Where PROGRESS PROFIT Intersect

Beef Improvement Federation

45th Annual Research Symposium & Convention

June 12 - 15, 2013
Oklahoma City, OK

Oklahoma State University Extension

BIF

Table of Contents

2013 BIF Board of Directors

Front row (Left to Right): Mark Enns, Joe Cassady, Ben Eggers, Larry Mehlhoff, Mark Cowan, Sally Northcutt, Mike Tess
Back row (Left to Right): Steve Munger, Gordon Stucky, Larry Keenan, Mark Thallman, Tom Field, Brian House, Chris Shivers, Susan Willmon, Craig Bieber, Joe Hampton

President

Mark Cowan
2393 FM 3281
Detroit,l TX 75436
903-495-4522 (O)
markccattle@yahoo.com

Vice President

Steve Whitmire
Ridgefield Farm
1960 Brasstown Road
Brasstown, NC 28902
828-837-6324 (O)
828-835-8376 (F)
swhitmire@aol.com

Regional Secretaries

Mark Enns
Dept. of Animal Sciences
Colorado State University
Fort Collins, CO 80523-1171
970-491-2722 (O)
970-491-5326 (F)
menns@lamar.colostate.edu

Jane Parish
Animal and Dairy Sciences
Box 9815
Mississippi State, MS 39762
662-325-7466 (O)
662-325-8873 (F)
jparish@ads.msstate.edu

Bob Weaber
Animal Sciences and Industry
Kansas State University
227 Weber Hall
Manhattan, KS 66506
785-532-1460 (O)
785-532-7059 (F)
bweaber@k-state.edu

Executive Director

Joe Cassady
Department of Animal Science
North Carolina State University
Box 7621
Raleigh, NC 27695-7621
919-513-0262 (O)
919-515-6884 (F)
Joe_cassady@ncsu.edu

Historian

Twig Marston
University of Nebraska
NE Research & Extension
601 E. Benjamin Ave., Ste 104
Norfolk, NE 68701
402-370-4001 (O)
402-649-2365 (C)
402-370-4010 (F)
tmarston2@unl.edu

2013 BIF Board of Directors

Breed Association Representatives

Larry Keenan
Red Angus Association of America
4201 N I-35
Denton, TX 76207
940-387-3502
larry@redangus.org

Sally Northcutt
American Angus Association
3201 Fredrick Avenue
St. Joseph, MO 64506
816-383-5157 (P)
816-233-9703 (F)
snorthcutt@angus.org

Wade Shafer
American Simmental Association
1 Simmental Way
Bozeman, MT 59715
406-556-9627 (O)
406-587-9301 (F)
wshafer@simmgene.com

Chris Shivers
American Brahman Breeders Association
3003 South Loop W., Suite 520
Houston, TX 77054
713-349-0854 (O)
713-349-9795 (F)
cshivers@brahman.org

Robert Williams
American International Charolais Association
11700 NW Plaza Circle
Kansas City, MO 64153
(816) 464-2474 ext 103 (O)
(816) 464-5759 (F)
rwilliams@charolaisusa.com

Susan Willmon
American Gelbvieh Association
10900 Dover Street
Westminster, CO 80021
303-465-2333 (O)
303-465-2339 (F)
susanw@gelbvieh.org

Producer Representatives

Craig Bieber
Bieber Red Angus Ranch
11450 353rd Ave.
Leola, SD 57456
605-439-3628 (O)
605-439-3100 (F)
605-216-8169 (C)
craig@bieberredangus.com

Donnell Brown
R.A. Brown Ranch
PO Box 727
Throckmorton, TX 76483
940-849-0611 (O)
940-256-1406 (C)
dbrown@rabrownranch.com

Joe Hampton
2600 Back Creek Church Rd
Mount Ulla, NC 28125
704-278-9347 (O)
joe@backcreekangus.com

Barry Horsley
Horsley Red Angus
1301 N Gabbart Road
Stringtown, OK 74569
580-346-7023 (O)
580-346-7068 (F)
580-743-0006 (C)
Barry.horsley@arcadia-landcattle.com

Steve Munger
Eagle Pass Ranch
38398 145th St.
Mansfield, SD 57460
605-229-2802 (O)
605-380-0092 ©
steve@eaglepassranch.com

Marty Ropp
Allied Genetic Resources
2245 Ropp Road
Normal, IL 61761
406-581-7835 (O)
mropp@alliedgeneticresources.com

Other Representatives

Larry Mehlhoff
97 Duncan District Road
Sheridan, MT 59749
406-842-5693
406-596-1204
5lranch@3rivers.net

John Paterson
Montana State University
119 Linfield Hall
Bozeman, MT 59718
406-581-3492
jpaterson@beef.org

Doug Frank
ABS Global
PO Box 459
DeForest, WI 53532
608-846-6252 (O)
608-279-3172 (C)
Doug.Frank@genusplc.com

Bryon Templeton
Canadian Beef Breeds Council
320, 6715 – 8 Street N.E
Calgary, Alberta T2E 7H7
CANADA
403-345-3889 (O)
403-308-9971 (C)
xtcherf@shockware.com

Mike Tess
Montana State University
Animal Biosciences
Bozeman, MT 59717
406-581-9071 (O)
406-585-4685 (F)
michaelwtess@gmail.com

Mark Thallman
U.S. Meat Animal Research Center
PO Box 166
Clay Center, NE 68933-0000
402-762-4261 (O)
402-762-4173 (F)
mark.thallman@ars.usda.gov

Schedule of Events

Wednesday, June 12, 2013

8:00 am – 12:00 pm BIF Board Meeting (The Grand Avenue Room, Renaissance Hotel)
12:00 pm – 8:00 pm Registration (Prefunction East)
5:00 pm – 7:00 pm Oklahoma Welcome Reception (Prefunction East, Ballroom A, B, and C)
7:00 pm – 9:15 pm NAAB Symposium: The Newest Developments in Sexed Semen (Ballrooms A, B, and C)

7:00 pm Welcome
7:15 pm How the Sorting Process Works
Dustin Dean, Sexing Technologies
7:45 pm The Challenges of Producing Sexed Semen for AI Organizations
Willie Altenburg, Genex Cooperative
8:15 pm Developing Strategies to Optimize Use of Sex-Sorted Semen in Conjunction with Fixed-Time AI Breeding Programs
Dr. David J. Patterson, University of Missouri
8:45 pm Thoughts and Results of Using Sexed Semen From a Producer
Galen Fink, Fink Beef Genetics

Thursday, June 13, 2013

6:00 am – 5:00 pm Registration (Prefunction East)
8:00 am – 12:30 pm General Session I: Crossbreeding vs. Straight Breeding - Show Me the Money (Ballrooms A, B, and C)

8:00 am Welcome, Hon. Jim Reese, Secretary Oklahoma Department of Agriculture
8:30 am Crossbreeding: Considerations and Alternatives in an Evolving Market
Dr. Nevil Speer, Western Kentucky University
Tom Brink, JBS Five Rivers Cattle Feeding
9:00 am Crossbreeding: One of the Tools to Increase Profitability
Dr. Bob Weaber, Kansas State University
Dr. Matt Spangler, University of Nebraska-Lincoln
9:30 am Panel Discussion: Crossbreeding or Straight Breeding: How Does the Choice Impact Consumer Satisfaction?
Norlyn Tipton, SYSCO
Newley Hutchison, Chain Ranch
Mike Kasten, Mike Kasten Beef Alliance
Dr. Deborah VanOverbeke, Oklahoma State University
Chris Hitch, Hitch Feeders
Tom Brink, JBS Five Rivers
Dr. Nevil Speer, Western Kentucky University
Dr. Bob Weaber, Kansas State University
Dr. Matt Spangler, University of Nebraska-Lincoln
10:30 am Break
11:00 am Breed Utilization and Production Efficiency
Dr. Merlyn Neilsen, University of Nebraska-Lincoln
11:45 am That's Nice, but I Raise Cows
Dr. Dave Daley, California State University-Chico

12:30 pm – 2:30 pm Awards Luncheon (Ballrooms A, B, and C)
Commercial Producer of the Year awards

2:30 PM Technical Breakout Sessions

Advancements in Live Animal, Carcass and End Product (Ballroom D)
Committee Chair: Dr. *Robert Williams, American International Charolais Association*

2:30 pm Genetic Parameters for Udder Quality in Hereford Cattle
Heather Bradford, Kansas State University

3:15 pm Genetic Evaluation and Selection: Lost Opportunities for Improving Profit
Dr. Mark Enns, Colorado State University

4:00 pm Indicator Traits and the Challenge They pose for Obtaining High Accuracy Genetic Evaluations
Dr. Michael MacNeil, Delta G

4:45 pm Technology lag: Is there a cost for failing to do it right?
Dr. David S. Buchanan, North Dakota State University

Advancements in Selection Decisions (Ballroom E)
Committee Chair: *Dr. Bob Weaber, Kansas State University*

2:30 pm Life-Cycle, Total-Industry Genetic Improvement of Feed Efficiency in Beef Cattle: Blueprint for the Beef Improvement Federation
Dr. Merlyn Nielsen, University of Nebraska-Lincoln

3:15 pm Sparse Genome Scan
Dr. Mark Thallman, USDA-ARS, U.S. Meat Animal Research Center

3:30 pm What Do We Hope to Learn From Sequence Information?
Dr. Larry Kuehn, USDA-ARS, U.S. Meat Animal Research Center

4:00 pm Relationships Among Temperament, Immune Function, and Carcass Merit in Beef Cattle
Kerri Bates, Kansas State University

4:45 pm Strategies to Improve Production Efficiency and Calf Value in the Southern Plains
Dr. Joe Paschal, Texas A&M University AgriLife Extension

Advancements in Producer Applications (Meeting Rooms 16-18)
Committee Chair: *Dr. Jane Parish, Mississippi State University*

2:30 pm Mobile Apps that Make Cents for Cattle Producers
Dr. Rick Rasby, University of Nebraska

3:15 pm Management Practices of Developing Heifers that Affect Lifetime Productivity
Dr. Jack Whittier, Colorado State University

4:00 pm Sexed Semen: Tool for Genetics Improvement-How Can We Use it Now?
Dr. John Hall, University of Idaho

4:45 pm Selection for Traits not Included in National Cattle Evaluation
Dr. Dan Moser, Kansas State University

5:00 pm – 11:00 pm Shuttle to Cowboy Hall of Fame & Western Heritage Museum (Includes Tour & Entertainment by the Bunkhouse Band & Cowboy Jim Garling)

6:30 pm – 8:00 pm Dinner and Presentation of the Seedstock Producer of the Year Award

Friday, June 14, 2013

6:00 am – 5:00 pm Registration (Prefunction East)

8:00 am – 12:30 pm General Session II: Using Genetic Tools to Address Environmental Challenges and Cowherd Efficiency (Ballrooms A, B, and C)

8:00 am Addressing Cowherd Efficiency in a World of Mixed Messages for Producers: Matching Production Levels to Environmental Conditions

Dr. Dave Lalman, Oklahoma State University

9:00 am Bad News: They're all Carriers of Something – Understanding the Impact of Broken Genes in the Beef Business

Dr. Dorian Garrick, Iowa State University

10:00 am Break

10:30 am Do We Raise Cattle or Bugs? Exploring the Symbiotic Relationship Between Cattle and Microbes

Dr. Andrew Benson, University of Nebraska-Lincoln

11:30 am Charge and Session Wrap-Up

11:45 am Annual Meeting, Regional Caucuses, and Election of Directors

12:30 pm – 2:00 pm Awards Luncheon (Ballrooms A, B, and C)

Pioneer, Continuing Service , and Ambassador Awards
Presentation of Frank Baker Awards
Presentation of Roy Wallace Scholarship
President's Address

2:30 pm Technical Breakout Sessions

Advancements in Cow Herd Efficiency and Adaptability (Ballroom D)
Committee Chair: *Dr. Mark Enns, Colorado State University*

2:30 pm Feed Intake—Beyond the Guidelines: Data Standards and Multi-Trait Selection

Susan Willmon, American Gelbvieh Association
Dr. Patrick Doyle, California State University-Chico

3:30 pm Utilization of Genetic Resources to Match Environmental Conditions

Dr. Harvey Blackburn, USDA-ARS-NAGP, Fort Collins

4:30 pm National Program for the Genetic Improvement of Efficiency in Beef Cattle: Aims and Current Results

Dr. Matt Spangler, University of Nebraska-Lincoln

Advancements in Genetic Prediction (Ballroom E)
Committee Chair: *Dr. Mark Thallman, USDA-ARS, U.S. Meat Animal Research Center*

2:30 pm Reports on Incorporation of Genomic Predictions Into National Cattle Evaluations

Dr. Sally Northcutt, American Angus Association
Jack Ward, American Hereford Association
Dr. Lauren Hyde, American Simmental Association
Larry Keenan, Red Angus Association of America
Chris Shivers, American Brahman Breeders Association

	3:15 pm	Estimated Individual Animal MBV Reliabilities and Their Association with Realized MBV Reliabilities *Dr. Stephen Kachman, University of Nebraska-Lincoln*
	4:00 pm	Preliminary Estimates of Breed Differences from Recent Sampling in the Germplasm Evaluation Project *Dr. Larry Kuehn, USDA-ARS, U.S. Meat Animal Research Center*
	4:45 pm	Tying Market Value to Genetic Evaluations of Commercial Cattle *Lee Leachman, Leachman Cattle of Colorado*

Advancements in Emerging Technology (Meeting Rooms 16-18)
Committee Chair: *Jack Ward, American Hereford Association*

	2:30 pm	Update on USDA Feed Efficiency Grant *Dr. Jerry Taylor, University of Missouri*
	3:30 pm	Breeding Healthier Cattle *Kristin Gaddis, North Carolina State University*
	4:30 pm	Update on genomic projects and incorporation of marker information into genetic analysis *Dr. Dorian Garrick, Iowa State University*
5:30 pm		BIF Board Meeting (Meeting Room 14-15)

Saturday, June 15, 2013

7:00 am – 6:00 pm	**Northern Oklahoma Tour**, lunch provided by Pollard Angus Robert M. Kerr Food and Agriculture Products Center Oklahoma State Willard Sparks Beef Research Center M&M Charolais Pollard Angus Chain Ranch
6:45 am – 6:00 pm	**Southern Oklahoma Tour**, lunch provided by Noble Foundation Historic Oklahoma City Stockyards Raber's Saddlery Noble Foundation Stuart Ranch

USDA United States Department of Agriculture National Institute of Food and Agriculture

This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Project No. 2013-67015-20696. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

2013 BIF General Session Speakers

Nevil Speer, Ph.D.

