriculture is about converting natural resources of lower human value to higher human value products. Less than 1% of the solar energy that reaches Earth is captured by photosynthetic organisms, which is the energy that allows all heterotrophic life (i.e. non-photosynthetic, from bacteria to cattle to humans) to exist. Much of the solar energy captured by photosynthesis is in the form of the compound cellulose. Ruminants play a unique role in the food system by converting cellulose, which is indigestible by humans and the most abundant organic (carbon-containing) molecule on Earth, into high quality animal protein and ancillary products (e.g. leather). The monogastric animal industries (e.g. poultry, swine) have a limited capacity to use high cellulose-containing forages and by-product feeds (e.g. almond hulls, cottonseed), so while those species (and fish) may be more efficient when expressing feed efficiency as feed-to-gain, consideration should be given to the conversion of human inedible-to-human edible energy and protein.

Some have argued that because animals, and ruminants especially, are inefficient convertors of calories in crops into human food, shifting towards more vegetarian diets and particularly away from diets that contain beef would feed more people sustainably (Stehfest et al., 2009; Cassidy et al., 2013). The trade-offs of such dietary switches are often calculated by assuming pasture and cropland used for livestock production would be abandoned (Stehfest et al., 2009) or the forage component of livestock diets is simply

ignored (Cassidy et al., 2013). These assumptions and omissions likely limit the usefulness of the conclusions that can be drawn from such analyses, though, to be fair, accurately modelling the environmental impacts of the global food system or consequences of dietary shifts is a nearly impossible task due to the complexities and uncertainties involved. Oltjen and Beckett (1996) evaluated dairy and beef cattle systems using a costs and returns analysis of humanly edible energy and protein. Humanly edible returns for digestible energy ranged from 37 to 59% and returns to digestible protein ranged from 52 to 104% depending on the time spent in the feedlot and the feedstuffs used (increasing amounts of corn in the diet lowered the returns on humanly edible inputs, and increasing the use of by-products increased the return to humanly edible inputs; Oltjen and Beckett, 1996). Additionally, Oltjen and Beckett (1996) point out that ruminants add value to incorporating forages into crop rotations, which can improve soil conservation and health. Rangelands (approximately 50% of the Earth's surface, much of which is unsuitable for cultivation) and by-products will always be an important part of our agricultural system; therefore, cattle and other ruminants play an important role in our food system.

COW EFFICIENCY AND SUSTAINABILITY

The efficiency of the beef cow has important implications for beef sustainability, particularly when considering environmental impacts. Life cycle assessments that account for all greenhouse gas emissions from cradle-to-farm gate (e.g. including emissions from crop production, cow-calf, stocker/backgrounder, and the feedlot phases) find that the cow-calf phase accounts for the majority of greenhouse gas emissions, ranging from 68-80% of total emissions in simulated beef systems (Johnson et al., 2003; Beauchemin et al., 2010; Stackhouse-Lawson et al., 2012). The female breeding stock of the beef industry contributes a large share to the total environmental footprint of beef production because the largest number of animals are in this sector of the industry.

Additionally, beef cows primarily consume high forage diets compared to feedlot cattle, and consequently their enteric methane (a greenhouse gas 25 times more potent at trapping heat than carbon dioxide; IPCC, 2007) emissions tend to be higher per head as compared to feedlot cattle (Johnson and Johnson, 1995). Reducing the number of beef cows required to produce a given amount of beef can reduce environmental impacts and natural resource use per unit of beef. Indeed, Capper (2011) found a 16% lower carbon footprint, 19% less feed use, 33% reduction in land use, and 12% less water use in the 2007 US beef industry compared to 1977, due in part to a reduction in the number of beef cows and heifers required to support a given level of beef production.

Of course, putting forward the argument that cow efficiency impacts sustainability begs the question, by what measure of efficiency? Is one referring to biological or economic efficiency? Or optimizing cow efficiency, both at the cow and herd level, for a given environment and production system? The latter seems most appropriate. A one-size-fits-all optimally efficient cow will be an impossibility due to differences in environmental conditions, feed availability and quality, and the market being targeted across cow-calf operations. For example, cows with a larger body size and higher milk production (and, consequently, higher maintenance energy requirements) may be more suited to higher rainfall environments with abundant forage than low-rainfall environments in the arid Western US, where such cows would likely require significant feed supplementation and potentially suffer from reduced reproductive efficiency if energy and nutrient requirements could not be met. Improving reproductive efficiency and decreasing the number of open cows is important both for an individual operation's economic sustainability and for industry-wide sustainability, as reducing the number of breeding stock required to support a given level of beef production has a major impact on environmental sustainability as outlined above. Optimizing cow efficiency to meet the goals of the operation, the environmental resources available to the producer, and to ensure profitability

will have obvious benefits for the long-term sustainability of a given cow-calf operation. Intensified cow-calf production systems may be a way to optimize efficiency for some in the cow-calf segment of the beef industry.

CONCLUSIONS

Improving cow efficiency has many positive outcomes that can improve beef sustainability. While it is tempting to simply state that efficiency = sustainability, such a simplification overlooks many of the social aspects of sustainability that have dominated media coverage of US animal agriculture in recent years. Many consumers are concerned with the welfare of animals and the environmental impacts of concentrated animal feeding operations. Cow-calf operations have largely been immune to many of the criticisms of so-called "factory farms" due to the pastoral image of mother cows and their calves on grass — how will the intensive feeding of beef cows, driven primarily by economic sustainability considerations, be perceived by the general consuming public? While intensified cow-calf systems can likely be managed "sustainably", particularly when incorporating by-product feedstuffs, consideration should be given to the potential trade-offs and public perception issues surrounding intensified cow-calf systems.

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INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Nutritional and Management Considerations when Merging Cow-Calf and Feedlot Operations

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NUTRITIONAL AND MANAGEMENT CONSIDERATIONS WHEN MERGING COW-CALF AND FEEDLOT OPERATIONS

Bill Dicke, Dave McClellan, Jim Simpson, Ron Crocker, Paul Defoor, Roberto Eizmendi, Kenneth Eng

KENNETH ENG

As a background to my semi-confined cow experience, Caroline and I began building and expanding our cow herd in the Southwest and later in Nebraska 15 years ago. We put a few heifers of our own into production but the majority were purchased as cows of all ages usually out of drought areas. It seems there's always a drought somewhere in the Southwest and our strategy was to buy bred cows or cows with small calves that were often in poor body condition. Right or wrong, our assumption was that type of cow was probably a low maintenance cow. Because grass was usually not available we started the majority of cows in semi-confinement and provided them with mixed rations. Although we rotated to grass and roughage when available, almost all the cows spent a portion of their time in semi-confinement and some were in confinement the majority of the time.

The cows varied in size, age, color, type, etc. but the majority were medium frame size. We bought pretty good bulls, usually black but occasionally Charolais or Gelbvieh and as long as the cow raised a calf and rebred, we kept her regardless of age.

At the peak, we built the herd to over 2000. Until recently, I didn't say much about the program because many would think we were foolish and also, I didn't want the competition buying cows.

Obviously, semi-confined cows work better when feed is cheap and this certainly wasn't the case in some years. However, ranches and pasture leases were also not a bargain and sometimes, unavailable. A major advantage of semi-confinement feeding is that you reduce cow feed requirements by approximately 10-20%. This is

because we can feed a balanced mixed diet and program feed it on a restricted basis to the level of the cow's stage of production requires. Feed requirements are reduced because you reduce cow movement and maintenance requirements and increase ration digestibility by program limit feeding. Another major advantage is weaning becomes a "piece of cake". We usually let the cows and calves eat together or in close proximity and when the calf is weaned, it's accustomed to eating and doesn't miss its mother. The cow misses the calf much more than the calf misses to cow. Contrary to what many suspect, calf health has not been a problem perhaps because of better pre and post natal nutrition.

An advantage or disadvantage of confined or intensive production is that less land is required. If land accumulation is part of your cow business plan, confined cows are not for you. Another problem with confined cows in drought is predators such as coyotes can be a problem with small calves.

Personally, I believe the greatest advantage of a confined cow feeding program is it adds flexibility to your operation. You have the ability to maintain or expand your cow herd during a drought when cow prices are low. That's a distinct advantage compared to destocking your operation in a drought and restocking during good times. For example, a semi-confinement cow herd today that was put together two or three years ago probably cost half of what similar cows today would cost.

The following are additional observations of feedlot operators and consultants who have worked with semi-confinement operations.

RON CROCKER

Ron Crocker is the managing partner for CA CATTLE COMPANY located in Mason County, Texas. In the fall of 2012 CA CATTLE made the decision to convert their stocker grazing and feed yard operation to an intensively managed cow/calf herd. The goal was not to be as good as but better than a conventional cow/calf production system.

Operating costs, breed-up rates, calves weaned, weaning weights and the overall condition of the cattle and pastures has given CA CATTLE the confidence to expand the cow herd. CA CATTLE is excited about the future and what feeding a cow at the right point in her production cycle has done for the sustainability of their ranching operations and the continued utilization of their small feed yard.

Lessons have been learned about maintenance requirements, eating behavior in a restricted feed environment along with the day to day experiences of making things work. It has not only been exciting but a lot of fun to be in the “cow business” during these volatile and exciting times.

BILL DICKE

Confined feeding of beef cows and replacement heifers has gained momentum over the past few years. For some producers, it may well be one of the best profit opportunities in the cattle industry today given current feeder cattle prices and declining feed costs. Expanding existing herd size, efficient utilization of feedlot capacity, and application of value added technologies are just a few of the added benefits that can be part of production programs. Several of our clients have had very good experiences recently with cow ownership, replacement heifer development, and even export programs that utilized various limit fed confined feeding systems.

One of the advantages of confined or semi confined systems is the flexibility regarding structure of the program. Adapting to land resources, feedlot facilities, and available feed

resources at any given location can present both opportunities and challenges.

This production system may also be a good way to help get young people started in the cattle business.

DAVE McCLELLAN

Cows and Calves integrated into a Feed yard.

This year has brought some interesting scenarios to our involvement in confined cows.

I have three yards that have bought running age bred cows from dispersion sales and confine them part of the year and run corn stalks part of the year.

I have another yard doing the same rotation but with good black 1st calf heifers. That yard feeds a lot of heifers and preg. checks at processing. Anything that is late 2nd or 3rd trimester gets kept through calving and then rebred or fed to market weight.

My last yard has a cow herd that hasn't left the feed yard for the last six years. We utilize 2-4 pens depending on the time of year to better facilitate breeding, calving, weaning, etc.

We have taken a more Holistic approach to weaning feeding an All-Natural add pack with yeast, yucca, chelated traces, etc. This has resulted in lower morbidity and mortality among the calves.

We breed for late May/June calving to avoid bad weather and get past most of the planting pressure on shared help.

JIM SIMPSON

The severe drought starting in 2011 has resulted in a huge resurgence of interest in confined beef cow programs. While these type programs have been used for years on a small or regional basis, large scale cow herds in total confinement have

been rare. Many cow producers with genetic pools literally decades in development faced the uncomfortable options of relocation, dispersal, slaughter or feeding as a result of crippling drought.

Fortunately, or unfortunately, depending on which segment of the industry one was in, feedyard occupancy at that time was slipping which offered many empty pens to choose from. Some feedyards embraced the idea as a way to encourage pen occupancy and provide a much needed service to the cow sector of the industry. Dr. Kenneth Eng, in addition to his many accomplishments, may well be remembered for his foresight to initiate development of confined cow programs in the feedlot.

We have learned a great deal about feeding breeding cows in feedlots in the last several years, thanks in large part to the Dr. Kenneth and Caroline McDonald Eng Foundation sponsorship of research activities related to confined cow nutrition and management. We have learned that cows can be incredibly efficient utilizers of low quality feeds at intakes lower than many of us would have believed. We have learned that concerns over calf health of feedyard born calves were mostly unfounded probably due to adequate cow nutrition during gestation. We have learned that calves will readily consume feed early in life and that subsequent weaning is unbelievably easy if managed well. We have learned that it may be feasible to maintain huge cow herds on small parcels of land economically.

There is however much still to be learned. I have questions like:

1. What is the optimum body condition score for each stage of a cow's life in the feedyard? Due to our ability to adjust nutrient intake quickly, can we cheapen feed costs at some stages without long term damage to the cow?
2. What are the exercise requirements, if any, of beef cows?
3. What is the absolute minimum dry matter intake requirement to satisfy a cow?

4. Can a cow's productive life be extended 2, 3 or 5 years beyond normal in a feedlot setting? What factors contribute to longevity and can we influence this in a positive way?

5. Can beef cows be conditioned to stanchion use similar to milk cows allowing AI programs to easily be used?

6. Is it economical to select for increased milk production and theoretically higher weaning weights of calves?

I look forward to working on these and other questions regarding confined cows. Maybe next year we will be able to answer some of them.

INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Fetal Programming: Implications and Opportunities in Confinement Systems

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FETAL PROGRAMMING: IMPLICATIONS AND OPPORTUNITIES IN CONFINEMENT SYSTEMS

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INTRODUCTION

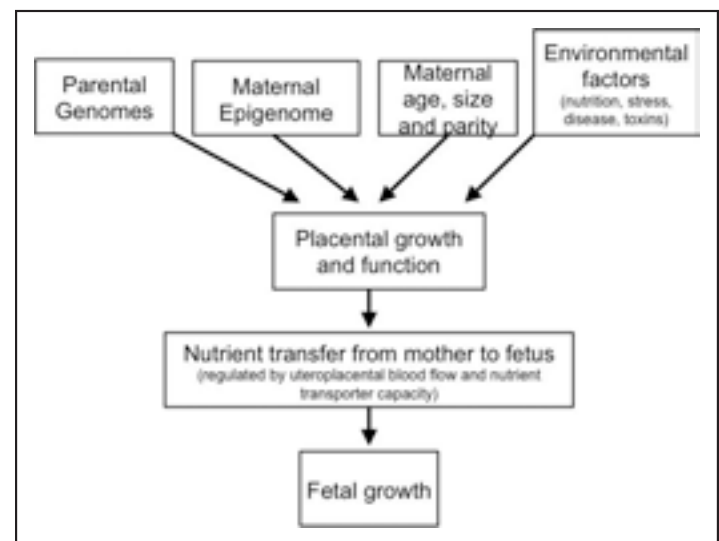
Selection of livestock for valuable traits, such as growth rate, milk production, and environmental adaptability, are fundamental practices that producers have been performing since the initial domestication of livestock species. Every so often the scientific community experiences a breakthrough that enhances our understanding of how these traits are regulated and/or inherited across generations. The unraveling of the bovine genome through whole genome sequencing projects is a shining example of the power of animal research to unlock new opportunities for development of sustainable beef production worldwide (Bovine Genome et al., 2009; Daetwyler et al., 2014). By now most producers are aware that traits are regulated at the level of individual genes (often working in concert) and that the genetic code is passed on from generation to generation at the time that the oocyte is fertilized by the sperm. The question many geneticists get asked from the production community is, “Why is there such variability between my calves if they all came from one bull?” The answer of is complicated, to say the least. Certainly it is simple to understand that while all the calves came from one bull they also came from many different cows, frequently with diverse genetic backgrounds. However, the reality is that the answer to this question is much more complex than just the parental genetic background and, in truth, the scientific community has only just begun to gain significant understanding of this problem (Figure 1). The answer to the question lies, in part, in understanding how the genes that are passed on from the sire and dam are turned on or off during life to give rise to the final phenotype, a new concept termed “fetal programming”. The objective of this paper is to improve our understanding of how the

uterine environment programs the regulation and expression pattern of genes throughout life. Simply seeking to answer the questions of: what environmental factors alter gene expression and have positive or negative consequence and how we can harness this new found understanding of genetic regulation to improve production practices, including the potential benefits of confinement cow-calf systems to improve the efficiency of beef production?

FETAL PROGRAMMING

Fetal programming is the theory that critical physiologic parameters, such as metabolism or stress tolerance, are patterned during the early stages of embryonic and fetal development and

Figure 1. Factors contributing to mammalian fetal growth. Growth of the fetus is not only regulated by the paternal and maternal genomes, but also can be influenced by the maternal epigenome, maternal age, size, and parity, as well as environmental factors such as nutrient availability. These factors regulate placental growth and therefore the fetal nutrient availability.



are established for the life of that individual and may in fact be heritable across generations. From a biological perspective, the concept of fetal programming has a number of advantages. Most importantly, this concept allows each fetus to predict the future quality of the extra-uterine environment (by cues transmitted to the fetus via the placenta) and set these physiologic parameters to give that offspring the greatest opportunity for survival and continuation of the species. This process gives each individual/generation a certain degree of adaptability beyond the comparatively rigid genetic code. One might envision a scenario where an animal is exposed to drought conditions during pregnancy, which would result in the offspring programming a very efficient metabolic rate, thus promoting fat deposition during periods of abundant nutrition to allow for sufficient reserves during the expected (predicted) periods of famine. In this scenario the individual would be well-suited to survive in suboptimal conditions. On the other hand, it is certainly possible that the poor uterine environment is an aberration and therefore the offspring will never truly be exposed to the conditions that it programmed itself to thrive in. In this case, the metabolic rate would still be extremely efficient, but nutrient availability would always be higher than predicted. This scenario would result in obesity and other associated health consequences. Therefore, one important concept to understand is that problems arise when the predicted environment does not match the actual postnatal environment. In fact, these mismatches between predicted and actual environment provided the scientific basis for the discovery and understanding of fetal programming.

The concept of fetal programming, particularly as it relates to lifelong health or disease in humans, was championed by Dr. David Barker, an epidemiologist, beginning in the early 1980's, and has gained considerable traction in the scientific community in recent decades. Dr. Barker's initial work found that low birth weight individuals (suggesting a poor uterine environment during pregnancy) were more susceptible to coronary heart disease as adults (Barker et al., 1993). The correlation between low birth weight and

susceptibility to illnesses in adulthood was found in subsequent epidemiological studies, as well (Barker and Osmond, 1986; Roseboom et al., 2001; Yajnik et al., 1995). The most convincing evidence for fetal programming came from epidemiological studies on victims of the Dutch Famine during World War II. This famine was unique in that it occurred for a relatively short, but well-defined period of time and impacted a society that kept detailed medical records. Mining the health records of individuals whose mothers were pregnant during this period of famine, found an increased likelihood for obesity, diabetes, cardiovascular disease, diseases of the airways, schizophrenia, neurological disorders, and reduced growth rate compared to individuals born to mothers pregnant immediately before or immediately after the famine (Roseboom et al., 2001). Not only did these studies highlight the broad range of physiological systems that can be impacted by a poor uterine environment during pregnancy, they also showed that an individual exposed to famine during early gestation was susceptible to a different set of diseases than an individual exposed to famine during late gestation. This observation highlights another critical aspect of fetal programming: timing of the insult may be just as important as magnitude of insult, and must be considered when evaluating the scientific literature.

Since the seminal epidemiological work by Barker and colleagues, a multitude of well-controlled experiments have been conducted to validate the proposed link between a poor uterine environment and propensity for adult disease. The phenomenon of fetal programming has been observed in every mammalian species studied, including non-human primates, laboratory rodents, sheep, pigs, horses, and cattle (DelCurto et al., 2013; Wu et al., 2006). While nutritional status (both insufficient and excess) has been the most well studied insult shown to alter the fetal developmental program, other factors such as maternal stress (i.e. shipping/handling stress), altitude, heat stress, and toxin or pollutant exposure have also been linked to altered postnatal function or health.

EPIGENETIC CONTROL OF GENE EXPRESSION

The genetic code of an individual is established at fertilization, when the male and female pronuclei fuse to form the single celled zygote. From this point on alterations in the genetic code only occur due to unrepaired genetic mutations, which are quite rare. Due to this seemingly rigid biological process, it has long been questioned how the phenotype of an individual's progeny can exhibit wide ranges in observed phenotype, particularly for complex traits such as growth rate or feed efficiency. The desire to better understand trait inheritance led to the search for alternative mechanisms to regulate expression of the genes encoded by the DNA. These studies led to the discovery that the intensity of the expression of a single gene could be controlled by alterations in the DNA-protein complex without any change in the DNA sequence (Godfrey et al., 2007; Wu and Morris, 2001). The DNA protein complex is the combination of the DNA itself and molecular and protein structures located on top of the DNA base pair sequence. These structures located on top of the DNA base pair sequence have been termed the "epigenome" and the study of the epigenome has been termed "epigenetics". These epigenetic molecules and proteins function to package the DNA within the nucleus, thus regulating whether a gene is turned on or off and to what extent. The structures control gene expression by regulating the ability of the transcriptional machinery to bind to a specific gene (Thambirajah et al., 2009). At least three distinct mechanisms have been shown to alter the DNA-protein complex and regulate gene expression: DNA methylation, histone modifications, and non-coding or inhibitory RNAs (Matouk and Marsden, 2008). As example, the addition of a methyl group on the start site of a DNA sequence reduces the ability of the transcriptional machinery to bind to the gene and therefore the expression of that gene is suppressed. In contrast, the removal of a methyl group has the potential to increase the activity of a gene (Matouk and Marsden, 2008). It is important to note that these epigenetic structures are localized to discrete regions within a gene and that certain genes are highly susceptible to these

epigenetic modifications, while other genes do not appear to be under epigenetic control at all.

While the genetic code is extremely stable, the epigenetic code exhibits a much higher mutation rate and has been shown to be somewhat susceptible to change in response to environmental triggers such as nutrient availability, stress, or environmental pollutants and toxins. Importantly, the epigenetic state is most susceptible to change during early embryonic and fetal development. At this time, the developing fetus responds to environmental cues to alter the epigenome as a means to "fine-tune" expression of genes involved in key physiologic processes. Once an individual is fully developed, the epigenetic state is simply maintained during the normal process of mitotic division of cells. The fact that the nutritional environment during pregnancy can alter the epigenome was observed in non-human primates fed 70% of their nutritional requirements during pregnancy. In this study, maternal nutrient restriction did not reduce fetal weight, but did alter tissue specific global methylation status in the kidney and other organs (Aagaard-Tillery et al., 2008). Another important aspect of epigenetics is that a growing number of studies have discovered that the epigenetic code can be inherited across generations, although the number of generations that it could be maintained has not been determined (Somer and Thummel, 2014).

BOVINE PLACENTAL DEVELOPMENT

The placenta is the mediator of nutrient and waste exchange between the mother and fetus. Therefore, understanding the process and timing of placental development is of critical importance to fully understand how environmental insults, such as poor nutrition, can alter the growth and development of the fetus.

Following fertilization and hatching from the zona pellucida the bovine blastocyst undergoes a rapid transition in shape from a spherical to a tubular and ultimately filamentous form. The elongated and filamentous embryo apposes the uterine

epithelial surface, thus becoming in contact with the luminal epithelium and beginning the implantation process. Within conceptus (embryo and extra-embryonic membranes) are specialized cells termed trophoblast binucleate or giant cells, which are detectable as early as d18 (Leiser, 1975). These cells will migrate to and ultimately fuse with the uterine luminal epithelium to form feto-maternal syncytial plaques (Wathes and Wooding, 1980; Wooding, 1992). The creation of these syncytial plaques followed by the regrowth of the uterine luminal epithelium by gestational day 40 is why cattle placentation is classified as synepitheliochorial.

During this early period of implantation and placentation secretions from uterine glands, termed histotroph, are essential for pregnancy success. Histotroph provides key growth factors, nutrients, and immune cell regulators to the developing conceptus. In addition to the presence of secretory uterine glands, the bovine uterus is also home to a number of aglandular areas of stroma that are covered by a single layer of luminal epithelial cells, which are termed caruncles. There are typically 75-125 caruncles present in the bovine uterus (Furukawa et al., 2014; Roberts, 1986). During pregnancy the caruncles will interdigitate with a structure on the fetal placenta called a cotyledon to give rise to a feto-maternal structure known as a placentome, which is the structure responsible for high-throughput nutrient transfer between the uterus and the fetus (Mott, 1982). A relatively small number (20) of cotyledons are first visible on the fetal placental membrane as early as day 37 of pregnancy, however that number has tripled by day 50 and the beginning of a caruncular-cotyledonary interrelationship is clearly present (Greenstein et al., 1958; Mossman, 1987). By day 90 of pregnancy there are greater than 100 placentomes present in the bovine uterus, each possessing a characteristic mushroom-like shape, rooted with a stalk like structure stemming from the original caruncle (Pfarrer et al., 2001). The placentomes are highly vascularized and undergo progressive growth and development throughout pregnancy. As these structures are responsible for an increasing percentage of blood flow

throughout gestation it is not surprising that they continue to experience modest changes in capillary area density from mid to late gestation (Reynolds et al., 2010; Vonnahme et al., 2007). Failure of placentome formation results in loss of pregnancy, however a surgical reduction in the number of caruncles results in an increase in the average size of placentomes (Meyer et al., 2010). This may prove to be a compensatory mechanism by which the uterus and placentomes work to provide support required for calf development.

Literature has shown that the ruminant placenta and associated structures (i.e. placentomes) are highly sensitive to the uterine environmental challenges. Indeed it has been shown that heat stress reduced total placental weight (Bell et al., 1989; Collier et al., 1982). Further placentae from hyperthermic animals have been shown to have a reduction in total DNA, RNA, and protein levels (Early et al., 1991; Tao and Dahl, 2013). Expression of common molecular markers of placental growth and function (placental lactogen and pregnancy associated glycoproteins) were similarly decreased in placenta of challenged pregnancies (Bell et al., 1989; Thompson et al., 2013). Also influenced greatly by maternal environment is blood flow. Realizing that these studies have primarily been conducted using the sheep as a model system, it is still important to note that maternal stress (heat and nutritional) resulted in a decrease of total uterine and umbilical blood flow as well as compromised placental vascularization (Dreiling et al., 1991; Regnault et al., 2003; Reynolds et al., 2006).

CONSEQUENCES OF A SUBOPTIMAL UTERINE ENVIRONMENT ON POSTNATAL PERFORMANCE

Early to Mid-Gestation

A number of recent studies have investigated the effects of maternal undernutrition during early to mid-gestation on postnatal performance in beef cattle (Table 1). Maternal undernutrition during early pregnancy results in an array of aberrantly programmed fetal tissues and organs. Long et al., found that maternal nutrient restriction from

Table 1. Postnatal consequences of maternal undernutrition from early to mid-gestation.