Western Kentucky University

Nevil Speer serves as Professor of Animal Science at Western Kentucky University. His primary responsibilities include teaching, applied research and industry outreach. His university duties also entail directing a master's program in Leadership Studies.

Speer remains highly involved with the livestock and food industry, serving on various national committees including the National Institute for Animal Agriculture's Board of Directors. Dr. Speer provides regular content for several publications including Feedstuffs, BEEF Magazine, and CALF News.

Tom Brink, M.S.

J&F Oklahoma Holdings, Five Rivers Cattle Feeding

Tom Brink is a Kansas native with a cow-calf background. Brink graduated from KSU with a B.S. degree in Animal Science and two M.S. degrees (Animal Science and Ag Economics). He has worked for Cattle-Fax, the American Gelbvieh Association, ContiBeef, and Five Rivers Cattle Feeding, LLC during the past 25 years.

Brink currently serves as President and COO of J&F Oklahoma Holdings, Inc., which is commonly known as the cattle ownership arm of Five Rivers. Brink has been married 26 years to his wife Mindy and has four children, ranging in age from 17 to 23.

Bob Weaber, Ph.D.

Kansas State University

Bob Weaber, Ph.D. joined the faculty of the Department of Animal Sciences and Industry at Kansas State University in 2011 as Cow-Calf Extension Specialist. Dr. Weaber also serves as central regional secretary for B.I.F., is a co-coordinator of the National Beef Cattle Evaluation Consortium education programs and has served as a member of the National Cattlemen's Beef Association Policy Division Board of Directors. The focus of his extension and research programs have been to broaden the availability, use and understanding of genetic selection tools (Expected Progeny Differences, DNA markers and selection indexes), as well as performance data collection schemes implemented by cattle producers. Dr. Weaber grew up on a cow-calf operation in southern Colorado and went on to earn a BS in animal science followed by a Master of Agriculture degree in the Beef Industry Leadership Program at Colorado State University. He completed his doctoral studies in the Animal Breeding and Genetics Group at Cornell University. Weaber is the recipient of the Midwest Section of ASAS Young Animal Scientist Extension Award (2013), B.I.F's Continuing Service Award (2011), Univ. of Missouri Extension's J.W. Burch State Specialist Award (2011), and the Univ. of Missouri Provost's Award for Creative Extension Programming by Young Faculty (2010). Bob and his wife, Tami, and their young children, Maddie, Cooper and Wyatt, reside near Wamego, KS.

2013 BIF General Session Speakers

Matt Spangler, Ph.D.

University of Nebraska

Matt Spangler grew up on a diversified crop and livestock farm in south-central Kansas where his family still farms and has a cow/calf operation. After receiving his B.S. degree in Animal Science from Kansas State University (2001) he attended Iowa State University and received his M.S. degree in Animal Breeding and Genetics in 2003. He received his Ph.D. at the University of Georgia in Animal Breeding and Genetics (2006) and is currently an Associate Professor and Extension Beef Genetics Specialist at the University of Nebraska-Lincoln. He works as part of a collaborative team with colleagues at UNL and US MARC to develop and evaluate methods related to genomic selection and is currently part of a collaborative effort funded by the USDA competitive grants program to develop genomic predictors for feed intake and efficiency in beef cattle.

Merlyn Nielsen, Ph.D.

University of Nebraska

Merlyn K. Nielsen is the Wagner Distinguished Professor in Animal Science at the University of Nebraska-Lincoln. A native of Nebraska, Nielsen completed his BS (1970) degree at the University of Nebraska-Lincoln and later his MS (1972) and PhD (1974) degrees at Iowa State University, majoring in Animal Breeding and minoring in Statistics. He joined the faculty in Animal Science at the University of Nebraska-Lincoln in 1974 and rose to the rank of professor in 1984. Significant academic service and recognitions have been Executive Committee for 3rd World Congress on Genetics Applied to Livestock Production (1984-86), Section Editor (Animal Breeding and Genetics) for the Journal of Animal Science (1991-95), the Rockefeller Prentice Memorial Award in Animal Breeding and Genetics (1999), Outstanding Scientist of Nebraska Chapter of Sigma Xi (2001), Holling Family Award for Teaching Excellence (2005), Kermit Wagner Distinguished Professor (2006), and President, Midwest Section of American Society of Animal Science (2007-08). Nielsen conducts research in animal breeding and genetics and teaches both undergraduate and graduate courses in animal genetics in addition to courses in the Nebraska Beef industry Scholars program.

Dave Daley, PhD.

California State University-Chico

Dave Daley currently serves as the Associate Dean of the College of Agriculture and administrator for the ATRC (University Farm). Dr. Daley has conducted an active, applied research program, receiving the first ARI grant in 1997. Since that time, he has received over $5 million in grants. Dave's research interest are varied but have focused primarily on the application of technology to the cattle industry, coupled with an emphasis on utilization of alternative feedstuffs. He has conducted a major studies on the utilization of DNA fingerprinting in genetic improvement with industry collaborators like Harris Ranch, the use of electronic identification (RFID) in national animal identification, the economic impacts of crossbreeding, and the utilization of brewery byproducts as a livestock feed. To Dr. Daley, the most important aspect is the involvement and education of undergraduates at the University Farm.

2013 BIF General Session Speakers

Dave Lalman, Ph.D.

Oklahoma State University

Dr. Lalman is currently a professor in the Animal Science Department at Oklahoma State University. His position is State 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 through improved forage utilization, defining optimal supplementation practices and evaluating beef production systems and alternatives.

Dr. Lalman has published 43 peer reviewed journal articles, 76 abstracts, 70 research progress reports, 68 extension publications, given 485 in-state extension presentations and 36 national and international presentations. Dr. Lalman's programs have generated $1,399,092 in extramural funding, been awarded $253,140 of internal (OSU) funding, and he has mentored 8 MS and 5 PhD students, as well as served on 36 other graduate student committees.

Dorian Garrick, Ph.D.

Iowa State University

Dorian Garrick has held the Jay Lush endowed Chair in Animal Breeding & Genetics at Iowa State University since 2007 following five years at Colorado State University and fifteen years at Massey University where he holds the A.L. Rae Chair. He received a First Class Honours degree in Agricultural Science from Massey University and a Ph.D. from Cornell University. Dorian has been integrally involved in the development and implementation of national animal evaluation programs, performance recording databases and breeding schemes.

His recent work has focused on exploiting genomic information for animal improvement. Dorian views animal breeding in a systems context, involving the integration of knowledge and understanding of business goals, production systems, processing and marketing, in concert with quantitative and molecular genetics. Dorian has worked with a variety of genetic improvement programs in addition to dairy cattle, including beef cattle, sheep, elk, pigs, chickens, and tree breeding. Dorian enjoys working with enthusiastic producer and industry groups that seek to include animal breeding approaches in the attainment of their farm business goals. Dorian is Executive Director of the U.S. National Beef Cattle Evaluation Consortium.

Andrew Benson, Ph.D.

University of Nebraska

Dr. Andrew Benson is a professor in the Food Science and Technology Department at University of Nebraska, where teaches Biotechnology and Food Science and Technology, and is a W.W. Marshall Distinguished Professor of Biotechnology. His research focuses on genome evolution in pathogenic bacteria (using comparative genomics, phylogenetics, and molecular biology), and evolution and development of gut microflora using 16S rRNA fingerprinting and sequencing.

He received a B.S. in Microbiology from Iowa State University, a Ph.D. in Microbiology from the University of Texas, and a Post Doc. Molecular Biology from Princeton University.

Sponsors

Platinum Sponsors

Angus Journal

Beef Magazine

Merck

Merial

Neogen

Zoetis

Bronze Sponsors

ABS Global

Accelerated Genetics

American Gelbvieh Association

American Hereford Association

American International Charolais Association

American Shorthorn Association

American Simmental Association

Armitage Livestock

Canadian Beef Breeds Council

Genex

International Brangus Breeders Association

Kiamichi Link Angus

M&M Charolais

Oklahoma Hereford Association

Reproductive Enterprises, Inc.

Select Sires

Temple Tag

TransOva

Silver Sponsors

Allflex

American Angus Association

Boehringer Ingelheim Vetmedica

Express Ranches

GrowSafe

Progressive Cattlemen

Red Angus Association of America

Donors

ADM Alliance Nutrition

American Brahman Breeders Association

American Akaushi Foundation

Diamond W Corrals

Insentec

JBS Five Rivers Cattle Feeders

Midwest Microsystems

Norbrook

Oklahoma Beef, Inc.

Oklahoma Angus Association

Oklahoma Gelbvieh Association

Oklahoma Limousin Breeders Association

Oklahoma Quality Beef Network

Origen

Progressive Molecular Diagnostics, LLC

The Happy Toy Maker

Taking A Second Look at
Crossbreeding: Considerations and Alternatives in an Evolving Market

Nevil Speer[1]

[1]*Western Kentucky University*

Introduction

The primary intent behind publication of the white paper entitled, *Crossbreeding: Considerations and Alternatives in an Evolving Market* (Speer, 2011), was to examine the prevailing decision-making process regarding genetic inputs within the commercial cow/calf sector.

Part of that endeavor included outlining key advantages associated with crossbreeding: "Research has clearly and repeatedly demonstrated benefits associated with implementation of crossbred mating systems in various production systems. Simply put, crossbred animals outperform their straightbred contemporaries. Moreover, those principles are underscored by similar outcomes in other species of livestock…producers weaning crossbred calves nursing crossbred cows typically realize an improvement of 10% to 20% in weaning weight. Moreover, realization of that crossbreeding advantage doesn't require much in terms of additional inputs—thus summoning [the] 'free lunch' caricature."

Despite those well-documented benefits of crossbreeding, cow/calf producers have seemingly deemphasized execution of breeding decisions that facilitate heterosis within their respective operations. That development is somewhat counterintuitive given the prominence of educational efforts around crossbreeding from various outlets including academia and breed associations.

The inference being that commercial producers are seemingly prioritizing factors separate from heterosis when making genetic investments for the cowherd. As such, the purpose of the white paper was clearly delineated as an endeavor, "…to explore some possible explanations for those broader genetic strategies within the U.S. cowherd…"

Meanwhile, the paper also possessed a final take-away suggestion for the cow/calf sector to carefully review <u>all</u> management and marketing decisions per the following: "…beef producers are encouraged to comprehensively consider relationships around traits of economic importance within the context of current market signals. Doing so will facilitate both effective selection and mating strategies to enhance operational profitability."

Unfortunately, some of those more important points have been lost in the broader discussion that's ensued since release of the white paper. Specifically, some voices have wanted to characterize the analysis as a primer for "debate" about the most appropriate path for the beef industry's commercial sector. Much of that has been framed as a crossbreeding versus straightbreeding deliberation. However, that's somewhat misplaced given the increasing complexities within the beef industry's production sector.

That is, the commercial industry remains highly fragmented with widely diverse operating priorities. That's especially true when considering an increasingly differentiated, value-driven marketing system. Therefore, when matching management and marketing, a one-size-fits-all genetic solution is likely inappropriate for producers – especially when considering the industry's growing number of differentiated marketing targets. Given that reality, the intent here is to take a second look at some factors that may further illuminate the decision-making process within the commercial sector since the initial white paper was released.

Review

As alluded to previously, *Crossbreeding: Considerations and Alternatives in an Evolving Market* outlined that many producers are not fully taking advantage of the benefits of heterosis. For example, respondents to surveys performed by *BEEF* magazine (2010) reveal that nearly half of all producers classify the genetic composition of their cowherds as being high-percentage or straight British. That's further reinforced by various industry estimates that the cow/calf sector is now predominately comprised of Angus genetics, accounting for upwards of 70% of the genetics in the nation's commercial beef production system.