Item	References
Altered postnatal growth patterns	Long et al., 2010; Long et al., 2012; Micke et al., 2010
Decreased lung and trachea weights at slaughter	Long et al., 2010
Altered concentrations of growth promoting hormones	Sullivan et al., 2010
Altered expression of metabolic genes	Long et al., 2010; Long et al., 2012; Swanson et al., 2013
Increased diameter of white adipocytes	Long et al., 2012
Reduced yield grade	Long et al., 2012
Increased muscle fiber diameter	Long et al., 2012, Swanson et al., 2013; Gonzalez et al., 2013; Micke et al. 2011
Reduced follicular pool and FSH concentrations in heifers	Sullivan et al., 2009
Increased testicular volume and FSH concentrations in bulls	Sullivan et al., 2010

early to mid-gestation decreased the weight of the lungs and trachea at slaughter (Long et al., 2010). In addition to alterations of the respiratory system, these steers exhibited alterations in expression of genes associated with whole-body metabolism and an increase in fat storage within white adipocytes (Long et al., 2010; Long et al., 2012). At slaughter, these steers exhibited a reduced yield grade, while muscle fiber diameter was increased (Long et al., 2012), suggesting that cuts obtained from steers born to nutrient restricted dams would exhibit reduced tenderness. The observation of increased muscle fiber diameter was supported by studies from Swanson et al. (2013) even during the fetal stages of development, as well as by Micke et al., in steers born to dams fed a low protein diet during pregnancy (Gonzalez et al., 2013; Micke et al., 2011). The study by Swanson et al., also found that mRNA levels of growth promoting hormones were reduced in fetuses whose mothers were exposed to maternal malnutrition during early gestation. Interestingly, a study by Sullivan et al., found that a low protein diet during early gestation, resulted in steers that had increased insulin like growth factor 1 (IGF1) levels (Sullivan et al., 2010). These results also support growth data presented by Micke et al., which found that feeding dams a low protein diet resulted in steer calves that were heavier at 191 days of age, while heifer calves were lighter at 552 days of age (Micke

et al., 2010). The observation that IGF1 levels are reduced during fetal life and then elevated during postnatal life may result from differences in the nutritional restriction (global nutrient restriction versus protein restriction) between the two studies or the postnatal increase may result as an adaptive response in an attempt to stimulate postnatal catch-up growth.

Feeding a diet deficient in total protein during early to mid-gestation has also been shown to alter development of the reproductive axis in both heifer and bull calves (Sullivan et al., 2009; Sullivan et al., 2010). Heifer calves born to protein-restricted dams exhibited a reduction in follicular size and density while also having a decrease in circulating levels of follicle stimulating hormone (FSH). In contrast, the same protein restriction resulted in higher circulating levels of FSH in bull calves, and was associated with an increase in testicular volume. The long-term significance of these observations has not been investigated to date.

Mid to Late Gestation

Feeding pregnant dams a poor diet from mid to late gestation also results in a number of perturbations in postnatal development and performance (Table 2). Underwood et al., found that a low protein diet fed to pregnant dams

Table 2. Postnatal consequences of maternal undernutrition from mid to late gestation.

Item	References
Reduced birth weight	Larson et al., 2009
Reduced weaning weight	Larson et al., 2009; Funston et al., 2012
Reduced hot carcass weight	Larson et al., 2009; Underwood et al., 2010
Increased muscle fiber diameter	Underwood et al., 2010
Reduced meat tenderness	Underwood et al., 2010
Decreased 12th rib fat thickness	Underwood et al., 2010
Reduced marbling	Larson et al., 2009
Decreased percentage of carcasses grading choice	Larson et al., 2009
Increased days to attainment of puberty	Funston et al., 2012
Increased percentage of calves needing post-weaning treatment	Larson et al., 2009

during late gestation decreased live weight and hot carcass weight of steer calves (Underwood et al., 2010). At slaughter these calves exhibited a reduction in tenderness, similar to results from calves exposed to undernutrition during early pregnancy, and reduced 12th rib fat thickness. The observation that 12th rib fat thickness was reduced in calves born to protein restricted dams is unexpected and warrants further investigation. Larson et al., also found that birth weight, weaning weight, and hot carcass weight were all reduced in calves born to dams fed low protein during late gestation (Larson et al., 2009). In addition, these calves possessed reduced marbling and had a smaller percentage of calves grading choice at the time of slaughter. Funston et al., found that heifers from low protein fed dams exhibited a decreased 205-day weaning weight and an increased age at puberty (Funston et al., 2012).

The study conducted by Larson et al., elucidated another potentially critical consequence of maternal low protein diets during late pregnancy. In this study, protein supplementation during late pregnancy had no effect on the percentage of calves needing to be treated for respiratory or gastrointestinal diseases from birth to weaning (Larson et al., 2009). However, from weaning to slaughter, calves born to protein supplemented dams required significantly less treatment for these disorders. It is interesting that post-weaning but not pre-weaning treatment was altered by

maternal protein supplementation. The fact that treatment rates were the same early in life regardless of maternal protein levels and exceeded post-weaning rates suggests that the inherent functionality of the immune system is not altered by maternal dietary protein level. However, the act of weaning creates an additional stress to the calves, which may act as a secondary factor to disease susceptibility. It may be that calves born to protein supplemented dams exhibit greater stress tolerance and therefore are capable of maintaining a functional immune system during more stressful periods of life compared to calves from unsupplemented mothers. Given the significant costs of respiratory and gastrointestinal disease to stocker and feedlot systems this hypothesis warrants further investigation.

OPPORTUNITIES IN CONFINEMENT COW-CALF SYSTEMS

At present the vast majority of the beef industry is structured such that calves are produced and reared to weaning on rather extensive forage based systems of varying composition and quality and then transitioned to more grain-based confinement systems to maximize growth from weaning/stocker to slaughter. This production system is highly susceptible to undesirable programming of an individual's metabolic and physiologic state due to a poor uterine

environment resulting from environmental factors such as drought. This system is fraught with production inefficiencies and lost opportunities. Further, these diverse production scenarios increase product variability, which has a negative impact on consumer satisfaction. Unfortunately, published studies to systematically test and calculate the true cost of inappropriate fetal programming in beef cattle have not been conducted. The lack of information supports continuance of the status quo, as confinement cow-calf systems represent a significant shift in the historical production paradigm.

One obvious advantage of transitioning to a confinement cow-calf system would be the enhanced ability to provide the near exact nutrient requirements for each cow throughout gestation. In traditional pasture-based systems, forage availability and quality are dynamic variables creating periods of nutrient excess and deficiency that we often fail to fully characterize and prevent through appropriately timed and/or nutritionally appropriate supplementation. Producers are often reactionary to the nutritional demands of the pregnant or lactating cow rather than proactively providing the appropriate level of nutrition. These cyclical patterns undoubtedly lead to a percentage of calves inappropriately programming their metabolic state to match the eventual calorically dense feedlot system.

For decades nutritionists have simplified the nutritional requirements of ruminants to three main components, protein, energy, and fiber, with the end goal of maintaining a healthy rumen environment and providing sufficient substrate for rumen microbial function. Research regarding the functional roles of specific macronutrients, such as amino acids, has been limited. In fact, the National Research Council Beef Nutritional Guidelines do not list dietary amino acid requirements for beef cattle at any stage of gestation. Recent work in our laboratory, using the sheep, has found that maternal arginine supplementation to pregnant ewes from Day 100 to 125 of gestation (term ~147) results in a roughly 50% increase in fetal brown adipose tissue deposition (Carey Satterfield et al., 2012;

Satterfield et al., 2013). Brown adipose tissue, is responsible for generating heat at birth to maintain the offspring's body temperature as the fetus is expelled from the mother into the, at times, harsh extrauterine environment. We subsequently found that offspring born to mothers supplemented with arginine during this period of gestation stayed warmer when exposed to cold temperatures after birth (Satterfield et al., unpublished results). As hypothermia is the most common cause of non-predator related lamb deaths (Simpson, 1995), discoveries highlighting the ability of select nutrients provided to the pregnant dam to augment critical functions within the offspring have tremendous potential to reduce production inefficiencies, such as perinatal mortality. This study exemplifies the need to look beyond rudimentary nutrient requirements for ruminants to improve production efficiency and highlights the ability to proactively enhance specific functions within the offspring related to prioritized areas of production losses. Although it remains to be tested, we hypothesize that offspring from arginine-supplemented mothers will also have an enhanced immune system. Previous studies have found that cold exposure and mild hypothermia reduce suckling drive (Radostits and S.H., 2007; Thompson, 1983). A reduced suckling drive at birth may reduce colostrum intake, and thus reduce postnatal immune function. Arginine supplementation reduces the risk for hypothermia, and thus has the potential to reduce the risk of insufficient colostrum intake.

While it is relatively easy to determine the potential for supplementation of select nutrients on their ability to improve postnatal performance of offspring, the implementation of such strategies into extensive production systems can be quite challenging, due to daily accessibility to livestock, intake regulation, and the need to deliver the nutrient at specific periods of gestation to minimize waste and impart the optimal fetal response. These challenges could all be mitigated in a confinement based production system. The use of confinement cow-calf systems provides the greatest opportunity to not only prevent the negative consequences of a poor uterine environment, but also facilitates

the implementation of cutting edge nutritional strategies to further optimize calf production beyond what is currently known.

CONCLUSIONS AND PERSPECTIVES

Optimal postnatal growth and performance is predicated on the establishment of a quality uterine environment during gestation. Importantly, the quality of the uterine environment is controlled not only by having superior maternal genetics and appropriately programmed epigenetics, but also through appropriately timed nutrition of the correct composition. A growing body of scientific evidence is uncovering the consequences of a suboptimal uterine environment on postnatal health. These consequences are not only manifest in reduced growth rates and altered metabolic efficiency, but have also negatively impacted carcass quality, immune function, and reproductive characteristics. This diverse array of consequences of a suboptimal uterine environment make calculating the true cost of inappropriate fetal programming very challenging, however this is a challenge that the beef industry must address as increased demand for animal protein clashes with decreasing land availability. Further, observations in the sheep highlighting the ability of select nutrients to beneficially pattern fetal growth in a manner that reduces postnatal inefficiencies justifies future research into these areas of pregnancy and fetal growth. Importantly, the societal challenges associated with population increases and traditional resource decline coupled with an increasing understanding of the relationship between nutrition during pregnancy and postnatal performance may support a production shift from extensive grazing operations to confinement cow-calf production systems.

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INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

*Intensified Cow/Calf
Production in the Southern
Great Plains Using Wheat
Pasture, Semi-Confinement
and Cover Crops*

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INTENSIFIED COW/CALF PRODUCTION IN THE SOUTHERN GREAT PLAINS USING WHEAT PASTURE, SEMI-CONFINEMENT AND COVER CROPS

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INTRODUCTION

In 1999 the world human population was about 6 billion. According to the U.S. Census Bureau (2011), the population is expected to increase to 9 billion by 2044, representing a 50% increase in a 45-year period. Increased demand for red meat is driven by population growth, urbanization, and improved economies (FAO, 2009). At the same time, U.S. rangelands have decreased at an average rate of 350,000 acres per year since 1982 (Reeves and Mitchell, 2012). This decline is primarily due to increased conversion of grazing lands to cropland, increased woody plant expansion, and urban development/residential land uses. To a large extent, current record prices in the U.S. cattle industry reflect this dichotomy of demand in relation to cost and availability of traditional resources and production systems.

Reduced access to grazing land, increased demand for red meat and associated elevation in cattle prices will encourage (perhaps require) more intensive beef cattle production systems. In this new paradigm less land area per unit of beef production is required.

Small grain forage has been used extensively in the stocker industry in the Southern Great Plains with little use in the cow/calf segment. Stocker calves with ad libitum access to abundant wheat forage typically gain two to three lb per head per day. High quality forage, maximum forage intake and faster rate of weight gain is generally associated with greater profitability because maintenance costs are diluted over more pounds

of weight gain. Alternatively, under normal circumstances, the goal for beef cow wintering programs is to maintain fall weight and body condition, supply the nutrients required for fetal development and in the case of fall calving systems, provide nutrients for milk production. However, winter small grains forage exceeds beef cows' protein and energy requirements to the extent that ad libitum access to abundant forage results in excessive weight gain and "unproductive" body fat accumulation in both pregnant and lactating beef cows.

A logical form of cow/calf enterprise intensification in the Southern Great Plains is expanded use of small grains forage as a compliment or supplement to lower quality forages. However, few published works are available evaluating limit-grazed small grains forage as a supplemental protein and energy source for beef cows. Phillips et al. (2010) reported increased carrying capacity of the operation as well as increased calf gain per acre of wheat pasture when cows were provided limited access. The use of limit-grazed winter wheat pasture as a supplement for cows and their calves was shown to increase profitability when compared to continuous grazing of native pasture and feeding an oilseed protein supplement (Apple et al., 1991; Apple et al., 1993a). Alternate day winter wheat grazing of both cows and calves resulted in an increase in calf average daily gain of 0.84 lb when compared to cows and calves wintered on native range pastures only (Apple et al., 1993a). Grazing winter wheat for four hours on alternate days during the graze-out period

from February to April resulted in dramatically greater calf weight gain and a slight economic advantage in cow wintering costs (Apple et al., 1993b).

The objective of this experiment is to document the economic and production outcomes of an extensive cow/calf enterprise utilizing native rangeland alone compared to an intensified system utilizing native rangeland, semi-confinement combined with winter wheat pasture, and a summer cover crop on the wheat acreage.

MATERIALS AND METHODS

This report summarizes the first year's results in a multi-year project. The experiment is being conducted at the Range Cow Research Center, North Range Unit, and wheat pasture unit, just West of Stillwater, Oklahoma. Fall calving Angus and Angus x Herford cows ($n = 84$; $BW = 1162 \pm 155$; $BCS = 5 \pm 0.9$) were allotted randomly by BW and age into two forage system treatments: extensive (EXT) or intensive (INT). Cows were assigned to three pasture or management groups within the EXT system and three pasture or management groups within the INT system. The INT system was designed to reduce the land area required per cow/calf pair and increase production either through increased calf weaning weight, increased reproductive efficiency, or both.