The white paper covered a number of different topics that are currently influencing the business and the corresponding decisions made by commercial producers. Chief among those items included the following:

- Increasing demand for, and subsequent emphasis upon, beef quality
- Increased prevalence of value-added programs
- Cowherd consolidation
- Retained ownership
- Time / labor management priorities
- Relative ease of implementing crossbreeding
- Realization of benefits of crossbreeding

The objective here is <u>not</u> to review nor rehash those considerations. Rather, most important is a fresh look at additional factors influencing cow/calf producers regarding management of their breeding programs and genetic strategies.

Reproduction / Longevity

The benefits of crossbreeding have been well documented – heterosis enables additional opportunities (beyond usage of additive breed effects and breed complementarity) to increase efficiency of commercial beef operations. One of the greatest advantages is derived from improved reproductive performance and subsequent longevity of the beef cow. (The reproduction / longevity relationship inherently assumes many operations cull cows upon realization of pregnancy failure - more on that aspect below.) Parish (2012) aptly describes this phenomenon:

> “The greatest improvements in using crossbred dams rather than straightbred dams involve reproductive traits. Higher reproductive rates, longer productive lives (by more than 1 year), and less frequent replacement need are documented advantages of crossbred cows over straightbred cows. In addition to having more calves because of improved reproduction, cross bred cows tend to have greater calf survival rates and greater calf weaning weights.”

Given that background, the assumption would be the nation’s beef cow reproductive performance has diminished in recent years concomitant with reduced heterosis. That’s a difficult item to monitor given the complexities associated with measuring reproductive performance (other than pregnancy status) and limited amount of meaningful data regarding reproductive proficiency (including results from pregnancy checking). For example, even among larger operations (those greater than 500 cows) only about half normally pregnancy test cows; less than 20% of the nation’s cows across all operations are regularly checked for pregnancy status (USDA:NAHMS, 2009a).

Despite the deficit of information, industry-wide data may provide some insight into broader reproductive performance over time. More precisely, if reproductive performance has worsened, resultant of reduced hybrid vigor in the cowherd, there should be a corresponding shift in herd performance and/or management strategies that emerges over time.

One source of pertinent information derives from the various Farm Management Association programs across the country. Comprehensive enterprise analysis allows for establishment of meaningful production and financial benchmarks ultimately leading to improved decision-making over time.

The Kansas Farm Management Association (KFMA) is one of the largest programs in the country. Moreover, given Kansas’ beef cow inventory ranking, KFMA data provides good insight into long-term general trends among cow/calf producers representative of many operations throughout the United States. The data outlined in Figure 1 details annual five-year moving averages for three key variables beginning with ’96-’00 time frame: 1) number of cows maintained, 2) marketing weight, and 3) number of calves marketed. Several trends are evident:

- One, consistent with national trends, cowherds incrementally increased in size (~7%) during the first half of the decade; the trend has plateaued in recent years.
- Two, the marketing weight of calves has also increased over time

- Last, and most important to this discussion, the marketing rate (relative proportion of calves marketed per number of cows maintained) has remained steady over time.

In other words, KFMA participants have remained fairly reticent about expanding their operations but have managed to market more total weight over time – the latter likely resulting from a combination of better management and genetics. And while doing so, commercial producers (based on KFMA marketing rate data) have proven successful in also maintaining reproductive performance within the cowherd.

From another perspective, KFMA cowherd inventory trends are consistent with assessment of overall cow population trends in the United States. As delineated in the white paper, the beef industry's cow-calf sector has undergone significant transition during the past 20 years or so. Primarily, the U.S. beef cow inventory has undergone an enduring and sizeable reduction that began in 1996: 2013's starting beef cow inventory was pegged at 29.3 million cows marking a selloff of approximately 6 million cows during the past 17 years (USDA:NASS). Second, while relatively small operations (<50 cows) still comprise the majority of beef cow operations in the United States, they also represent the category that overwhelmingly accounts for decline in the number of beef cow operations over time (LMIC, 2012). In combination, cow liquidation has largely occurred because of smaller operators exiting the business.

With that background, Figure 2 reflects relative beef cow slaughter and heifer retention rates since 1996 coupled with the annual change in beef cow inventory. The data reveals the overwhelming importance of beef cow slaughter when accounting for decline in the nation's beef cow population. Meanwhile, heifer retention rate has remained relatively constant.

Keeping in mind disappearance of smaller operators, liquidation has been a fairly deliberate process driven by a multitude of factors (including weather, producer demographics and financial considerations). Therefore, liquidation has likely NOT stemmed from a sudden decline in reproductive performance. Were there an inordinate surge in open cows, there'd likely be a disproportionate rise in the heifer retention rate to offset loss of cow inventory and ensure the production pipeline was being replenished.

Change in operational size, management priorities and marketing opportunities has influenced selection among commercial producers. Indirectly, from several aspects, that's potentially influenced reproductive performance in a positive manner despite declining hybrid vigor within the cow/calf sector.

One aspect revolves around calving ease. The white paper noted, "…it appears that beef producers have overwhelmingly emphasized calving ease predictability from a large and reliable data base; the risk/reward relationship of losing calves at birth versus heavier calves at weaning is heavily tilted towards the former." Assuming that selection pressure has been effective, it's probable reproductive performance / pregnancy rate has improved given the negative influence dystocia has on postpartum interval and subsequent rebreeding performance.

The second aspect involves sustained selection pressure upon marbling. Research indicates selection for improved marbling may be favorably related to two-year-old heifer success and subsequent cow longevity: "…estimates suggest that sire marbling EPD had a desirable influence (if any) on both heifer success and length of productive life" (Tess et al., 2013). (Conversely, selection for increased leanness and/or retail product, independent of other considerations, proves antagonistic towards overall cow productivity. Tess et al., 2013; Speer, 1993)

Research also suggests that well-managed, straightbred cattle populations are fully capable of achieving high pregnancy rates (91%) in a defined breeding season of short duration (Brinks et al, 1990). Similarly, results from Heartland Cattle Company (McCook, NE) reveal that long-term selection pressure among Angus producers led to gains in inherent fertility thereby allowing commercial producers to relinquish some requirement for heterosis. Accordingly, Director Janet Rippe notes that: "If you get a true hybrid or an F1-cross or even just a quarter something else, those cattle are generally more fertile. But we might not see as much difference in the numbers because our long-term Angus customers have put so much selection pressure on fertility." (Reiman, 2012) Either way, pragmatic indicators imply overall reproductive performance has not sufficiently declined within the commercial sector to alter their general management strategies.

Lastly, it's important to note that reproductive performance is typically associated with cow's lifetime productivity and subsequent longevity (depending on culling strategies). The consideration of number-of-calves born is highly influential upon net present value when making cow investment decisions. Simultaneously, cows are often culled for reasons other than pregnancy status or failure to wean a calf: "…nearly two of three operations (62.3 percent) sold cows for purposes other than breeding." (USDA: NAHMS, 2009b) Any functional trait that influences culling decisions is equally important with respect to longevity and establishing net present value.

Certified Beef Programs

The rapid development of certified beef programs in recent years underscores the significance of beef demand and subsequent influence on consumer expenditures (both domestically and internationally) at the restaurant or retail level. Final demand is of primary importance to all beef producers given their fundamental connection to beef sales. Failure to consistently generate favorable eating experiences negatively influences demand. That ultimately results in lower needs for production output, weaker markets and less available revenue for all stakeholders in the beef business (Marsh, 2003). Conversely, establishing positive changes in demand spells prosperity: more customers buying more beef at higher prices.

With that context, maintaining (let alone growing) market share is an enduring process that mandates constant innovation and positioning. Those considerations require continuous improvement regarding product quality, consistency and efficiency of production. Accordingly, the National Beef Quality Audit noted in 2000 (NBQA2000: CBB and NCBA, 2001) that "low overall uniformity and consistency" remained the number one concern within the beef industry. The issue was also identified as the greatest quality challenge in which the industry had made the least amount of progress during the previous 10 years. The industry was seemingly ignoring the consumer and beef's demand subsequently deteriorated.

The industry provided lots of rhetoric during the '90s about value-based marketing as a means to induce better quality and consistency, but market structures still hadn't sufficiently evolved to facilitate that occurrence (Purcell, 2002). Broad-based, quality-driven incentives were not generally available or sufficiently strong to have the industry respond in a meaningful way prior to 2000. Even with the advent of grid pricing, weight remained the primary market signal and overwhelming driver of revenue. For the beef industry to reestablish its core position in the marketplace going forward, a new emphasis upon quality and efficiency needed to be established.

That reality is best reflected by quality grade results cited by the National Beef Quality Audits: Prime and Choice had bottomed out around 50% within the harvest mix between 1995 and 2000 (Figure 3). (Annual averages, based on data from USDA: AMS would mark that figure closer to 60% and since improved to 69% in 2011.) The industry needed to instill more systematic, process-driven incentives to ensure a reliable, steady supply of cattle in the future to meet customer demands.

The outcome has been a decidedly sharp surge in the number of alliances and USDA certified beef programs during the past 10 years. Certified Angus Beef (CAB), initiated in 1978, holds the distinction as the first USDA-certified beef program. It took more than 20 years for 10 additional programs to be established. However, in the 13 years since then, 129 new programs have been introduced (see Figure 4) – nearly 80% of which are Angus-based.

Perhaps most significantly, the increasing presence of Angus program brand management has influenced beef industry genetics and breeding systems in recent years. Most notably, the 2011 National Beef Quality Audit outlined the growing percentage of predominately black-hided cattle (see Figure 5). That's especially important given that higher degrees of marbling are positively associated with USDA's A-stamp percentage (Emerson et al., 2012): A-stamp rate for Traces, Slight, Small, Modest, Moderate, Slightly Abundant and Moderately Abundant marbling scores being 49, 55, 66, 71, 81, 84 and 92 percent, respectively. Stated another way, A-stamp cattle possess a higher probability of grading Choice or better thus explaining quality grade improvement to meet market specifications described above.

That development has also pervaded perception among various sectors. When asked about the definition and/or description of "genetics" (see Figure 6), "primarily black hided" was most cited response among retailers, food-service, packers and feeders. Meanwhile, secondary response among retailers, packers and feeders highlighted the category as "genetic potential for marbling"; the second most frequent response among the food-service sector being "primarily British". While those terms are somewhat innocuous, the implication is a reference to the rapid rise and ensuing success of Angus-based programs.

That outcome has largely underpinned price signals throughout the supply chain. Producers now have a variety of means to garner additional revenue from their respective management and genetic decisions over time. That's best illustrated by data available through Superior Livestock Video Market sales over time (Figure 7). Feeder calf market premiums and discounts for health management and cattle genetics are especially important. For example, a producer who invested in a VAC 45 program and possessed documentation for Angus-based loads would have received over $11/cwt in "premiums".

The business has begun to establish a self-reinforcing loop. Market signals have sufficiently worked to increase available supply for branded programs; in turn, that allows programs to build demand by providing volume assurances and/or price stability. Successful growth and promotion of breed-specific programs and ensuing product availability influences perception; meanwhile, perception mandates increased production of product derived from breed-specific programs. The outcome has been a sharp increase in the percentage of branded sales in recent years (Figure 8).

Meanwhile, the market is attempting to pull even more high-quality product into the harvest mix (Figure 9). The branded program spread has surpassed $20. Even more striking, the Prime/Select spread has experienced a sharp uptick in recent years with the 26-week moving average having tested $60/cwt (~$500/head). Those are important signals from a final-demand perspective; consumers are increasingly calling for high-quality, program-backed beef products.

Looking Ahead / Conclusion

Deming's core philosophy of quality and production revolved around the concept that any sub-process should be evaluated only in terms of its relative contribution to the entire system, not based upon segregated individual production merit or profit (Neave, 1990). Unfortunately, the beef industry is a good example of what occurs when the broader aim of the system is overlooked. History reveals that consumer indifference is devastating: the beef complex endured the 1980-to-1998 era with minimal consumer demand growth.