Cows assigned to the EXT treatment were continuously grazed with year-around access to 13.4 acres of open native rangeland for each cow/calf pair. This is considered to be a low stocking rate in this region and should provide adequate forage through the winter and with little supplemental hay required except in the case of severe drought. Only during severe inclement weather were cattle fed prairie hay (5.5% CP, DM basis).

A cottonseed meal and wheat middling-based supplement (38% CP, DM basis) was provided to the EXT cows and calves through the winter at a rate of three lb/pair/day and two lb/pair/day during late fall and early spring. Supplement

feeding rate for EXT managed cows was designed to provide adequate rumen degradable protein while grazing low quality dormant forage. The feeding rate was not increased to meet energy requirements because fall-calving cows typically compensate for winter weight loss during the spring and summer, to the point where they can become over-conditioned.

Cows assigned to the INT system were fed prairie hay (5.5% CP, DM basis) and mineral supplement in a dry lot through the winter period beginning December 9, 2013. During this time, INT cows had access to one acre of wheat pasture per cow/calf unit on Monday, Wednesday and Friday each week and were allowed to graze for four hours on each of those days. Calves were allowed continuous access to wheat through creep gates. Beginning March 27, cows and calves were given free-choice access to wheat pasture because it was "getting ahead" of the cows and calves. The graze-out period continued through May 7 when most of the wheat forage had been consumed. The INT cows were moved back to native rangeland on May 7 with a stocking rate of 7.8 acres of open native rangeland per cow/calf pair.

Experimental pasture groups assigned to both treatments grazed their respective native rangeland pastures from May 7 through July 16 when the cattle were gathered and calves were weaned.

A cover crop of brown mid rib sorghum-sudan and cowpeas was no-till planted in the wheat acreage on June 15. As of mid-July, the cover crop was well established and our research group was preparing to move INT treatment cows and their weaned calves to graze this cover crop for approximately 45 days. After cover crop grazing, cows will be returned to the native rangeland pastures for approximately three months until wheat pasture is established. At that point in time, cows will be returned to the dry-lot and limit-grazing system.

Cow and calf wheat consumption was estimated during the four-h limit grazing period on six different occasions: March 7, 10, 14, 17, 24,

and 27. Intake data was collected twice within each pasture. Each day, two different pairs from the same pasture were randomly selected. An individual body weight was recorded immediately prior to turnout on wheat pasture. Cows were separated from their calves by a fence during the collection period to prevent nursing. Cows and their calves were closely monitored during the grazing period defecation. Fecal material was immediately collected in plastic bags and later weighed on an electronic scale. After four hours of grazing, cattle were gathered immediately and body weight was recorded. The following equation was used to determine wheat consumption:

$$\text{Wheat Consumption} = (\text{Final Weight, lb} - \text{Initial Weight, lb} + \text{Fecal Weight, lb}) * \text{Wheat DM, \%}$$

Forage samples were collected after the cows were placed back in the dry lot. In addition, forage samples were collected once a month in all of the pastures to evaluate forage availability. The samples were weighed, and placed in a drying oven at 115°F for 72 hours, and then weighed again to determine DM content of the forage.

Enterprise costs were estimated based on current local commodity prices, pasture rental rates and calf prices (National Stockyards, Oklahoma City, OK, July 2014). Income was based on calf weights at weaning and the U.S. Number 1 classification for sale price.

RESULTS AND DISCUSSION

The winter of 2013-2014 was remarkable with long periods of extreme cold, above average snowfall, and below average rainfall. The minimal precipitation provided favorable conditions for INT cow/calf pairs in the dry lot. However, total precipitation was sufficient to produce adequate amounts of wheat forage to be used as a winter supplement and later for high quality grazeout forage during early spring. During the winter period, wheat forage availability ranged from 1,597 lb DM/ac in December to 2,125 lb DM/ac in February (Figure 1). Also shown in Figure 1,

native rangeland forage availability was abundant throughout the wintering period for EXT system cows and calves. A prescribed burn was executed in April in all experimental native rangeland pastures. Consequently, forage availability was low in the early spring and gradually increased to around 2500 lb DM/ac in July (Figure 2) in both treatment groups' pastures.

During this first winter of the experiment, cattle assigned to the EXT system were fed hay on five occasions during severe weather events. Cows from both treatments lost weight during the winter period although EXT system cows lost substantially more weight and body condition ($P < 0.01$; Table 1). As expected INT system calves gained more weight during winter (53 lb or 0.8 lb/d). At the beginning of the limit grazing period, the INT calves did not utilize the creep gates to the wheat pasture. As the trial progressed, a limited number of the calves began to access the wheat pasture via creep gates. Additional weight was thought to come from the allotted limit grazing time and potentially higher milk production of the cows.

Wheat forage intake was measured during several four-hour grazing bouts. Results indicated that on average the cows consumed 16.1 lb of forage DM and calves consumed 2.7 lb of forage DM during each four-hour grazing bout. Cows consumed 1.4% of their body weight and calves consumed 0.7% of their body weight of wheat forage. The wheat forage ranged from 35-45% DM across pastures and collection days.

Hay bales were weighed on an electronic scale before being placed in basket style ring feeders. Hay disappearance averaged 24.5 lb DM per cow/calf pair each day. During the winter period, hay was fed every three to six days. After the onset of the wheat pasture grazeout phase, pairs consumed very little hay.

During the graze-out phase, continuous access to wheat pasture resulted in more rapid weight gain for INT system cows and calves ($P < 0.01$). Cows assigned to the INT treatment started the spring grazing phase in greater body condition score and

Figure 1. Winter and early spring forage availability in wheat pasture (INT) and native rangeland (EXT).

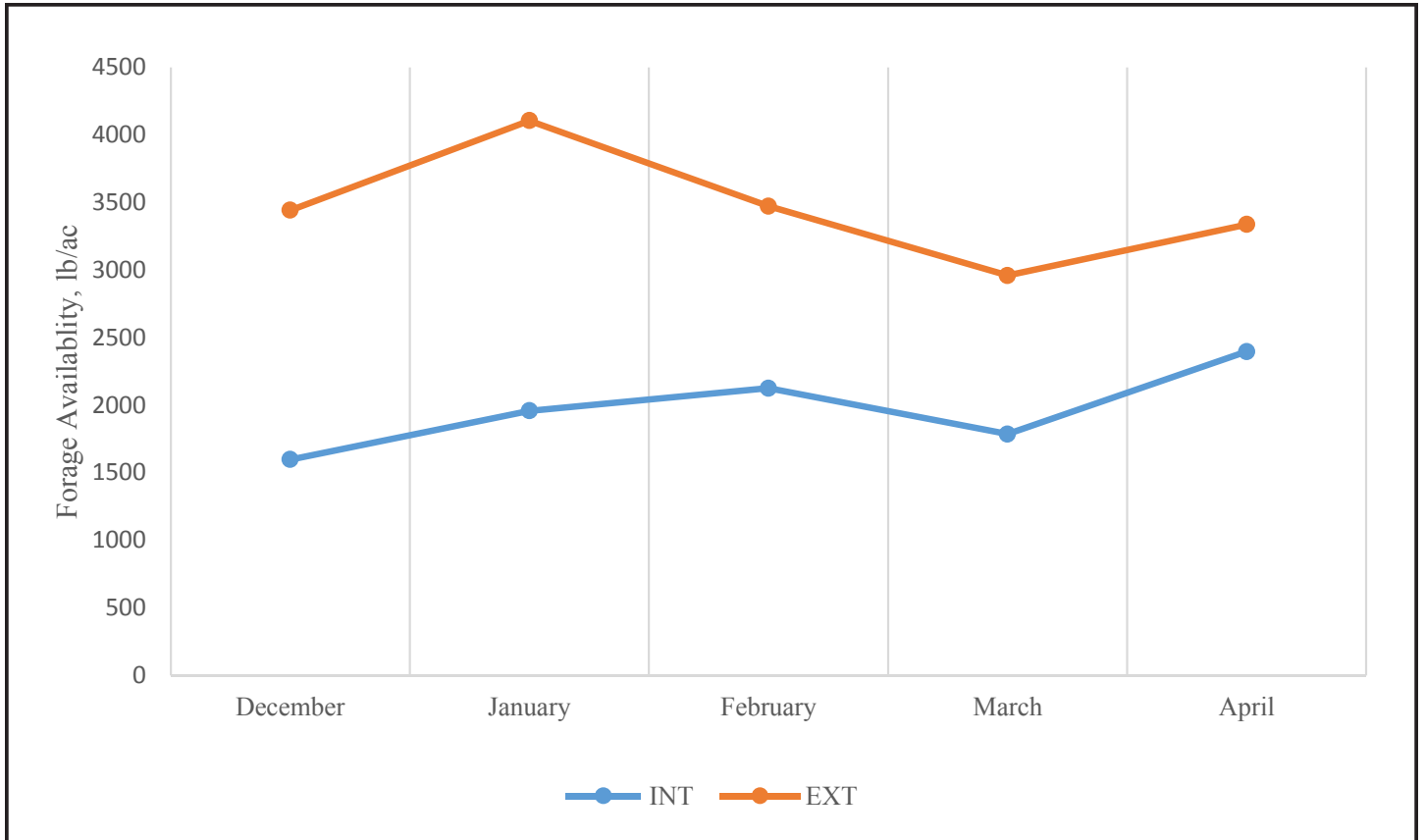


Figure 2. Late spring and summer forage availability in native rangeland pastures.

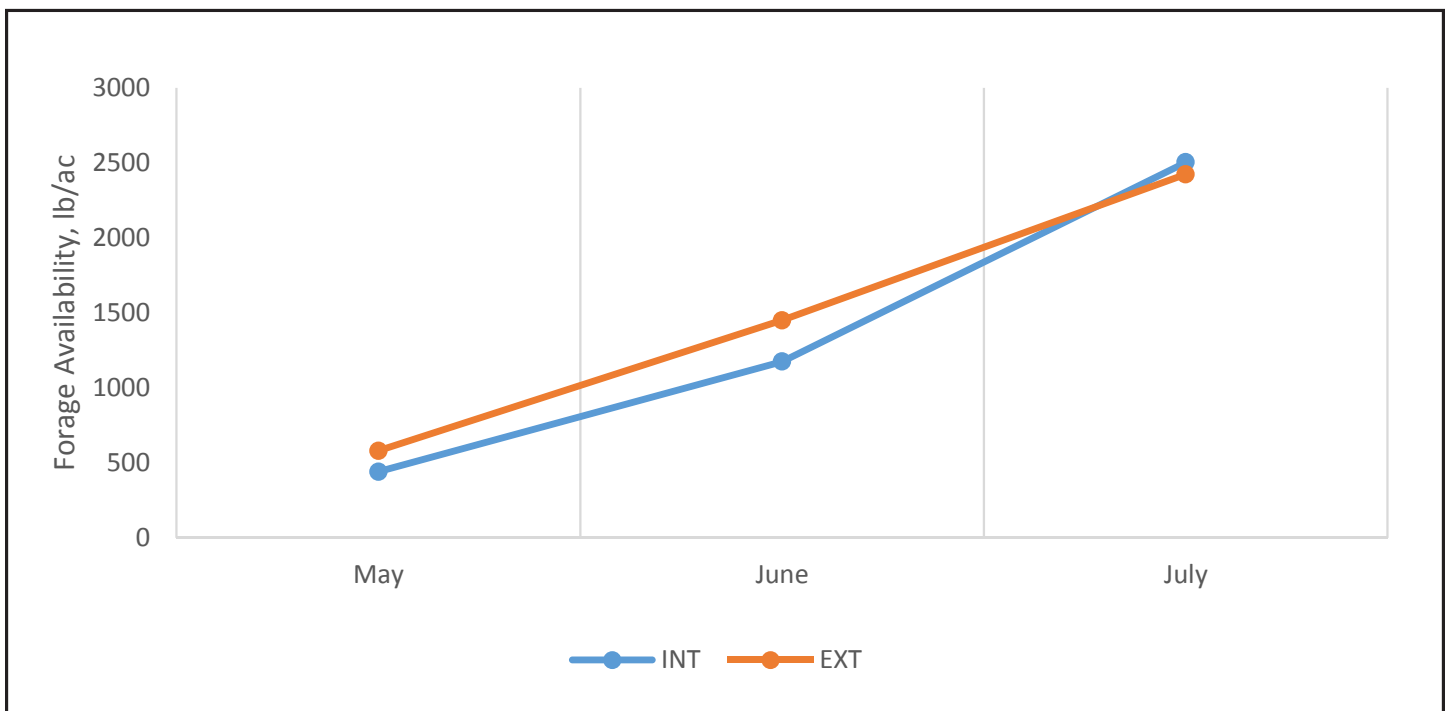


Table 1. The effects of cow/calf forage system on cow and calf performance.

Item	INT	Forage System ¹		P-value
		EXT	SEM	
No. of Pastures	3	3		
Cow BW, lb				
December 9	1164	1159	4.49	0.31
March 28	1127	1028	18.3	<0.01
May 7	1258	1117	14.1	<0.01
July 16	1439	1329	20.9	0.09
Cow BCS				
December 9	5.1	5.1	0.05	0.25
March 28	4.7	3.6	0.26	0.01
May 7	6.1	4.8	0.16	<0.01
July 16	6.7	6.0	0.16	0.01
Calf BW, lb				
January 16	287	277	10.6	0.46
March 28	443	380	17.2	0.02
May 7	576	489	21.6	0.02
July 16	767	702	7.37	0.04
Calf ADG, lb (January 16 - May 7)	2.6	1.9	0.12	<0.01
Calf ADG, lb (May 7 - July 16)	2.5	2.8	0.11	0.03

¹INT = Semi-confinement with hay and limited access grazing one acre per cow/calf pair on wheat pasture during winter, native rangeland during spring and fall at high stocking rate, limited access grazing cover crop during summer; EXT = Graze native rangeland continuously with a low stocking rate and oilseed meal supplementation during winter.

continued to increase this advantage during spring ($P < 0.01$). During the 41 day spring grazeout stage calves grazing wheat pasture gained 24 lb more than the calves grazing native range forage ($P < 0.01$).

The first week of May INT system cows were returned to native rangeland pastures with a high stocking rate. During the late spring and early summer, treatment group rate of weight gain was reversed as EXT cows and calves tended to gain more weight ($P = 0.09$ and 0.11 , respectively). Previously, calves grazing wheat pasture before native range performed better than calves wintered on native range (Apple et al., 1993a). In the following year, there was no difference in calf gain (Apple et al., 1993b). However, different situations may have different effects on calf performance.

Similarly, EXT system cows had greater ($P < 0.01$) gains in body condition score during the early summer period than did INT system cows.

A summary of observed and estimated costs are shown in Table 2. Winter period costs were slightly greater for the INT system. The additional labor and purchase of hay at \$70 per ton in the INT system was essentially offset by the additional land and protein supplement cost in the EXT system. No credit was given to the soil nutrients brought in to the INT system through the hay.

As expected, late summer costs were estimated to be substantially greater for the INT treatment due to the high cost of establishing the cover crop and increased labor required to limit-graze the cows. We chose to limit-graze on a daily basis during

Table 2. Cow/calf enterprise costs (per cow/calf pair) by forage system and period.

Item	¹ Forage System	
	INT	EXT
Winter, 109 d	\$249.23	\$226.78
Spring, 41 d	\$64.44	\$71.74
Early Summer, 69 d	\$96.00	\$86.42
Late Summer, 30 d	\$90.36	\$56.14
Fall, 116 d ²	\$168.67	\$139.50
Total cost ²	\$668.90	\$582.58
Calf value at weaning	\$1558.41	\$1488.85

¹INT = Semi-confinement with hay and limited access grazing one acre per cow/calf pair on wheat pasture during winter, native rangeland during spring and fall at high stocking rate, limited access grazing cover crop during summer; EXT = Graze native rangeland continuously with a low stocking rate and oilseed meal supplementation during winter.

²The project is ongoing. Late summer and fall expenses were estimated.

this period to minimize trampling and to keep the cows from getting any fatter. We anticipate grazing the cows on one half of the cover crop and giving steer calves access to the other half.

Overall, annual costs per cow/calf pair are estimated to be \$95.63 greater for the INT system. However, calf value at the time of weaning was estimated to be \$69.56 greater for the INT system due to 65 lb heavier calf weaning weights.

The INT system used 4.6 ac/pair less total land area compared to the EXT system. However, some of this land area would be offset by the hay used in the INT system. Approximately one additional acre per cow/calf pair would be required to produce the amount of hay fed during the winter period. Consequently, the INT system represents a 27% reduction in total land area required.

IMPLICATIONS

At this early stage, added cost of labor, hay, and wheat pasture used in the INT system offset the value of substantially increased calf weaning weights. The INT system did result in an additional 110 lb of cow body weight and 0.7 units of body condition score at the time of weaning. However, this increase in cow condition may be of little economic benefit. This suggests that stocking rate can be increased or total nutrient resources, and therefore cost should be reduced in some component of the system. In future years, it would seem advantageous to limit INT system cows' access to hay or to spring and summer forage. Perhaps, this would lead to preservation of forage that could be harvest within the system and fed during winter (reducing the amount of purchased hay).

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INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

Herd Health Observations in Nebraska Intensive Cow-Calf Systems Project

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HERD HEALTH OBSERVATIONS IN THE NEBRASKA INTENSIVE COW-CALF SYSTEMS PROJECT

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INTRODUCTION

In recent years, a multitude of factors related to commodity prices, interest rates, and urban encroachment have strengthened land values and initiated the conversion of traditional pastureland to other uses. When these diversions in land use are coupled with drought, the availability of forage for maintaining the beef cow-calf enterprise becomes challenged. Partial or total intensive management (confinement) of cowherds offers a potential alternative to conventional cow-calf production, given the system is economically viable. Health and reproduction are imperative for economically sustainable cow-calf systems as calf losses at any point during the production cycle represent lost revenue. In addressing these greater industry challenges, we have conducted research on total intensive management of cow-calf production for two years. The objective of this report is to review the health risks associated with intensively managed cow-calf systems, discuss our health program and initial observations, and identify management practices implemented to maintain animal health and well-being.

HEALTH RISKS IN INTENSIVE COW-CALF PRODUCTION SYSTEMS

Cattle health and well-being is centered upon risk management; and managing risks necessitates a clear understanding of factors associated with animal health hazards. Given that data in the literature regarding health of cows and calves managed in partial or total intensive management are limited, and the natural tendency of some

people to automatically associate these production systems with negative health outcomes, a brief review of the major health risks, as presented by Smith (2013), potentially associated with intensively managed cow-calf systems is warranted.

Recent survey data (National Animal Health Monitoring System, 2008) demonstrated approximately 3.0% of calves were born dead with an additional 3.5% dying or being lost before weaning, and these rates were independent of herd size. From these nation-wide data, calves died during the first three weeks after calving from the following reasons and frequencies: calving related (25.7%), weather related (25.6%), unknown causes (18.6%), digestive system related (14.0%), respiratory disease (8.2%), and injury or predation (6.2%). As reported by Smith (2013), these data indicate that on average the greatest hazards to the survival of newborn calves include: 1) issues during and around the time of calving; 2) environmental conditions; and 3) contagious diseases.

Dystocia and other health problems at calving are the result of factors related to either the calf or the cow (Rice, 1994). Large birth weight is most often the cause of dystocia when considering factors associated with the calf. Dystocia factors related to the dam include age, pelvic size, and metabolic health. Calving difficulty is most likely to occur in first calf heifers and females with decreased pelvic area. Nutritional or metabolic disorders can be the result of protein, energy, or mineral deficiencies or exhaustion from prolonged muscle contractions. Dystocia may cause physical or metabolic injury to either the

calf or the cow which may be fatal. Regarding intensively managed systems, exercise during gestation may be important for dystocia prevention.

The environment a cowherd is managed in can either create or minimize health hazards. Environmental conditions can include weather, crowding, predators, and other physical sources of injury. Extremely warm or cold conditions place newborn calves at risk for hyperthermia, or hypothermia, respectively; certainly when coupled with dry/dusty or wet/muddy conditions given the calf has a limited ability to regulate its body temperature. Managing cow-calf pairs in a drylot, particularly during calving, may increase the chance of injury by being butted or stepped on due to crowding. Pregnant cows heavy with calf may be more prone to slip and fall if the pen surface is slick from snow or ice or has a steep grade. Likewise, if breeding occurs in the pens, bulls may be more prone to injury from slick or wet pen surfaces. Hazards from pens including loose nails or wire, broken posts, standing water and electricity all represent potential sources of injury. The risk of injury to cows and calves can be reduced by conducting routine pen maintenance, providing adequate access to shade, windbreaks, and water, and by ultimately designing breeding and calving seasons to occur during periods of optimal weather conditions.

As cattle in an intensively managed system have increased animal to animal contact, there may be greater opportunities for pathogen transmission as compared to pasture systems. Additional risk factors for the introduction of diseases include movement of cattle to or from other operations and fence line exposure aside from the degree of confinement. Neonatal calf diarrhea (scours) is the disease most likely to affect newborn calves during the first few weeks of life. Typically, the average dose-load of pathogen exposure is likely to increase throughout a calving season as calves that are infected initially serve as multipliers and are the foremost source of exposure to young susceptible calves. Consequently, calves born later during the calving season can receive greater dose-loads of pathogens and may also

become more infective to other calves. The three primary strategies for preventing outbreaks of calf scours include: 1) removal of pathogens from the herd; 2) improve calf immunity against pathogens; and 3) adapt the production system to minimize opportunities for pathogen exposure and transmission. Pneumonia (bovine respiratory disease or BRD) is also a prevalent source of calf losses early in life. Maternal immunity against infectious agents decreases with time, because by 90 to 120 days of age, a calf will retain less than 2% of the antibodies it initially absorbed from colostrum. Given the calf's immune system, although functional, is undeveloped calves that are 90 to 120 days of age may have increased susceptibility to respiratory disease. Management practices that provide opportunities for infection, such as weaning or commingling, may have a reduced influence on health if done before or after calves are 3 to 4 months of age. Developing sound vaccination protocols against respiratory disease in young (≤ 5 months) calves is important, and future research in this area is essential. Pinkeye and coccidiosis are two additional contagious diseases that may have increased chance of occurrence in intensively managed systems. In general, because of increased opportunity for pathogen transmission, the likelihood of diseases such as scours, respiratory disease and others occurring is greater for intensive than pasture systems. The importance of newborn calves nursing and receiving adequate colostrum immediately following birth cannot be overemphasized.

HERD HEALTH PROTOCOLS

In our system, the cow vaccination protocol consists of two annual vaccinations. Cows are vaccinated with a killed virus product approximately 1 month prior to the start of calving to protect calves against scours. Pathogens vaccinated against include: bovine rotavirus, bovine coronavirus, E. Coli, and clostridium perfringes type C. At the same time, cows receive a topical pour-on for the control of external parasites and either a pour-on or injectable solution against internal parasites. After calving

and approximately 1 month prior to the start of the breeding season cows are vaccinated with a modified live virus product to protect against persistently infected calves and to prevent abortion. Pathogen strains included in this vaccine are: IBR, BVD types 1 & 2, PI3, BRSV, and multiple leptospirosis strains. At weaning, cows again receive a topical pour-on for external parasites.

Calves are vaccinated initially at birth for blackleg, malignant edema, black disease, enterotoxemia, and haemophilus somnus. At birth, navels are sprayed with iodine and bull calves are band castrated. At approximately 90 days of age, calves again receive the same vaccination that was given at birth and a modified live virus product to guard against IBR, BVD 1 & 2, PI3, and BRSV. After weaning at approximately 205 days of age, calves remain in the feedlot for growing and finishing, and receive additional respiratory and clostridial vaccinations at that time.

The vaccination program is not a substitute for adequate nutrition, which is discussed in more detail in another paper. Cows are fed balanced diets to meet requirements and maintain body condition and weight throughout the production cycle. An ionophore (Rumensin®) is continually included in the diet fed to both cows and calves which may aid in the prevention and control of coccidiosis.

SANDHILLS CALVING SYSTEM

When initiating the intensively managed cow-calf system in 2012, our primary concern regarding calf health was scours. Thus, we selected a summer (June & July) calving season in an effort to avoid calving in cold and wet/muddy pen conditions. An open feedlot pen with essentially no protection from wind and snowfall is not a favorable environment for newborns. Certainly, pens can be muddy from summer rains, especially in Eastern Nebraska, but they typically dry out much faster than during late-winter or early-spring. In addition, we utilized the Sandhills Calving System (Smith et al., 2004; Smith, 2009)

which was developed at the University of Nebraska – Lincoln as a management technique designed to control neonatal calf scours. The underlying basis behind the Sandhills Calving System is to prevent pathogen transmission from older to younger calves by age segregation. In the system, pregnant cows are moved to clean calving lots or pastures on a scheduled basis throughout the calving season in an attempt to recreate ideal conditions of cows calving on ground unoccupied by older, infective calves. Moving pregnant cows to new calving areas minimizes the accumulation of pathogens in the environment and guards against the exposure of newborn calves. This system was designed for pasture systems, but we adopted it for use in our research feedlot pens.

In our system, all cows begin the calving season in one previously cleaned pen, and pregnant cows are moved to a new clean pen after approximately one third of the calves are born. Of this remaining group, pregnant cows are again moved into another clean pen upon half of the calves being born resulting in three groups of cow-calf pairs at the end of the calving season. Our goal is to have pens cleaned and dry for approximately 1 week prior to introducing cattle. Critical components of the Sandhills Calving System in general are segregating calves by age, moving pregnant cows ahead of cow-calf pairs to clean calving areas, and allowing calves sufficient opportunity to consume adequate amounts of colostrum. As of this writing, we have experienced no cases of calf losses from clinical neonatal calf scours during two calving seasons with over 150 cows. This system requires facilities for calving and water resources in each new calving area used, which can be a limitation for some pasture systems, but may not be an issue in a feedlot setting.