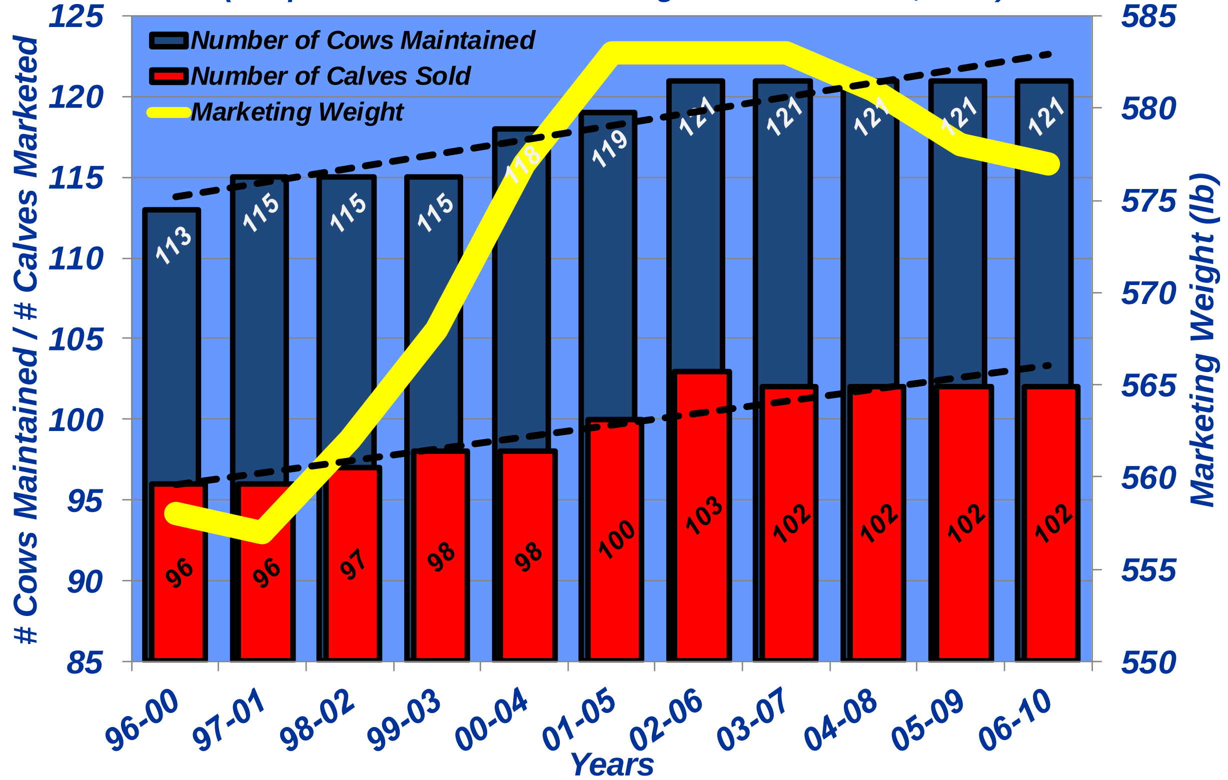
During that time the market signals were designed to reward only efficiency of production before cattle became the possession of the processor. The result was declining beef demand and challenging markets. The industry needed to refocus to reward both efficiency and encourage production of high-quality cattle, carcasses and the ensuing beef products.

Since that time, though, the beef industry has witnessed sharp improvement across all fronts. Gains in efficiency have been exceptional; production per cow has effectively reduced the need to maintain as many cows. That's dramatically reduced the industry's overall resource requirement and subsequent carbon footprint (Capper, 2011). Simultaneously, uniformity and tenderness no longer top the list among quality concerns. That's resulted in substantial enhancement in customer satisfaction proven to anchor spending – especially important given consumer fallout from the financial crisis in recent years.

That emphasis can't end there. The protein business, like all businesses, is highly competitive. The beef complex must produce and deliver consistent, high-quality products in an efficient manner to maintain competitiveness in the marketplace. Shifting consumer demand and market-channel influences by restaurants and retailers will increasingly mandate the need for responsive and efficient business models going forward. That equates to the need for even greater influence on genetic inputs and breeding systems that establish high-valued beef carcasses. Simultaneously, production management will also need to continually improve to ensure avoidance of shortfalls and maintain efficiency.

In combination, there will likely be increasing delineation around market premiums and discounts for producers to consider. As such, debate about the appropriateness of specific breeding systems separate from the context of evolving market signals and management priorities is somewhat misplaced. Well-designed, systematic crossbreeding systems can be, and are, valuable to both the producer and the industry. Simultaneously, though, opting out of such an approach isn't necessarily flawed. That's especially true when considering varying operational priorities, shifting market opportunities, new technology and selection tools all within the context of production capabilities of the current gene pool.

Figure 1. Moving Five-Year Averages:
 # Cows Maintained, # Calves Marketed, Marketing Weight
(Adapted from Kansas Farm Mgmt. Ass'n - KFMA, 2013)



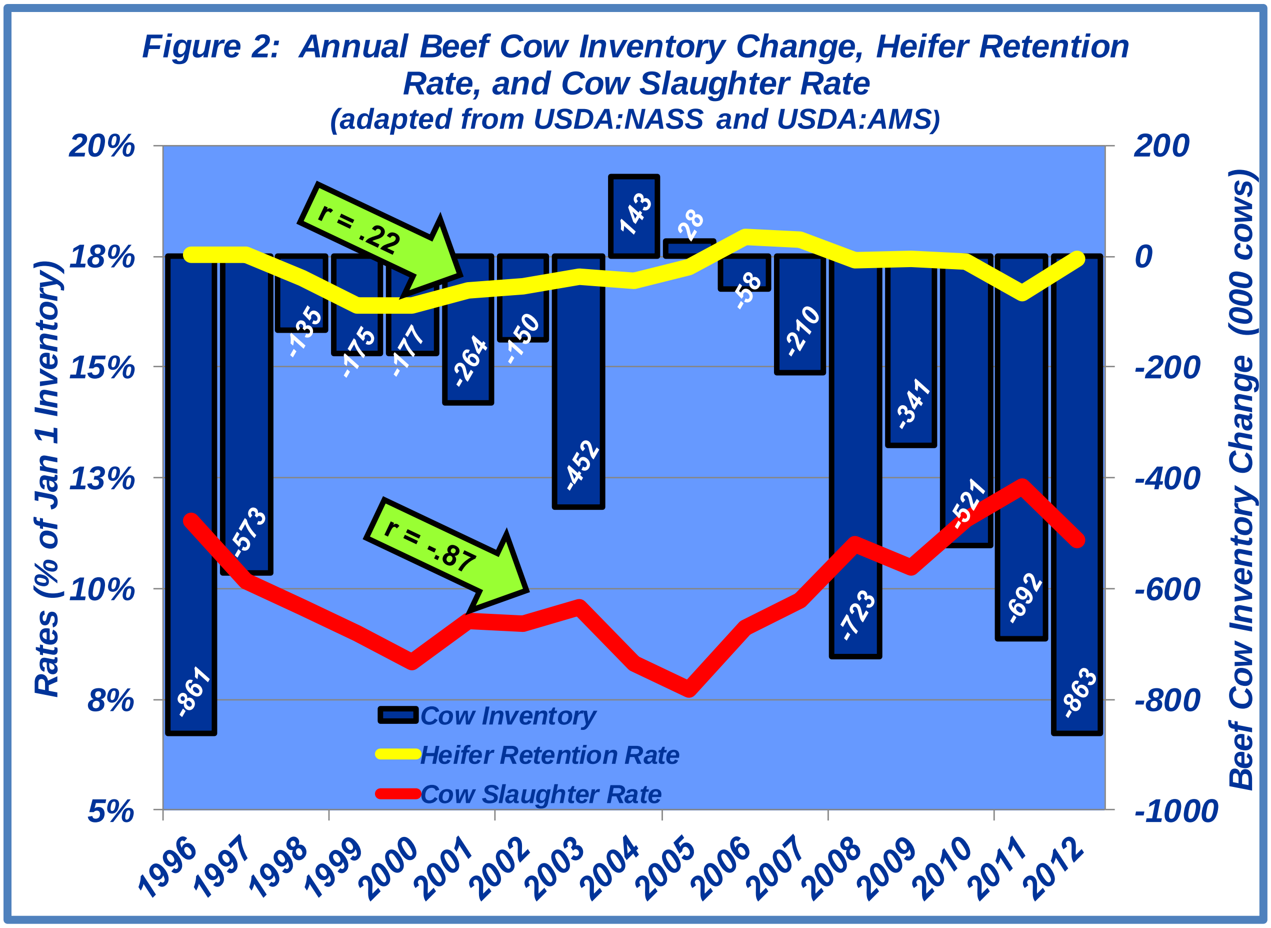


Figure 2: Annual Beef Cow Inventory Change, Heifer Retention Rate, and Cow Slaughter Rate
(adapted from USDA:NASS and USDA:AMS)
Rates (% of Jan 1 Inventory)
Beef Cow Inventory Change (000 cows)
20%
18%
15%
13%
10%
8%
5%
200
0
-200
-400
-600
-800
-1000
r = .22
r = -.87
-861
-573
-135
-175
-177
-264
-150
-452
143
28
-58
-210
-723
-341
-521
-692
-863
Cow Inventory
Heifer Retention Rate
Cow Slaughter Rate
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

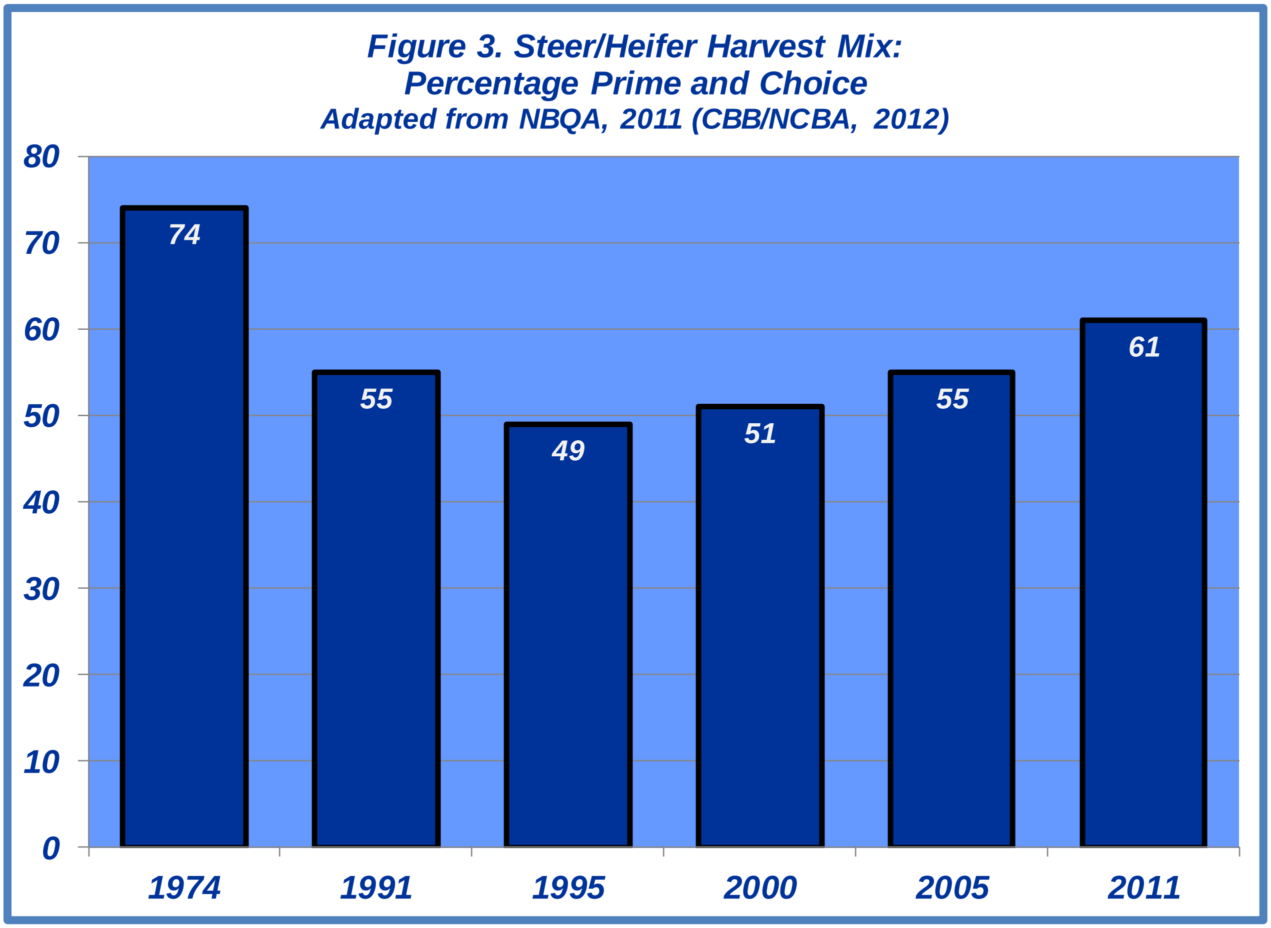


Figure 3. Steer/Heifer Harvest Mix:
Percentage Prime and Choice
Adapted from NBQA, 2011 (CBB/NCBA, 2012)
80
70
60
50
40
30
20
10
0
74
55
49
51
55
61
1974
1991
1995
2000
2005
2011

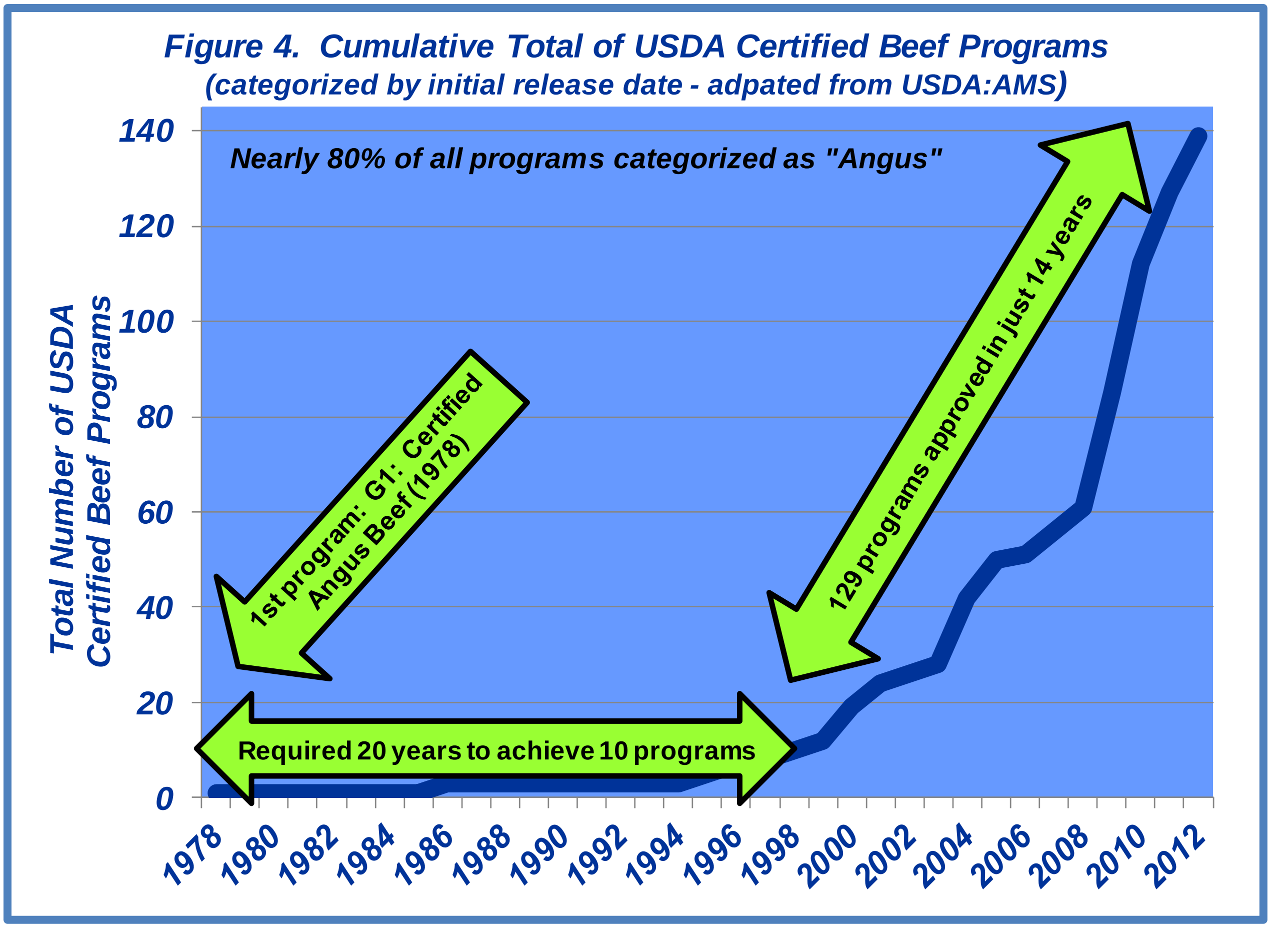


Figure 4. Cumulative Total of USDA Certified Beef Programs
(categorized by initial release date - adpated from USDA:AMS)
Nearly 80% of all programs categorized as "Angus"
1st program: G1: Certified Angus Beef (1978)
129 programs approved in just 14 years
Required 20 years to achieve 10 programs
Total Number of USDA Certified Beef Programs
140
120
100
80
60
40
20
0
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

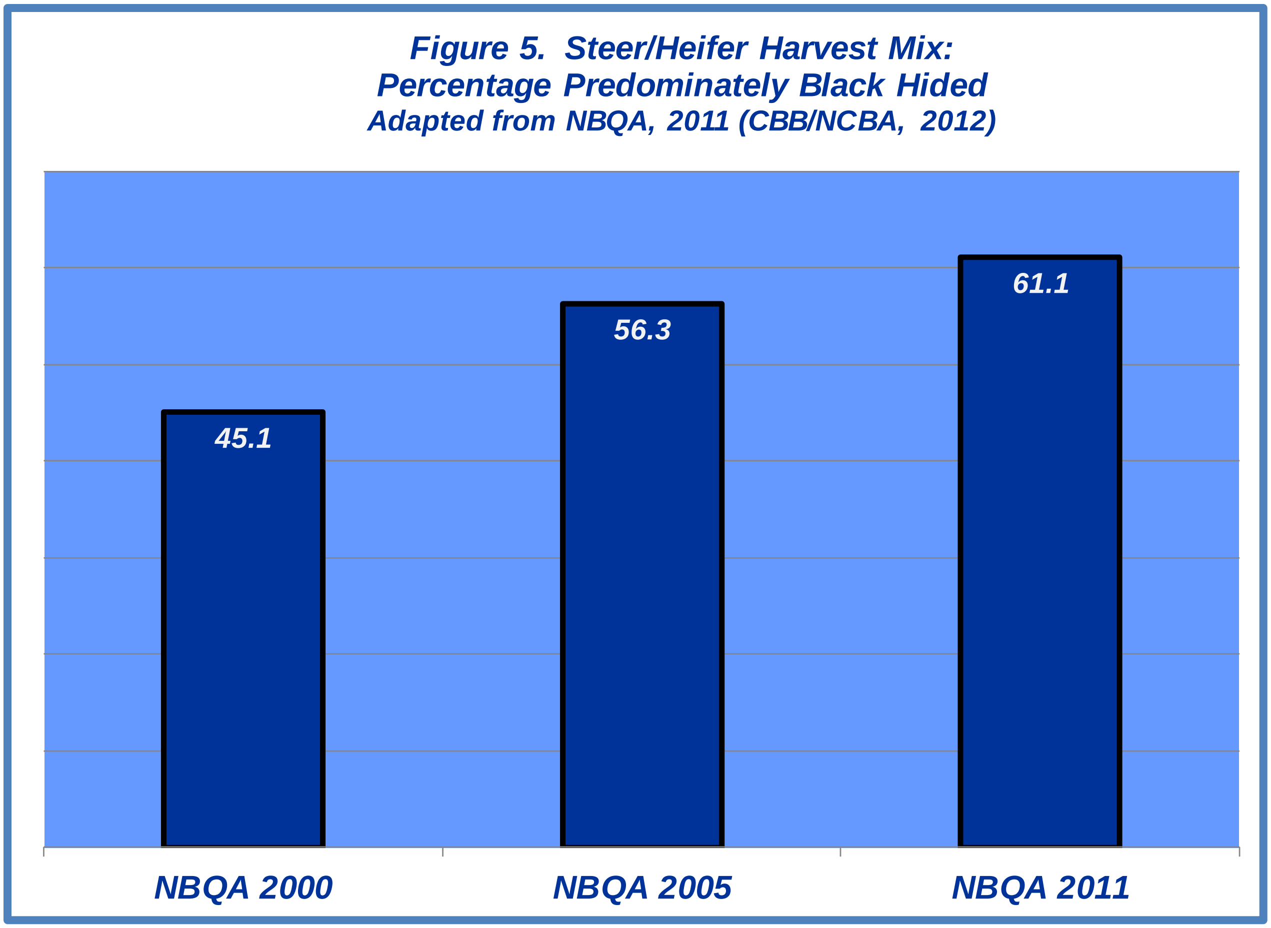


Figure 5. Steer/Heifer Harvest Mix:
Percentage Predominately Black Hided
Adapted from NBQA, 2011 (CBB/NCBA, 2012)
45.1
56.3
61.1
NBQA 2000
NBQA 2005
NBQA 2011

Figure 6. How Do Market Sectors Define / Describe "Genetics"?

2011 National Beef Quality Audit (CBB/NCBA, 2012)

Based on number of times each characteristic was mentioned as response to question

Retailers	Foodservice	Packers	Feeders	Government & Allied Industry
Primarily black hide	Primarily black hide	Primarily black hide	Predominately black hide	Quality genetics
Genetic potential for marbling	Primarily British	Genetic potential for marbling	Genetic potential for marbling	Genetic potential for marbling
NOT Bos indicus	NOT dairy type	Primarily British	Genetic potential to gain	EPDs

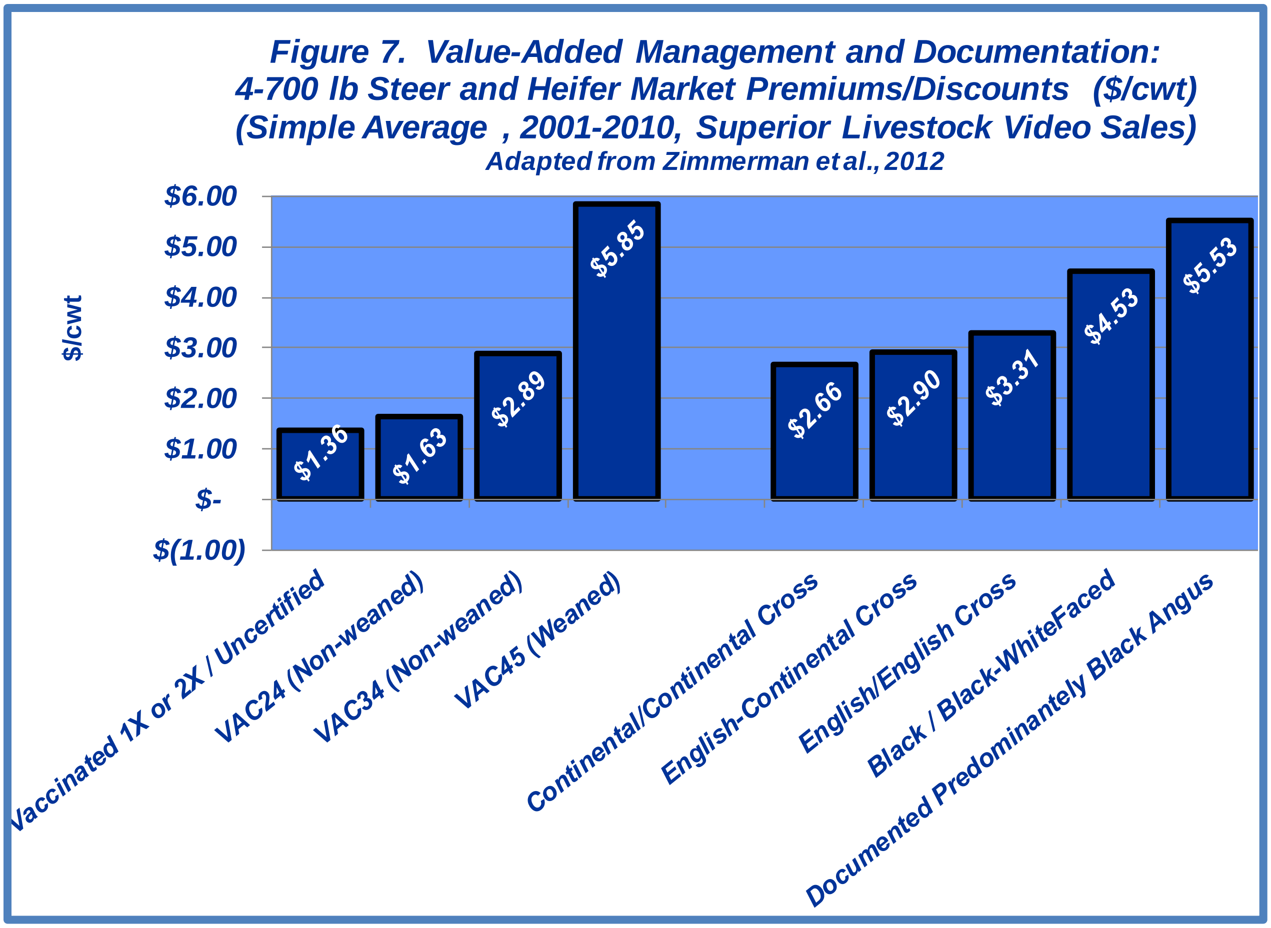


Figure 7. Value-Added Management and Documentation:
4-700 lb Steer and Heifer Market Premiums/Discounts ($/cwt)
(Simple Average , 2001-2010, Superior Livestock Video Sales)
Adapted from Zimmerman et al., 2012
$/cwt
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$-
$(1.00)
$1.36
$1.63
$2.89
$5.85
$2.66
$2.90
$3.31
$4.53
$5.53
Vaccinated 1X or 2X / Uncertified
VAC24 (Non-weaned)
VAC34 (Non-weaned)
VAC45 (Weaned)
Continental/Continental Cross
English-Continental Cross
English/English Cross
Black / Black-WhiteFaced
Documented Predominantely Black Angus