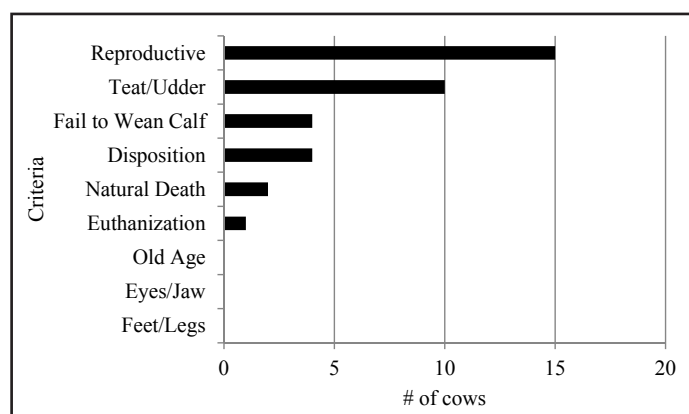
COW & CALF MORBIDITY

In our management system, identifying and treating sick or injured animals and recording health data is left to the descretion of feedlot employees at each location. Calf health probably represents an area of greater concern than

cow health, given mature cows have a more functioning and active immune system as compared to their calves. However, managing cow health and well-being is essential for optimum performance and reproduction. In commercial settings, cows are culled from the herd for various reasons. The total number of cows removed from our research herd across both locations over the last two years and the criteria for removal is shown in Figure 1. Failing to conceive or maintain a pregnancy is clearly the greatest reason cows have been culled, followed by poor teat/udder conformation. Additional cows have been removed for various reasons, but none would be considered atypical for most herds. These data indicate cows in our system thus far have not been exiting the herd for health reasons related to being maintained in intensive management. Cow morbidity has been very low. In two years, no cows have been treated for respiratory, pinkeye, or other infectious diseases. A limited number of cows (≤ 3) have been treated occasionally for footrot.

Experimental treatments imposed during the first two years have been early (91 ± 18 d of age) and normal (203 ± 16 d of age) calf weaning, which has been previously discussed in detail. In year 1, early-weaning occurred September 25th at PHREC and September 27th 2012 at ARDC. Normal-weaning occurred January 22nd at ARDC and January 24th 2013 at PHREC. In year 2, early-weaning dates were October 15th and 18th 2013, for ARDC and PHREC, respectively.

Figure 1. Cows removed from the experiment across both locations from 2012 — 2014, and their criteria for removal.



Normal-weaning occurred February 3rd 2014 at both locations. In our system, early-weaning occurred during the same time frame that other feeder cattle are arriving at the feedlot during the traditional fall receiving period.

In year 1, no morbidity was reported during the weaning trial at PHREC. However, at ARDC, 10 of 39 calves (26%) were treated for BRD during the weaning trial. Of these cases, seven were of early-weaned calves and the other three were normal-weaned. Cases of BRD began about two weeks after the initiation of the weaning trial (Figure 2). On average, calves were 110 d of age when treated for BRD, with only two cases occurring in calves less than 100 d (Figure 3).

Interestingly, no morbidity was reported during the weaning trial at ARDC in year 2. At PHREC, 32 of 38 calves (84%) were treated for BRD. Of diagnosed cases, 50% were in early-weaned calves and 50% were from calves that nursed their dams. Unlike in year 1, BRD cases surfaced approximately six weeks following early-weaning and a small number of cases occurred even at nine weeks (Figure 4). Consequently, calves were 137 d of age on average when treated for BRD, and most were 4 to 5 months of age (Figure 5).

The divergence in BRD incidence between years and locations is interesting, and likely related to differences in weather conditions, stress, and possible exposure to cattle from varying environments. These data support the concept that calves less than 5 to 8 months of age may be at greater risk to infectious diseases, and that timing stressful management events to occur during periods when calves are at less risk may be advantageous. Vaccination protocols for calves in intensively managed systems may need to be different from those for calves in pasture systems.

WEANING RATES

Calf crop percentage (calves weaned of females exposed during the breeding season) is an excellent measure of reproductive management because it identifies where potential calves are

lost during the production cycle. We have data on a complete production cycle beginning with the fall 2012 breeding season that produced the summer 2013 calf crop which was weaned in January 2014. Data for this analysis are combined for both locations (ARDC and PHREC), as they are considered one herd, and adjusted to account for cows sold and transferred in using SPA (Bever and McCorkle, 2014) guidelines. On average, our pregnancy % was 90.1 after the breeding season, and our calving % was 87.5, thus a 2.6% pregnancy loss from pregnancy diagnosis until calving. Calf death loss during calving and up until weaning was 8.3%, resulting in a final weaned of exposed of 79.2%. Calf death loss of approximately 8% is consistent with, but slightly greater than results from the survey data discussed previously. However, these data only represent one full production year with a limited number of females (n = 96). Regardless, this confirms calf losses at calving and until weaning represent a large portion of lost income aside from nonpregnant females.

Of these losses, the greatest were from calves born dead followed by calves that were weak and slow to nurse (Figure 6). This observation from the first complete production cycle indicates the majority of calf losses occurred during calving, which reiterates the importance of management during this time period.

GENERAL MANAGEMENT PRACTICES & OBSERVATIONS

Managing heat stress is critical in intensively managed systems, particularly in areas prone to extreme heat and humidity. The high temperatures that can occur on the pen surface during heat waves are well documented (Mader, 2003), and may pose a greater challenge to newborn calves than cows since calves have less ability to regulate their body temperature. This is a concern with our summer calving system, and reiterates the importance of hydration and ensuring calves nurse. As part of routine management during heat waves, the pen surfaces are sprinkled 1-2 times per day in an effort to

provide a means for cattle to dissipate body heat. We have noticed 2-3 week old calves at the watering tank, indicating these young calves will drink water if offered to them from a fountain they can reach. Likewise, shade can be an effective tool in helping to mitigate heat stress, and may be advantageous if cows are breeding in a drylot during the warmest part of the summer. In our system, pens are not shaded and both cows and calves have been observed panting during very hot days. In summer 2014, from an animal well-being standpoint, we began placing shades within the pens in an area that only the calves can access. The shades are approximately 5 ft high and provide 3-4 ft² of shaded area per calf. Another practice to consider is to provide an escape or “creep” area out of the back or side of the pen that only calves have access to. This area could be a limited amount of pasture or woods that would enable calves to escape dust, heat, and potential injury during the breeding season, yet still remain with their dams. While this may not be practical for large feedlots, it may be applicable in other facilities. In general, flies and other nuisance insects have not been a challenge. This may be due to extremely dry conditions in 2012 and relatively dry conditions again during late-summer 2013. Our pens have adequate slope to prevent standing water after a rain event, and pens are cleaned and maintained regularly. There may be greater opportunity to implement fly control practices in intensive as opposed to pasture systems. Finally, mature cows have been observed nursing one another on occasion. Although this has been limited to only a few select cows in our system, this is an important observation. This is likely the result of hunger as cows are limit-fed, in close quarters, and possibly bored. No other abnormal behaviors have been observed.

CONCLUSIONS

Minimizing calf losses prior to weaning is fundamental for economically viable cow-calf systems. Issues during and around calving, environmental conditions, and contagious diseases represent the greatest hazards to the survival of calves which is confirmed by the initial

observations from our system. While there is potential for these risk factors to be magnified in intensively managed systems, these hazards can be mitigated through proper management. These data from a total intensively managed cow-calf system are critical for developing management and health recommendations for producers given few people have extensive experience with such cow-calf systems.

Figure 2. Epidemic curve for 10 calves diagnosed with BRD at ARDC in 2012.

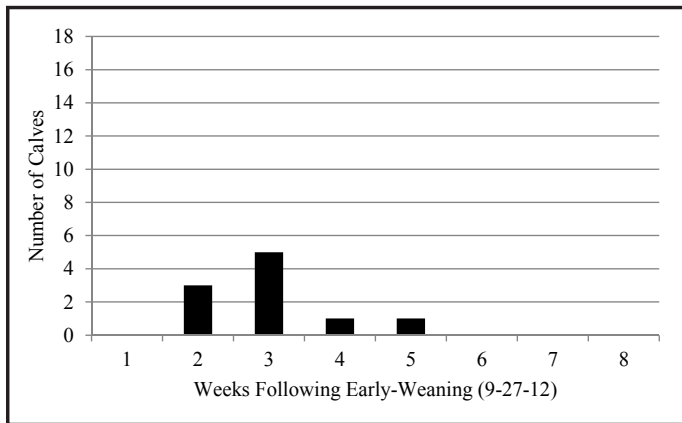


Figure 3. Age distribution for 10 calves diagnosed with BRD at ARDC in 2012.

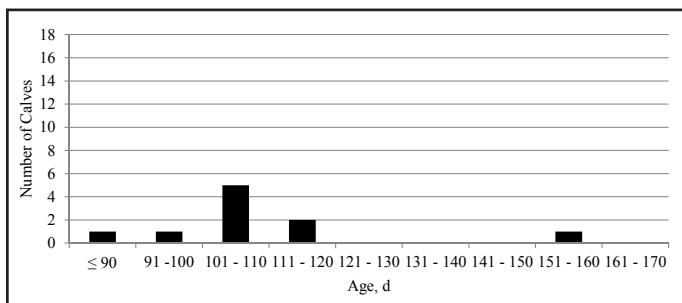


Figure 4. Epidemic curve for 32 calves diagnosed with BRD at PHREC in 2013.

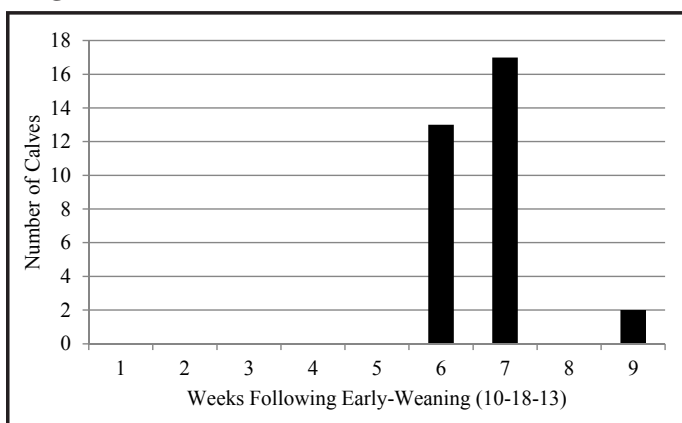


Figure 5. Age distribution for 32 calves diagnosed with BRD at PHREC in 2013.

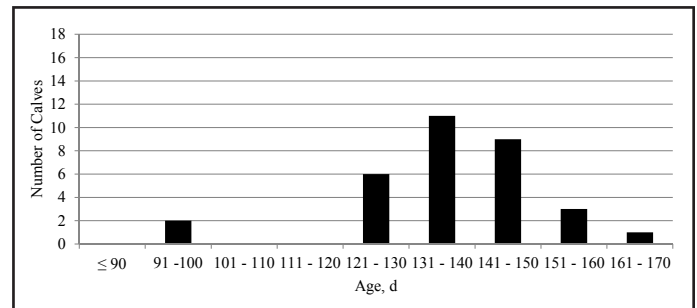
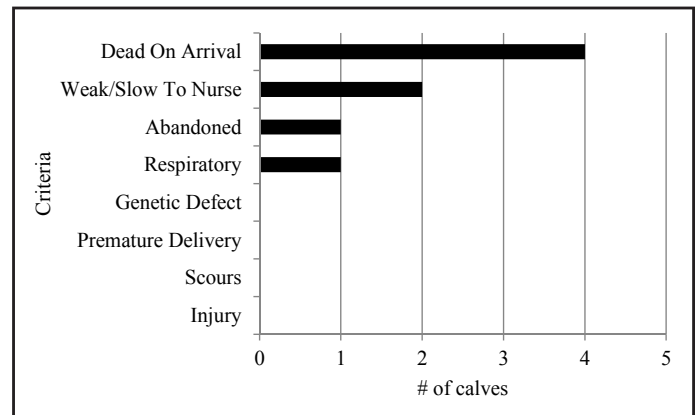


Figure 6. Calf death loss in 2013 calf crop across both locations, and criteria for death.



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INNOVATIVE INTENSIFICATION IN COW-CALF SYSTEMS

*Does Intensification Improve
Sustainability?*

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DOES INTENSIFICATION INCREASE SUSTAINABILITY

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“Sustainability”, “sustainable development”, and “sustainable systems” are terms that have become an increasing element of public conversation. These topics have sufficiently cemented themselves in the public mind that businesses have seized on them through a sense of corporate responsibility to society; from a strategic marketing perspective; or in reaction to regulatory, customer or consumer pressure (real, anticipatory, or perceived). Activists in a variety of arenas utilize these terms to galvanize public action or reaction; and governments and non-government organizations have adopted these terms in promulgation of public policy. For individual operators and the beef industry as a whole, the notion of sustainability and the public perception of agriculture have become an increasing point of contention. Industry participants perceive that many of their management efforts enhance sustainability of the food supply, while these same actions or production systems are vilified by some members of the public as being unsustainable. We propose that at least one element of this tension is the lack of common, valid, and defensible descriptors of ‘sustainability’; the potential for false inference from insufficient indicators; and the tendency for public opinion to deal in absolutes rather than recognize trade-offs in complex situations.

Sustainability has been defined in a number of ways. Sustainability is a property of a system – fundamentally, it describes the ability of the system to persist. Because sustainability is often viewed in terms of resource constraints, an expanded definition is as a property describing the use of a resource required for system function in such a manner that the resource is not depleted, allowing the system to persist. This definition is analogous to the ecological concept of carrying capacity – consumption of resources within a system do not exceed the supply of such

resources; the point at which consumption is equal to, but does not exceed resource supply is the carrying capacity of the system (Heitschmidt et al., 1996).