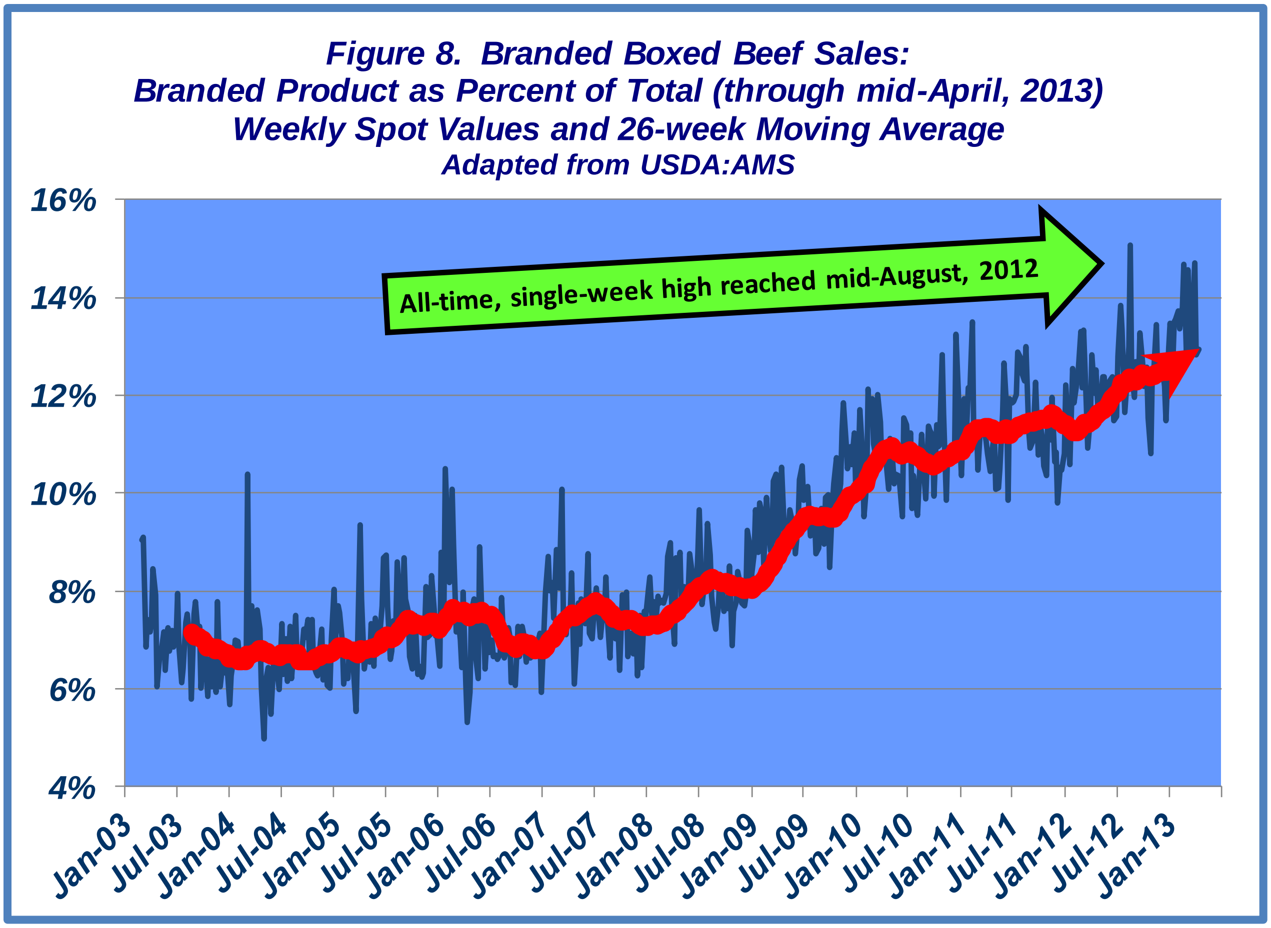


Figure 8. Branded Boxed Beef Sales:
Branded Product as Percent of Total (through mid-April, 2013)
Weekly Spot Values and 26-week Moving Average
Adapted from USDA:AMS
All-time, single-week high reached mid-August, 2012
16%
14%
12%
10%
8%
6%
4%
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13

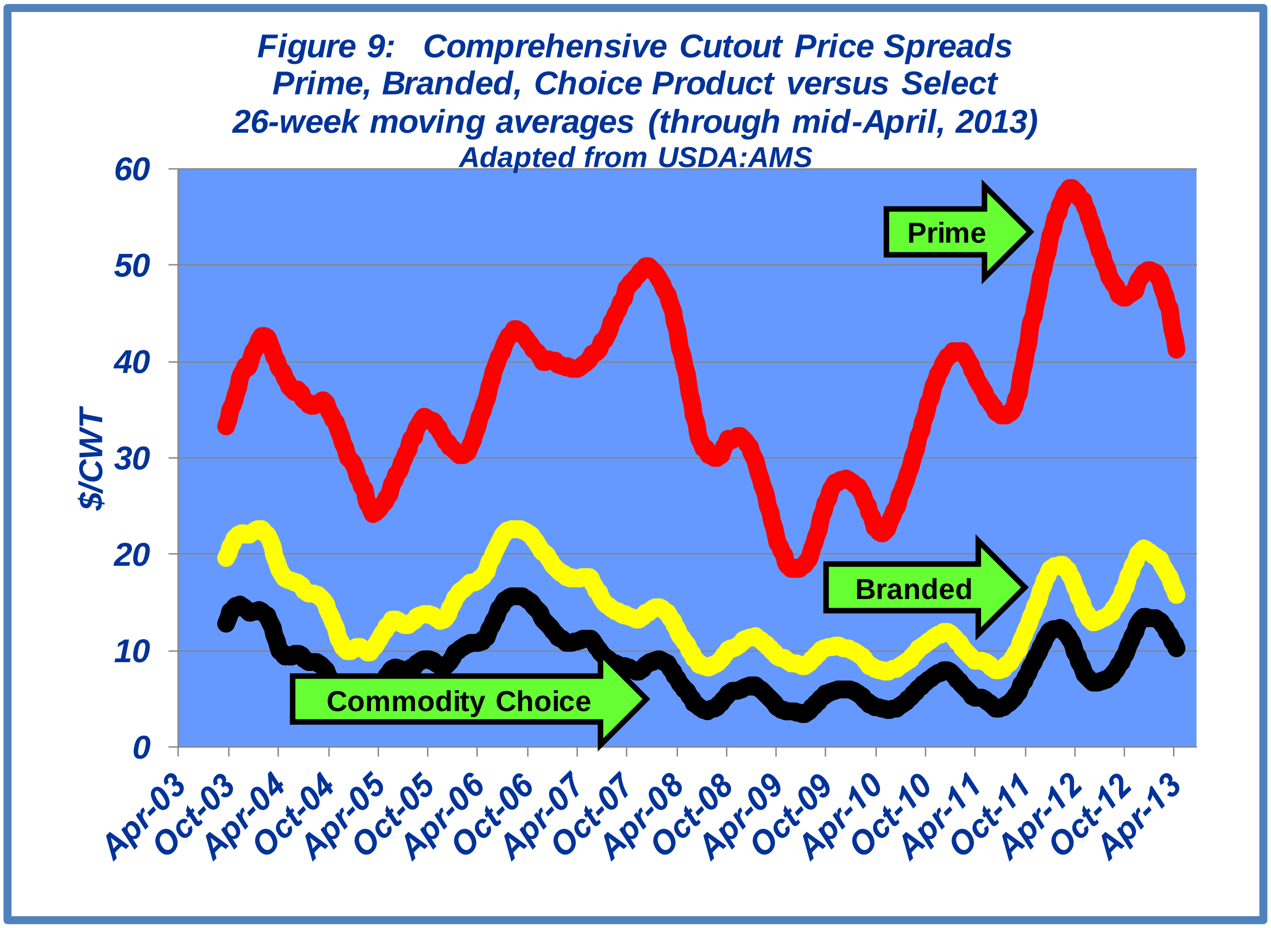


Figure 9: Comprehensive Cutout Price Spreads
Prime, Branded, Choice Product versus Select
26-week moving averages (through mid-April, 2013)
Adapted from USDA:AMS
$/CWT
60
50
40
30
20
10
0
Prime
Branded
Commodity Choice
Apr-03
Oct-03
Apr-04
Oct-04
Apr-05
Oct-05
Apr-06
Oct-06
Apr-07
Oct-07
Apr-08
Oct-08
Apr-09
Oct-09
Apr-10
Oct-10
Apr-11
Oct-11
Apr-12
Oct-12
Apr-13

Literature Cited

BEEF®, 2010. *Cattle Production Genetics 2010*. Penton Media. Minneapolis, MN.

Brinks, J.S., N.C. Speer, D.W. Schafer, D.G. LeFever and J.L. Moon. 1990. *Factors affecting pregnancy rates to synchronized breeding: repeatability and heritability estimates.* Beef Program Report, Colorado State University, Department of Animal Sciences, Ft. Collins, CO.

Capper, J. 2011. *The environmental impact of beef production in the United States: 1977 compared with 2007.* J. Anim. Sci. 89:4249-4261.

Emerson, M.R., D.R. Woerner, K.E. Belk and J.D. Tatum. 2012. *Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes.* J. Anim. Sci. 91:1024-1034

KFMA. 2013. Enterprise summaries by year: beef cows – sell calves. Kansas Farm Management Association, Kansas State University. Retrieved April 30, 2012 from: http://www.agmanager.info/kfma/

LMIC. 2012. Cattle operation size data sourced from USDA. Livestock Marketing Information Center. Denver, CO.

Marsh, J.M. 2003. *Impacts of declining U.S. retail beef demand on farm-level beef prices and production.* Am. J. Agri. Econ. 85(4): 902-913

Neave, H.R. 1990. The Deming Dimension. SPC Press, Knoxville, TN.

CBB and NCBA, 2001. National Beef Quality Audit – 2000. Cattlemen's Beef Board and National Cattlemen's Beef Association. Centennial, CO.

CBB and NCBA, 2012. National Beef Quality Audit – 2011. Cattlemen's Beef Board and National Cattlemen's Beef Association. Centennial, CO.

Parish, J. 2012. *Cattle Business in Mississippi – Beef Production Strategies: Crossbred Cows 101*. Mississippi State University, February, 2012. Retrieved April 30, 2012 from: http://msucares.com/livestock/beef/mca_feb2012.pdf

Purcell, W.D. 2002. *Communicating value to cattle producers: Issues, opportunities and looking ahead.* J. Anim. Sci. 80(E. Suppl. 1):E87-E93

Reiman, M. 2013. *Older vs. better cows.* Angus Beef Bulletin. February, 2013. P118. Angus Productions, Inc. St. Joseph, MO

Speer, N.C. 2011. *Crossbreeding: Considerations and Alternatives in an Evolving Market*. Published through Certified Angus Beef, Wooster, OH.

Speer, N.C. 1993. *Genetic relationships between sex-specific traits in a crossbred beef cattle population*. PhD Dissertation, Colorado State University, Department of Animal Sciences, Ft. Collins, CO.

Tess, M.W., K.C. Davis and M.D. MacNeil. 2013. *Effects of sire selection for carcass quality on female reproduction.* In: Annual Report Bair Ranch Foundation, Billings MT

USDA:NAHMS, 2009a. *Beef 2007 – 08 Part II: Reference of Beef - calf management practices in the United States, 2007-08*. Retrieved April 30, 2012 from: http://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/beef0708/Beef0708_dr_PartII.pdf

USDA:NAHMS, 2009b. *Beef 2007 – 08 Part IV: Reference of Beef - calf management practices in the United States, 2007-08*. Retrieved April 30, 2012 from: http://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/beef0708/Beef0708_dr_PartIV.pdf

USDA:NASS. 2013. United States Department of Agriculture, National Agriculture Statistics Service.

USDA:AMS. Agricultural Marketing Service. United States Department of Agriculture, Washington, DC.

Zimmerman, L.C., T.C. Schroeder, K.C. Dhuyvetter, K.C. Olson, G.L. Stokka, J.T. Seeger and D.M. Grotelueschen. 2012. *The effect of value-added management on calf prices at Superior Livestock Auction video markets.* J. Ag. and Res. Econ. 37(1):128-143.

Breeding Programs from a Cattle Feeder's Perspective

J. Tom Brink[1]

[1]*President, J&F Oklahoma Holdings, Inc.*

View From Here

J&F Oklahoma Holdings, Inc. feeds over 1.6 million cattle each year in Five Rivers Feed yards. These cattle originate in nearly all of the 50 States, Mexico, and Canada. We regularly feed some of the very best cattle found in North America. We also feed some of the worst. If you would like to understand what the beef industry is really doing when it comes to breeding programs, take a two-week trip and visit as many feed yards as you possibly can. Drive the alleys and look at hundreds of pens of cattle. What you will encounter is what we deal with every single day (both for better and worse). There are many good ranchers and farmers across America who raise outstanding cattle. They know what they are doing. Their cattle grow and grid exceptionally well. Unfortunately, there appears to be about twice as many producers that have no idea how to structure an effective breeding program.

Witnessing this situation over the past 15 years has convinced me of this:

(1) Planned crossbreeding is not the problem
(2) Planned straight breeding is not the problem
(3) Breeding cattle without any consistent plan is the PROBLEM!

Let's be clear about this. Both crossbreeding and straight breeding can be done well, or done poorly. The risk with crossbreeding is that (while seeking heterosis) the producer will bounce around from one sire breed to the next, buy a dozen crossed up cows from one location and another group somewhere else. They end up with a lot of hybrid vigor and very little value and consistency in their calf crops. We see lots of cattle like this, and it is not just a problem with part-time producers or small herds. There are way too many 200+ head cowherds that are following unplanned and/or poorly executed crossbreeding programs, with disappointing results. Crossbreeding for the sake of crossbreeding is not what we need in this industry.

The risk with straight breeding (besides giving up heterosis) is that the wrong breed may be chosen, or even if the correct breed is utilized (Angus, or maybe Red Angus), the right genetics within that breed may not be employed. Effective straight breeding with Angus requires the use of cattle with cow traits as well as elite growth and carcass genetics. Those genetics are increasingly available, but not yet on every street corner.

Probably because of all the genetically mediocre and poor cattle that come through our system, I will readily applaud any producer who follows a well-conceived breeding plan year after year. He or she may be using structured crossbreeding. That is admirable. They may be using hybrid bulls in a disciplined way. I am okay with that. Or they may be straight breeding and targeting excellent feedyard performance and high quality grades. A program like that can work well too.

As long as there is a logical breeding plan and the resulting calf crop offers consistency and value, the industry should accept that there is more than one path to success. In baseball, most batters hit right handed. They represent the planned crossbreeding group. A smaller-percentage hit left-handed. These are producers following a straight breeding plan. We should not coach each and every producer to bat right handed by telling them that crossbreeding is the only solution. Each producer line up on the side of the plate where they feel most comfortable, and go hit the ball! A solid base hit is analogous to a calf crop that stays healthy, grows fast and efficiently in the feed yard, and ultimately produces a valuable carcass that will satisfy consumer demands.

Value of Top-End Genetics

A few months ago, I asked Five Rivers' feed yard managers to quantify the performance of the top 10% to 15% of the genetics they feed. We put the numbers together and compared them to our average cattle performance. Both sets of numbers below are for yearling steers placed at 750 to 800-lbs.

	ADG	Dry Feed/Gain	Grid
Average Performers	3.40 lbs.	6.00 lbs.	+$20
Top 10%-15% Performers	4.75 lbs.	5.25 lbs.	+$85

Source: Five Rivers Cattle Feeding

At current market prices and production costs, the value of this better feeding performance is equivalent a whopping $154 per head. There is an additional $65 per head difference in grid value.* The total economic advantage for the top performing cattle is +$219 per head. Let me repeat this: the best cattle we feed outperform the average animal by $219 per head. Astounding! The leading edge of the U.S. beef industry's genetics is now able to create dramatically more value than we could have dared to dream about in the past. This is a game changer. First, it illustrates what is possible today with the best of the best genetics. Secondly, it says we can now pay much higher prices for feeder cattle and calves that are known to create exceptional value in the feedyard and packing plant. That is exactly what is starting to happen in the marketplace. Larger and larger premiums are being paid for top-end genetics at all levels in the system.

*U.S. Premium beef reported that the top 25% of their harvested cattle generated a $116 grid premium in 2012.[2]

Economics of Crossbreeding and Straight Breeding

Older data suggests an increase in calving rate of almost 4%, an increase in longevity of more than one year, and a lifetime increase of 600 pounds of cumulative weaning weight in *Bos Taurus* crossbred dams.3 Such an increase is beneficial indeed. However, there would be additional expenses to pay in capturing these extra pounds. For the sake of simplicity, I will assume this can be accomplished with one additional year's carrying cost of $600 per cow. We therefore spend another $600 to capture 600 more pounds of weaned calf, which nets a $300 profit over the cow's lifetime at a $150/cwt. average calf price. Not bad.

Interestingly, however, such results can be duplicated with a high-end Angus straight-breeding program. As shown above, stacking top growth and carcass genetics can result in cattle that are worth $200+ per head over the industry average animal. Suppose a straight-bred cow produces five such high-value offspring in her lifetime; she has created $1000 in extra value potential. If a cow-calf producer can capture just a 30% of this value, they have matched the crossbreeding advantage.

Some will argue that my numbers should be a little different a one point or another in this comparison. That is fine. One set of number crunching would show a net advantage for crossbreeding, while another will favor straight breeding. There are many unique situations to consider, not the least of which is geography and forage/feed resources. The key takeaway, however, is that these two approaches to breeding beef cattle are financially closer together than many people think. My personal belief is that structured crossbreeding should be the breeding program of choice for a majority of U.S. cow/calf producers. However, I also believe that straight breeding is appropriate for others who are serious about creating high-performance, high value calves that will top the market and be highly demanded by cattle feeders. This appears to be the reason why a significant number of producers forgo known advantages of crossbreeding to pursue a different path they find equally rewarding.

Literature Cited

[2] U.S. Premium Beef, 2012 Annual Report.

[3]A. Van Eenennaam, *Does Crossbreeding Still Work?* California Cattlemen, May 2013.

Crossbreeding-One of the Tools to Increase Profitability

Bob Weaber, Ph.D.[1]*, and Matt Spangler, Ph.D.*[2]

[1]*Kansas State University,* [2]*University of Nebraska-Lincoln*

There are a multitude of issues currently facing National Cattle Evaluation, and thus numerous researchable questions that need answers in order to advance the tools used by seedstock and commercial bull buyers alike. Among these are the refinements of methodology for the inclusion of genomic information into NCE, the development of bio-economic index values that include more input traits, and the development of genetic predictors for novel traits such as feed intake, disease susceptibility, and others. Instead, in 2013, US Beef Producers representing a > $79 billion industry find themselves in a circular debate over the benefits of exploiting non-additive genetic effects in the pursuit of profitability. Despite well-documented benefits of heterosis and breed complementarity, the majority of germplasm utilized in the US has migrated towards a single breed. In 2012, the National Association of Animal Breeders (NAAB) reported that Angus semen accounted for over 74% of domestic semen sales. The second most was Simmental with 8.4% of the semen sales market. As a point of reference, domestic dairy semen sales are dominated by Holstein (86.7%) followed by Jersey (10.7%). The 2011-2012 report from the National Pedigreed Livestock Council (NPLC) summarized the annual registrations of 15 beef breeds. From this, 47.8% of registered beef cattle were Angus. From 1995 to 2010, the percentage of fed cattle marketed that were black hided doubled reaching 64%. Furthermore, some surveys have suggested that upwards of 60% of bull turn out is Angus. Although a uniform distribution of semen sales and breed registrations is not expected, nor necessarily desired, some degree of balance relative to commercial bull breed composition is beneficial.

The lack of utilization of crossbreeding can be broken down into those issues that are logistical in nature and those that represent a knowledge gap. Logistical issues revolve around developing a sustainable crossbreeding system that optimizes resources with gains in breed complementarity and heterosis. Failed crossbreeding programs can often be attributed to unnecessary complexity and failures in planning and implementation. Knowledge gaps exist relative to the biological benefits of heterosis, implementation of crossbreeding, and the economic benefits of crossbreeding. One of the most incorrect assumptions regarding heterosis is the inability to maintain phenotypic uniformity. Data from the US Meat Animal Research Center (USMARC) has illustrated (see Table 1) the similarity in the coefficient of variation for several growth and carcass traits between composites and their purebred contemporaries (Gregory et al., 1999).

The pervasive thought that one breed can excel in all areas of production in a segmented and geographically diverse industry is simply not logical. Every breed has strengths and weaknesses relative to an individual firm's production and marketing goals. That is the benefit of crossbreeding, blending strengths from various breeds to meet production goals while fitting within environmental constraints, and heterosis becomes the reward for having done so. Consequently, knowledge of current breed differences, not historic generalizations, and honest accounting of environmental constraints coupled with identified marketing goals are among the first steps in developing a sustainable and profitable breeding system.

Table 1. Coefficients of variation for purebred vs. composite steers[a]

Trait	Purebreds	Composites
Birth weight	0.12	0.13
Wean weight	0.10	0.11
Carc. weight	0.08	0.09
Retail Product %	0.04	0.06
Marbling	0.27	0.29
Shear Force	0.22	0.21

[a]Adapted from Gregory et al., 1999.

Large differences exist today in the relative performance of various breeds for most economically important traits. These breed differences represent a valuable genetic resource for commercial producers to use in structured crossbreeding systems to achieve an optimal combination of traits matching the cowherd to their production environment and to use sire selection to produce market-targeted progeny. As such, the selection of the 'right' breed(s) to use in a breeding program is an important decision for commercial beef producers. The determination of the 'right' breed(s) to use is highly dependent on a number of characteristics of a farm or ranch such that not every operation should use the same breed or combination of breeds.

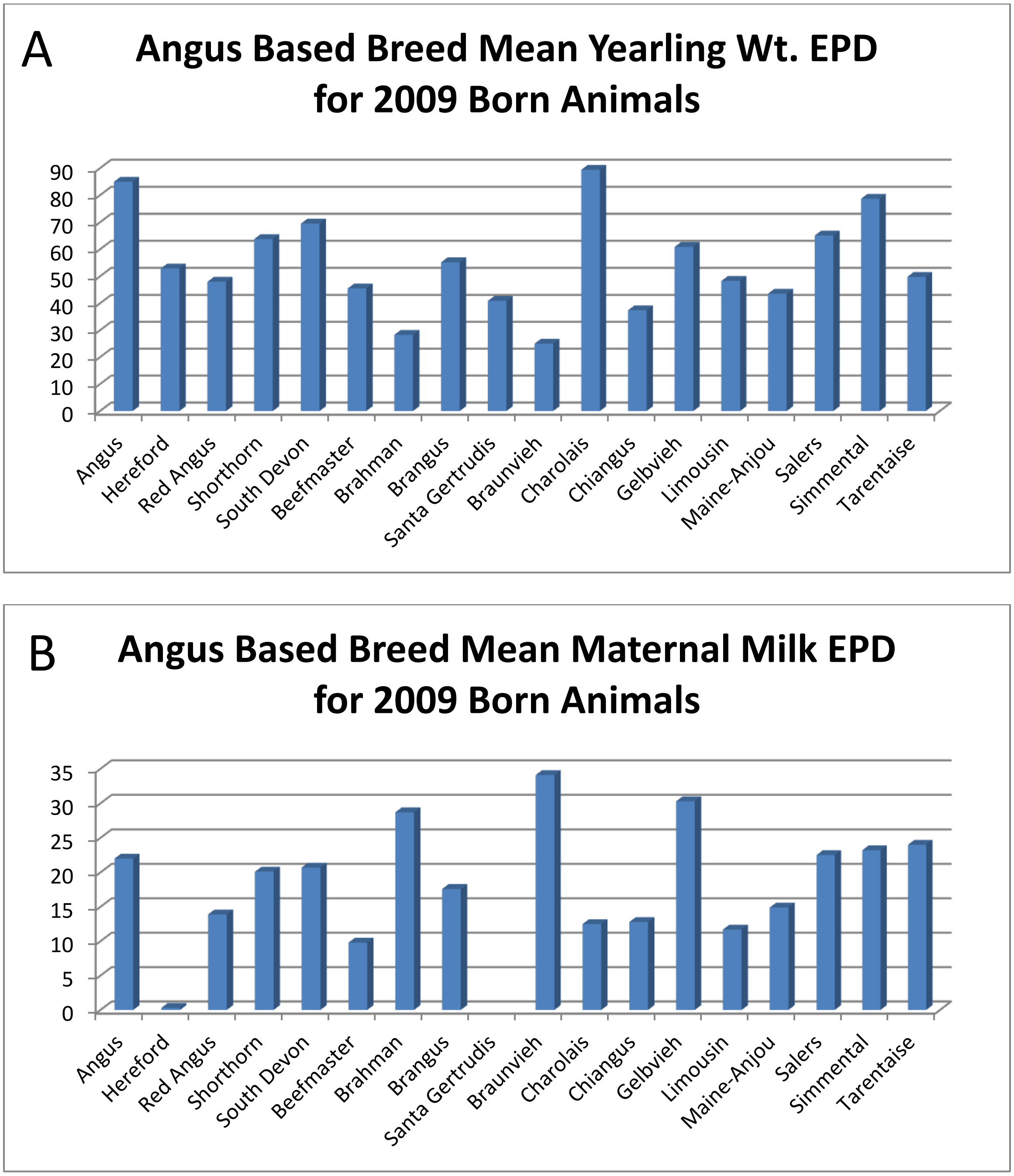
Beef Breed and Composite Characterization

A great deal of research has been conducted over the last 30 years at various federal and state experiment stations to characterize beef breeds in the U.S. . These studies have been undertaken to examine the genetic merits of various breeds in a wide range of production environments and management systems. During this time, researchers at the U.S. Meat Animal Research Center (MARC) have conducted the most comprehensive studies of sire breed genetic merit via their long term Germplasm Evaluation (GPE) project. This project evaluated over 30 sire breeds in a common environment and management system. The data summarized by the MARC scientists consisted of records on more than 20,000 animals born between 1978 and 1991, with a re-sampling of the most popular sire breeds in 1999-2000. The various sire breeds evaluated were mated to Angus, Hereford and crossbred cows. Thus, the data reported were for crossbred progeny. During the study, Angus-Hereford crossbred calves were produced in the study as a control for each cycle of the GPE project.