The United Nations (WCED, 1987) defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs”. This commission indicates that the concept of sustainability does imply limits, but that these limits are conditions of the present state of technology and “social organization” relative to resources. In the context of agriculture, sustainability has been defined as “capable of maintaining productivity and usefulness to society indefinitely” (USDA, 2007). In the 1990 Farm Bill, the US Congress placed additional properties into the definition of sustainability; notably, that sustainable agriculture “must meet human food and fiber needs, enhance environmental quality and natural resources, maximize efficiency of use of non-renewable resources, sustain economic vitality of agricultural operations, and enhance quality of life for society as a whole”. As additional properties, conditions, constraints and required outflows are added to the definition, they evolve into philosophical statements or positional statements rather than descriptions of the properties of a system (Heitschmidt et al., 1996). This shift loads the discussion of sustainability, as alternate views are perceived as attacks on a value system rather than debate on descriptions of system properties. Finding mechanisms to describe sustainability independently of this transition is vital to the effective incorporation of these concepts into actionable strategies or solutions.

The definition of sustainability – the ability to persist – is simple and straightforward. Ascribing this property to a system, or evaluating the

degree to which a system is likely to persist into the future, is not a problem of definition, but one of forecasting (Costanza and Patten, 1995). Thus, the inclusion of many other factors into definitions of sustainability is often an implication that certain features are predictive of sustainability. The identification of predictors should be separated from the definition. Predictors, or performance indicators, related to the likelihood of system persistence or fitness are desirable and essential for management (Searcy, 2012), but are only relevant if they are indeed predictive. Costanza and Patten (1995), using the simple definition of sustainability, suggest framing the question of developing indicators around three key questions:

- 1) What system, characteristic of the system, or outflow from the system should persist?
- 2) How long should the system persist?
- 3) When can the system be assessed to determine whether or not it has persisted?

The first may be the most straightforward. Answering this question defines a set of objectives for assessment. Because most large systems consist of nested or hierarchical subsystems, the same set of questions can be applied to subsystems to develop additional indicators relevant to the subsystem. However, because the higher order system may be robust to change (i.e., the failure of one subsystem does not necessarily cause the demise of the larger system), care should be taken to define relationships that can be quantified or empirically demonstrated. It is important to note that many 'indicators' that are often cited in reference to sustainability do not consider the output of the system. This can lead to a call to 'abolish the system' because it is consumptive or perceived to threaten human sustainability, failing to acknowledge that the outflow of the system may be in itself a necessary element of population sustainability.

The second question may be more challenging. As with any forecast, near-term predictions are likely to be more accurate than long-term predictions. No known system can last infinitely (e.g., the sun

will likely expire at some point in the future), but it is impossible to define a desired time limitation on the human population. Thus, while 'forever' may be the implication of sustainability, consideration of this question may also help to place a more realistic context on assessment. To resolve these conflicts, indicators that can be assessed routinely, at both short, intermediate and longer term time scales, can be used to define trends in the subsystems (shorter time scales) and metasytems (longer time scales) of food production. Alternately, the sensitivity of the indicator to trajectories in related variables can be used to project system response to shocks or to estimate trends in time. For example, if trends in fertilizer availability and price can be estimated as a function of energy supply or resource base, with current technology, then a point can be identified when the use of these is no longer viable in a consuming system. It is imperative that such analyses are repeated frequently, as new information, technical solutions, or relationships among variables may greatly alter the forecasts.

Finally, because the actual 'sustainability' of a system can only be evaluated post hoc, some determination of future assessment points is valuable so that trajectory can be evaluated and the suitability of indicators validated.

Key Performance Indicators of Sustainability
Sustainability predictors are often grouped into three broad dimensions:

- Resource consumption and/or resource degradation
- Economic viability
- Social responsibility

These elements are common to many reporting methodologies, including triple bottom line accountancy, and all arise from a common philosophical base around sustainability issues. The resource dimension typically involves measures of consumption or utilization of resources, especially focusing on resources considered to be finite and/or non-renewable (i.e., fossil fuels, minerals, water). The corollary to

consumption - resource degradation - is implied to predict the likelihood that changes or damages to a resource base have a similar functional outcome as consumption; degradation renders the resource unusable and thus functionally depleted.

Two important considerations emerge in this grouping of indicators. First, rate of depletion is only relevant in context of total supply. If 'imaginarium' is a finite element required for current system function, noting that it is being utilized at a rate of 1 million units per day may seem alarming. If the global supply of the element is 2 million units, this is indeed a concerning statistic. However, if the supply is 4 trillion units, usage at this pace can persist for 1,000 years. Second, resource utilization rate must be placed in the context of system output. As suggested previously, failure to consider this context can result in decisions that alter the output of the system, which itself reduces the ability of the population to persist. Destroying the system to preserve it is irrational.

The economic dimension implies that without an effective mechanism for allocation of resources, outflows will cease or consumption will accelerate. At finer scales, failure to adequately cover the costs of outflows will cause the system to falter or limit output. At a large scale, economic considerations might be considered systemic regulators, affecting the allocation of resources to systems of higher implicit value.

The social dimension incorporates philosophical and ethical considerations regarding societal expectations and interactions. In some cases, elements considered under the social dimension might predict the sustainability of human resources; in others, they might consider the reality that 'societal acceptance' of system elements may be necessary conditions of continuance, and thus persistence of the system. Measures often associated with the social dimension may be the most challenging to validate empirically.

Clearly, elements of these dimensions may be related; resource consumption and resulting

scarcity escalate costs, increasing costs of system outputs may jeopardize quality of life for vulnerable populations; other populations may or may not accept the methods or mechanisms of production and resource utilization. Ideally, sets of interrelated measures or methods of accounting for inter-dimensional relationships in sustainability assessment would be valuable.

If "sustainability" of a given system is a desired property, then measurements that are effective predictors of sustainability are needed if the system is to be managed (Searcy, 2012). While significant effort has been applied to the development of key performance indicators for 'sustainability' and 'sustainable development' over the last 50 years, few of these have been effectively operationalized across the beef industry, and even fewer have been critically evaluated. In many cases, assessments (e.g., energy yield, carbon footprint, water footprint, etc.) that have been used to describe other systems have been deployed (Heitschmidt et al., 1996; Capper, 2011a; Rotz et al., 2013) effectively. However, these methodologies may be impractical for enterprise-level use on a broad scale. Empirically valid proxies are perhaps more desirable and more feasible in management systems. Gross resource consumption is often utilized as a sustainability indicator, and measures of this type are considered "core" indicators in sustainability reporting by the Global Reporting Initiative (GRI, 2006); however, in the absence of a scaling variable (i.e., consumption relative total resource in existence) or other relevant comparator, these measures are not meaningful predictors in isolation. Ratios, time series measures, or other means are required to place gross measures into context and make them applicable for management (Liverman et al., 1995).

CONCEPTS APPLIED TO AGRICULTURE

If the primary role of agriculture is to provide food and fiber to support the human population, then the outflow of food from the system can be defined as the outflow to be sustained; alternately, the ability to supply food sufficient to

meet the needs of the population might be the characteristic of the system to be sustained. Note that this concept relies on the basic definition of sustainability, but provides a more concrete metric by which to assess system fitness. Arguably, if the system and its components cannot fulfill this need, they are not viable and change is required. This important notion – adaptation or system evolution to sustain the desired outflow – is related to the need to consider output in sustainability assessment (Costanza and Patten, 1995).

Population is not static. It may be more desirable to refine this system characteristic (food production) and express it per unit of population or per capita. Thus, the characteristic (food production) scales with population size. Individuals have a base food requirement; thus, a minimum threshold of food production per capita can be established to meet this requirement, or to achieve a target level of surfeit above it assumed to confer ‘quality of life’ rather than survival. Because a minimum below which the population cannot be sustained exists, the indicator (food per capita) has a directional relation; reducing food production per capita is negative to the likelihood of sustaining the population, increasing it is positive to the likelihood of sustaining the population. An appropriate time scale for forecasting this indicator might be related to the time scale over which population dynamics can be reliably forecast.

Food production per capita can be increased in two ways (increasing food output, or reducing population). Some might suggest population reduction as a move toward sustainability as it would drive the indicator in a positive direction. However, because this violates a fundamental premise of the argument (sustaining or supporting the population) an additional boundary constraint is implied, such that population reduction is not a viable mechanism. Beef production systems, as a subset of food production systems, can be considered using the same rationale.

Particular production systems and the associated strategies, tactics, and technologies applied

within these systems can be described in terms of resource utilization and product outflow. Applying values to the set of inputs and outflows allows description of the system in economic terms, and the joint description of the biological and economic features of the system is necessary to assess sustainability. Thus, ratios of output to resource utilization, and the associated costs or values per unit, may serve to integrate the components of the system (resources) with the feature of the system (output) for which sustainability is desired (Liverman et al., 1995). Dale et al. (2013) suggest a list of criteria that may serve as an effective guide in selecting indicators of sustainability:

1. Practicality (easy and inexpensive to measure)
2. Sensitivity (responsive to changes in the system)
3. Straightforward (clear and unambiguous regarding what is measured, how it is measured, and how responses are measured)
4. Anticipatory (of impending disruptions or alterations in system function)
5. Predictive (of responses to management actions)
6. Estimable (known or determinable response to changes)
7. Sufficient (when integrated with other indicators to describe the necessary dimensions of sustainability)

An effective set of indicators would meet these criteria; an optimal set might be considered the set of the fewest indicators required to describe system performance. If single indicators effectively inform multiple dimensions, then the size of the set of indicators can be reduced.

Resource utilization can be measured in several ways. Resources of public concern might include fossil fuel consumption, non-renewable water consumption, land (especially arable land) utilization, or consumption of other resources of concern. Gross resource consumption is not sufficient, however, to describe the function of the system, nor is this gross measure comparable

across systems or management alternatives without consideration of the output from the system. Therefore, resource utilization indicators should be developed as ratios; quantity of resources consumed per unit of output (resource use intensity) or units of output per units of resources consumed (resource efficiency). These indicators meet the criteria above, and may be especially useful in comparing management alternatives or predicting the outcomes of management changes such as intensification. Many firms may have data required to develop these indicators in hand, or could easily append current systems to include its collection.

Economic indicators within the system can be described as cost functions. Because costs represent resource consumption, similar ratios can be applied. In most cases, cost ratios with units of production should respond directly with resource ratios; i.e., cost efficiency and resource use efficiency are correlated. Deviations from this relationship are likely to be temporal and reflect volatility in resource pricing, and thus simultaneous estimation of both indicators is likely to confer some additional element of anticipatory value to impending system changes or allow the forecasting of the response of the system to various shocks. Additionally, price data per unit can be compared to cost data as an indicator of the firm's economic sustainability. Most firms already track this indicator.

Social sustainability indicators should also include the object function (food per capita) as a priority indicator. This is often ignored in sustainability measures. While it is intuitive that gross output or production per capita is a meaningful metric as the sector or industry level, it is not meaningful at the firm level. However, if a baseline per capita target is established, then output from a firm can be characterized in "food units" or similar measure as a scaling variable. As with other dimensions, ratios might be more meaningful, such as the amount of product per unit of resource input or the accumulated cost of a unit of output. These are the same measures suggested previously, and illustrate the reality that food production is a social benefit of the system.

Measures of social acceptability may be difficult to generate at the firm level; proxy values can likely be generated from sector or industry level data if demand information and the estimation of demand elasticity for specific product lines can be collected. As products with attributes that differ primarily in terms of perceived social acceptability are marketed, market size and demand functions are illustrative of true social acceptability – these functions measure how persons behave, not how they claim they will behave. Thus, as firms consider management changes, they may be able to forecast the likely effects of selecting alternate strategies on this dimension of sustainability by comparing systems adjusted for product type demand functions.

An additional element relevant to social sustainability revolves around animal well-being. Indicators in this area should be constructed so that they can be expressed relative to the output function, and should meet the criterion of unambiguous evaluation. Examples might include measures already commonly tracked, such as morbidity and mortality rates, and their trends over time. Expressing these per unit of beef produced rather than per head or in aggregate might provide more context and comparability across systems. Benchmarking across other systems might also prove valuable in this dimension. For example, while morbidity rate might be perceived as an indicator that cattle were in poor health, comparing morbidity rate within a system to the illness rate or proportion of employees in the United States that took at least one 'sick' day off from work might create more context. In 2004, 46.6% of United States workers between 19 and 64 years of age had to miss at least one day of work due to illness. If those reporting illness, but not sick days, are included, the total is increased to 69.6% (Commonwealth, 2005). This is analogous to morbidity rate, and might suggest that morbidity rates in production systems are relatively low, or that the 'well-being' of American workers is relatively lower than that of American cattle.

SUSTAINABLE INTENSIFICATION IN BEEF PRODUCTION SYSTEMS

If appropriate ratios are developed, such as food or protein output per unit of input (ie., efficiency), cost of inputs per unit of output, or other measures of resource consumption such as land area required (especially if time scaled, such as acre*years), assessment of alternate production systems might be straightforward.

Heitschmidt et al. (1996) calculated energy ratios (food energy yield per 'cultural' energy input) for beef production systems. In this report, cultural energy is a measure of direct and indirect fossil fuel utilization, as it considers the energy inputs in fuel, fertilizers, machinery, etc. across both feed and cattle production systems. These authors evaluated systems of increasing intensity within 3 production strategies. Intensity of production in this study was reflected by increasing days in a feedyard within a given operating strategy. Because increasing days on feed increased purchased feed usage and machinery and fuel inputs, it reflects an increase in total energy inputs in to the production system as intensity is increased. However, in all cases, energy yield increased by 50 to 60% when comparing the lowest to highest intensity systems. Thus, while more total energy was consumed, the marginal energy yield was sufficient to offset inputs and resulted in more energy efficient production. Intensification increased this indicator of sustainability, effectively reducing the fuel usage per unit of output. In terms of sustainability, if fossil fuels are considered a finite resource, then the efficiency of utilization of this resource was enhanced, a goal of sustainable production according to USDA. It is also notable that resource utilization is a proxy for cost when considered at concurrent time points or on real rather than nominal dollars. Higher energy yield thus translates to lower production costs per unit of output, although total costs per animal might be greater. This is a social benefit as a greater proportion of consumers have access to the product at a lower cost (and thus price) point.