One of the major outcomes of the GPE project was the characterization of sire breeds for a wide variety of economically important traits. Because all of the animals were in a common management system and production environment, the average differences observed in performance were due to genetic differences. Following the analysis of progeny data, the breeds can be divided into groups based on their biological type for four criteria: 1) Growth rate and mature size 2) Lean to fat ratio 3) Age at puberty, and, 4) Milk production. The breeds evaluated at MARC are grouped by biological type in Table 2. Historically, British breeds such as Hereford, Angus, Red Angus and Shorthorn have been evaluated as moderate in growth and mature size, relatively higher in carcass fat composition, reach puberty at relatively younger ages and are moderate in milk production. However, with the dramatic changes growth rate and lactation potentials of several popular British breeds, these views need updated. Contemporary evaluations of lactation potential and growth rate to a yearling endpoint suggest that some British breeds have closed the gap that once existed between British and Continental breeds. Figure 1 panel A and B illustrate the Angus based breed mean Yearling Weight and Maternal Milk EPD for 2009 born animals for a number of breeds resulting from the application of the US MARC 2012 across-breed EPD adjustment factors. Continental European breeds, with a heritage that includes milk production, including Simmental, Maine-Anjou, and Gelbvieh tend to have high growth rates, larger mature sizes, moderate ages at puberty and relatively high levels of milk production. Another group of Continental European breeds, with a heritage of meat and draft purposes, including Charolais, Chianina and Limousin tend to have high growth rate, large mature size, older ages at puberty, very lean carcasses and low milk production. Cundiff et al. (2007) summarized a large body of data collected at US MARC for a variety of traits. The most recent reported sampling of breed germplasm suggests that there are no differences among the major British and Continental breeds for mature weight of cows with the exception of Gelbvieh sired cows, which were significantly lighter. Angus and Simmental sired calves had similar final carcass weights. These results stand in stark contrast to observations made among these breeds 30 years earlier (Cundiff et al., 2007). Although the convergence of breed means might erode complementarity, it does not mean we have witnessed and erosion in heterosis.

Another way to compare the relative genetic merit of breeds for various performance traits is through conversion of their EPD to a common base. This can be accomplished using the across breed EPD adjustments published each year in the proceedings of the Beef Improvement Federation's annual meeting. These adjustments are generated by researchers at MARC. Table 3 presents the average across breed EPD of animals born in 2010 as reported from 2011 genetic evaluations from the most widely used breeds on a common genetic base (Angus). Differences in across breed EPD averages represent genetic differences for each trait. Table 3 provides a more contemporary look at the differences in breed genetic potential for various traits and accounting for genetic trends occurring in each breed due to selection. Due to selection pressure placed on growth and maternal traits over time, many breeds have made considerable gains in those traits. In some cases, the large gains in performance have resulted in subtle changes in the overall biological type of a breed.

Figure 1. Angus based breed mean Yearling Wt. and Maternal Milk EPD.[a]



[a]Adapted from breed means (Kuehn and Thallman, 2012a) and Across Breed EPD Adjustment factors (Kuehn and Thallman, 2012b).

Table 2. Breeds grouped into biological type by four criteria.[a,b]

Breed Group	Growth rate and mature size	Percent retail product	Age at puberty	Milk production
Jersey	X	X	X	XXXXX
Longhorn	X	XXX	XXX	XX
Angus	XXX	XX	XX	XXX
Hereford	XXX	XX	XXX	XX
Red Poll	XX	XX	XX	XXX
Devon	XX	XX	XXX	XX
Shorthorn	XXX	XX	XXX	XXX
Galloway	XX	XXX	XXX	XX
South Devon	XXX	XXX	XX	XXX
Tarentaise	XXX	XXX	XX	XXX
Pinzgauer	XXX	XXX	XX	XXX
Brangus	XXX	XX	XXXX	XX
Santa Gertrudis	XXX	XX	XXXX	XX
Sahiwal	XX	XXX	XXXXX	XXX
Brahman	XXX	XXX	XXXXX	XXX
Nellore	XXX	XXX	XXXXX	XXX
Braunvieh	XXXX	XXXX	XX	XXXX
Gelbvieh	XXXX	XXXX	XX	XXXX
Holstein	XXXX	XXXX	XX	XXXXX
Simmental	XXXXX	XXXX	XXX	XXXX
Maine Anjou	XXXXX	XXXX	XXX	XXX
Salers	XXXXX	XXXX	XXX	XXX
Piedmontese	XXX	XXXXX	XX	XX
Limousin	XXX	XXXX	XXXX	X
Charolais	XXXXX	XXXX	XXXX	X
Chianina	XXXXX	XXXX	XXXX	X

[a]Adapted from Cundiff et al., 1993
[b] Increasing number of X's indicate relatively higher levels of trait

Table 3. Average Across-Breed EPD for animals born in 2009 by breed from 2011 genetic evaluations and 2012 US-MARC Across-Breed EPD adjustment factors[a].

	Birth Wt. EPD	Weaning Wt. EPD	Yearling Wt. EPD	Maternal Milk EPD
Angus	1.8	47	85	22
Hereford	6.3	41.2	52.9	0.3
Red Angus	2.3	31.4	48	13.9
Shorthorn	8.4	30.7	63.8	20.1
South Devon	6.8	43.7	69.5	20.7
Beefmaster	7	43.3	45.5	9.8
Brahman	12.8	57.2	28.3	28.7
Brangus	4.4	36	55.2	17.6
Santa Gertrudis	8	42.7	40.9	
Braunvieh	4	21.7	25	34.1
Charolais	9.2	64.3	89.4	12.5
Chiangus	5.3	21.9	37.4	12.8
Gelbvieh	5.2	45.7	60.9	30.3
Limousin	5.3	44.5	48.3	11.7
Maine-Anjou	5.8	26.4	43.6	14.9
Salers	3.6	38.2	65.1	22.5
Simmental	5.9	55.7	78.7	23.2
Tarentaise	3.6	49.1	49.8	24

[a]Adapted from Kuehn and Thallman, 2012a,b

Use of Breeds and Composites for Genetic Improvement

Inclusion or exclusion of germplasm from a breed (or composite) is a valuable selection tool for making rapid directional changes in genetic merit for a wide range of traits. Changes in progeny phenotype that occur when breeds are substituted in a breeding program come from two genetic sources.

The first source of genetic impact from a substitution of a breed comes through changes in the additive genetic effects or breeding values that subsequent progeny inherit from their sire and dam. Additive genetic merit is the portion of total genetic merit that is transmissible from parent to offspring and on which traditional selection decisions are made. In other words, additive genetic effects are heritable. EPD are estimates of one-half of the additive genetic merit. The difference in average performance for a trait observed between two breeds is due primarily to differences in additive genetic merit.

The second source of genetic change is due to non-additive genetic effects. Non-additive effects include both dominance and epistatic effects. Dominance effects arise from the interactions of paired genes at each locus. Epistatic effects are the interaction of genes across loci. The sum of these two interactions result in heterosis observed in crossbred animals. Since each parent only contributes one gene to an offspring and dominance effects depend on the interaction of a pair of genes, a parent cannot transmit dominance effects to its progeny within a breed. However, the selection of which breeds and how much of each breed to incorporate into progeny has a large impact on dominance (or heterosis) effects which affect phenotype. Because epistatic effects arise from the interaction of genes at different loci, independent segregation of chromosomes in the formation of gametes causes pairings of genes not to always stay together from one generation to the next. Like dominance effects, epistatic effects are not impacted by mate selection but by the frequency of different alleles and their dominance effects across breeds.

Both additive and non-additive genetic effects can have a significant impact on a particular phenotype; therefore, it is important that both are considered during breed selection. Due to their different modes of inheritance, different tactics must be employed to capture the benefits of each.

Additive genetic merit may be selected for in two distinct ways. First, by the selection of individuals within a breed which have superior genetic merit for the trait under selection. Typically this is achieved through the use of EPD to identify selection candidates, although it can also be done through selection for specific alleles using DNA markers. The rate of improvement in phenotypes due to selection within breed is limited by the heritability of the trait. Heritability describes the proportion of phenotypic variation that is controlled by additive genetic variation. So, for traits with moderate to high heritability, considerable progress in progeny phenotype may be achieved through selection of superior animals within the breed as parent stock. The second approach to change additive genetic merit is through the selection of animals from a different breed(s) that excels in the trait under selection. Across breed selection can provide rapid change in progeny phenotype given that large differences exist between breeds in a number of economically relevant traits. Selection of superior parent stock from a different breed that excels in a trait is often more effective than selection within a breed (Gregory et al., 1999) as the breed differences have a heritability of nearly 100%.

The use of breed differences to achieve the best overall results across multiple traits may be achieved through the utilization of breed complementarity. Breeds are complementary to each other when they excel in different traits and their crossbred progeny have desirable levels of performance in a larger number of traits than either of the parent breeds alone. Making breed and mating selections that utilize breed complementarity provide an effective way to aggregate the core competencies of two or more breeds in the progeny. Moreover, use of breed complementarity can be a powerful strategy to genetically match cows to their production environment and progeny to the market place. For example, a crossbreeding system that mates Charolais bulls to Hereford-Angus crossbreed cows utilizes breed complementarity. The Charolais bull contributes growth and carcass yield to progeny genetics while the Hereford-Angus crossbred cows have many desirable maternal attributes and contribute genetics for carcass quality. When considering crossbreeding from the standpoint of producing replacement females, one could select breeds that have complementary maternal traits such that females are most ideally matched to their production environment. Matings to produce calves for market should focus on complementing traits of the cows and fine tuning calf performance (growth and carcass traits) to the market place.

One of the challenges of breed selection is the interaction of the animal's genotype with its production environment. Table 4 describes common production environments by level of feed availability and environmental stress and lists optimal levels of a variety of performance traits (Gosey, 1994). Here, feed availability refers to the regular availability of grazed or harvested forage and its quantity and quality. Environmental stress includes parasites, disease, heat and humidity. Ranges for mature cow size are low (800 to 1,000 lb.), medium (1000 to 1,200 lb.), and high (1,200 to 1,400 lb.) Clearly, breed choices should be influenced by the production environment in which they are expected to perform.

Table 4. Matching Genetic Potential for Different Traits to Production Environments[1]

Production Environment		Traits					
Feed Availability	Stress[2]	Milk Production	Mature Size	Ability to Store Energy[3]	Resistance to Stress[4]	Calving Ease	Lean Yield
High	Low	M to H	M to H	L to M	M	M to H	H
	High	M	L to H	L to H	H	H	M to H
Medium	Low	M to H	M	M to H	M	M to H	M to H
	High	L to M	M	M to H	H	H	H
Low	Low	L to M	L to M	H	M	M to H	M
	High	L to M	L to M	H	H	H	L to M
Breed role in terminal crossbreeding systems							
Maternal		M to H	L to H	M to H	M to H	H	L to M
Paternal		L to M	H	L	M to H	M	H

L = Low; M = Medium; H = High.
[1]Adapted from Gosey, 1994.
[2]Heat, cold, parasites, disease, mud, altitude, etc.
[3]Ability to store fat and regulate energy requirements with changing (seasonal) availability of feed.
[4]Physiological tolerance to heat, cold, internal and external parasites, disease, mud, and other factors.

Crossing of breeds or lines is the primary method to exploit beneficial non-additive effects called heterosis. Heterosis refers to the superiority of the crossbred animal relative to the average of its straightbred parents and heterosis results from an increase in heterozygosity of a crossbred animal’s genetic makeup. Heterozygosity refers to a state where an animal has two different forms of a gene. It is believed that heterosis is primarily the result of gene dominance and the recovery from accumulated inbreeding depression of pure breeds. Heterosis is, therefore, dependent on crossbred animals having a greater percentage of heterozygous animals than is present in straightbred animals. The level of heterozygosity an animal has depends on the random inheritance of copies of genes from its parents. In general, animals that are crosses of unrelated breeds, such as Angus and Brahman, exhibit higher levels of heterosis due to more heterozygosity, than do crosses of more genetically similar breeds such as a cross of Angus and Hereford.

Generally, heterosis generates the largest improvement in lowly heritable traits (Table 5). Moderate improvements due to heterosis are seen in moderately heritable traits. Little or no heterosis is observed in highly heritable traits. Traits such as reproduction and longevity have low heritability. These traits respond very slowly to selection since a large portion of the variation observed in them is due to environmental effects and non-additive genetic effects, and a small percentage is due to additive genetic differences. But, heterosis generated through crossbreeding can significantly improve an animal's performance for lowly heritable traits, thus the importance of considering both additive and non-additive genetics when designing mating programs. Crossbreeding has been shown to be an efficient method to improve reproductive efficiency and pre-weaning productivity in beef cattle.

Table 5. Summary of heritability and level of heterosis by trait type.[a]

Trait	Heritability	Level of