The methodology of the referenced study did not utilize a complete life cycle analysis. However, the energy yields estimated are analogous (adjusting for different units of measure across studies) to those reported by Capper (2011a) or Rotz et al. (2013) for comparable systems. Empirical data must be used to develop the relationships and models required for LCA analysis; cross validation of LCA studies affirms the validity of the models, and the elements of the model inputs can thus be extracted as proxy indicators by managers.

When comparing beef productions systems across time, productivity increases (output per animal) were linked to reductions in GHG emission and carbon footprint (Capper 2011a). These measures are difficult to obtain in real time by individual firms, proxy measures are desirable. Energy use intensity (the inverse of energy efficiency) is a direct proxy for GHG emissions and carbon footprint per unit of outflow. Because increases in intensity are expected to increase outputs, one can predict the response to intensity impacts on sustainability indicators by estimating the change in output due to intensification, and by estimating the increase in resources required to implement the management change. Because these values are relatively straightforward to estimate, a realistic indication of sustainability impacts of an intensification step can be determined. As each of these resources has cost, an estimate of the impact of intensification on indicators of economic sustainability is straightforward to estimate. In fact this approach to analysis of alternatives is commonplace.

Most examples in the literature support the concept that increasing intensity increases resources use efficiency, although these same steps typically increase total resource or energy consumption because output from the system is also increased. This applies to all resources considered, from land and water to fossil fuels. Intensification in management reduced land use for dairy production by 90% and the number of cows required to produce a constant milk supply by 79% (Capper et al., 2001b), leading to 63% reductions in carbon footprint. Arguably, much of the research and development of modern

agricultural systems has been aimed at reducing the resource utilization required to produce a unit of food, a central indicator of sustainability. We have simply referred to this objective by a different name – production efficiency.

Overall, it can readily be demonstrated that increasing intensity of operations improves many indicators that are predictors of sustainability. Unfortunately, the tendency of the public to evaluate single, gross indicators, failing to account for system outputs or the ratios of inputs to outputs, can result in the formation of policy that may reduce sustainability rather than enhance it. By developing and implementing a suite of performance indicators, managers have the opportunity to manage toward a target level of a given indicator, or predict the trend in the indicator over time. Developing, validating and standardizing a set of sustainability indicators in animal agriculture has become a high research priority, and is vital, ironically, to the sustainability of the beef production chain in today's market environment.

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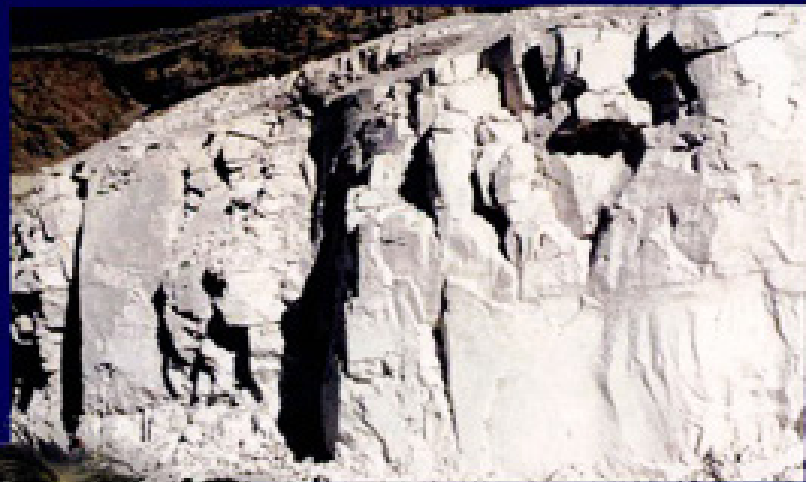
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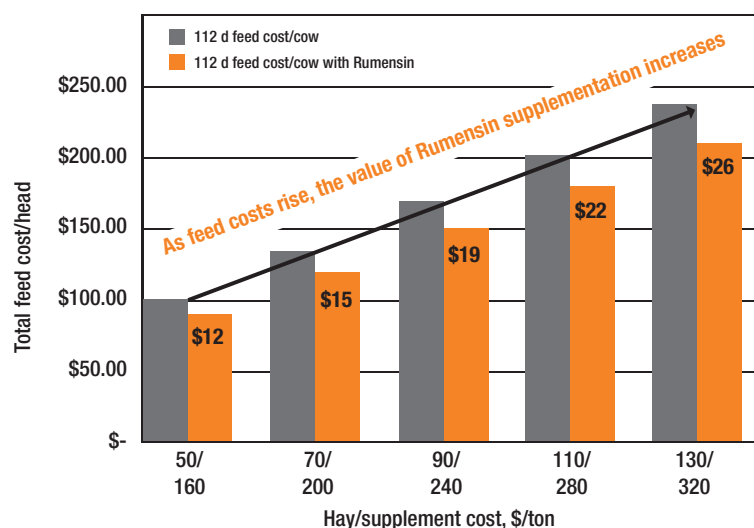
Elanco conducted four trials¹ to evaluate dose range of Rumensin and the corresponding effect on reduced feed requirements. The results in Table 1 demonstrate feeding Rumensin at 50 or 200 mg of monensin daily reduces the feed requirement 5 to 10 percent, respectively. Reproductive studies^{1,2} confirmed feeding Rumensin had no negative impact on the reproductive performance of mature beef cows.

Table 1. Summary of Rumensin in the cow herd

Variable	Monensin: mg/hd/d		
4-trial summary¹ (171 days)	0	50	200
Weight change, lbs	-47	-44	-39
Feed intake			
DM/d/exp. unit, lbs	164.2 ^a	155.7 ^b	146.4 ^b
Control, %	100	94.8	89.2
Reproductive safety studies			
Percent conception, ¹ %	90.9	92.5	97
Calving percentage, ² %	80.7 ^a	n/a	91.9 ^b

^{a,b}Means within a row without a common superscript differ ($P < 0.01$).

Table 2. Total feed cost savings per cow with Rumensin during a 112-day supplementation period to increase BCS from 4 to 5³



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Rumensin: Growing cattle on pasture or in drylot (stockers, feeders, and dairy and beef replacement heifers)

For increased rate of weight gain: Feed 50 to 200 mg/hd/d of monensin in at least 1.0 lb of Type C medicated feed. Or, after the 5th day, feed 400 mg/hd/d every other day in at least 2.0 lbs of Type C medicated feed. The Type C medicated feed must contain 15 to 400 g/ton of monensin (90% DM basis).

For the prevention and control of coccidiosis: Feed at a rate to provide 0.14 to 0.42 mg/lb of body weight/d of monensin up to a maximum of 200 mg/hd/d. The Type C medicated feed must contain 15 to 400 g/ton of monensin (90% DM basis).

Free-choice supplements: Approved supplements must provide not less than 50 nor more than 200 mg/hd/d of monensin.

Rumensin: Mature reproducing beef cows

For improved feed efficiency when receiving supplemental feed: Feed continuously at a rate of 50 to 200 mg/hd/d of monensin. Cows on pasture or in drylot must receive a minimum of 1.0 lb of Type C medicated feed/hd/d. Do not self-feed.

For the prevention and control of coccidiosis: Feed at a rate of 0.14 to 0.42 mg/lb of body weight/d of monensin up to a maximum of 200 mg/hd/d.

¹Rumensin for Beef Cows — 4-trial dose titration summary. Elanco Animal Health. Data on file.

²Bailey et al., 2007. Can. J. Anim. Sci. 88:113.

³Lalman, OSU Cowculator v 2.0. Beef Cow Nutrition Evaluation Software. Oklahoma Cooperative Extension Service, CR-3280. Feed requirement data to generate the values in chart are based on the example calculations from the Cowculator. Hay and supplement prices reflect past, present and future cost per ton held at a constant ratio of hay to supplement cost.



963

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The Plains Nutrition Council

The Plains Nutrition Council was formed in 1970 by a group of professionals located primarily in the southern high plains region. Since that time the organization has grown and now has members from a wide area. The Council is an educational and professional organization for persons who work and serve in allied industries, consultation practices, research, extension, and education with a primary focus in beef cattle. The goal of the Council is to enable its members to more effectively cooperate with each other and to serve the livestock industry more successfully. The Council provides a forum for discussion, evaluation, and promulgation of current research in the field of nutrition and management. Joint efforts with related organizations in animal health, veterinary medicine, animal agriculture, and other groups allied to the livestock industry are encouraged.

The Plains Nutrition Council coordinates and hosts educational and professional development activities for its members and others annually. In addition, the organization supports and sponsors professional development activities coordinated by other organizations and institutions. The signature event is the annual spring conference that draws professionals and graduate students with interests in beef cattle nutrition and management from the USA, Canada, Mexico, and South America. At this event, the Dr. Kenneth and Caroline McDonald Eng Foundation, in conjunction with Plains Nutrition Council, recognize the research efforts of graduate students presenting their work at the conference.



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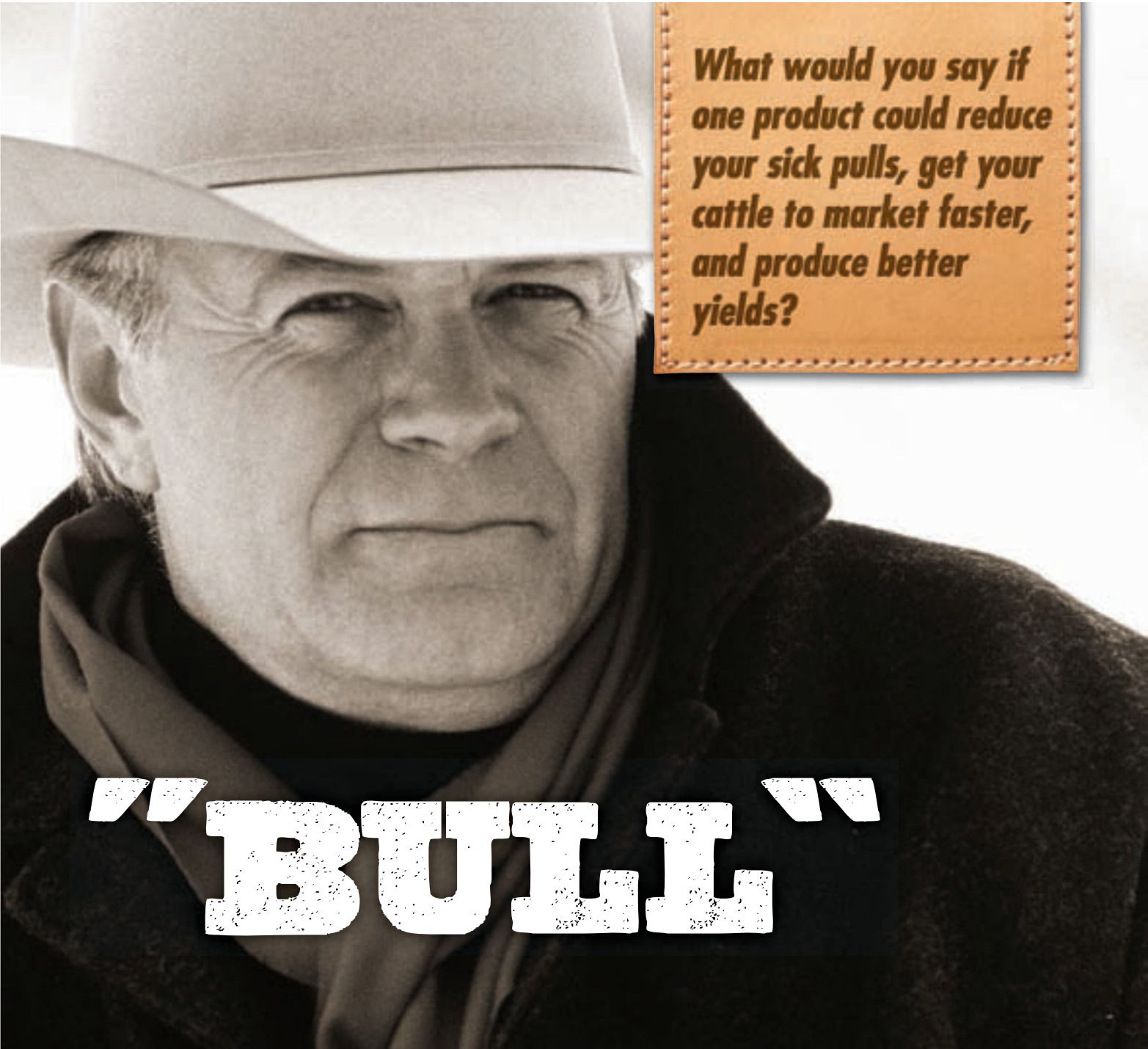
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¹This data is published in: Ponce, C.H., J.S. Shutz, C.C. Elrod, U.Y. Anele, and M. L. Galyean. 2012. Effects of dietary supplementation of a yeast product on performance and morbidity of newly received beef heifers. Prof. Anim. Sci. 28:618-622.

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Thank you for attending the 2014 Dr. Kenneth and Caroline McDonald Eng Foundation Symposium!

*We look forward to seeing you again
next year!*

—K—C—

Dr. Kenneth & Caroline McDonald Eng Foundation

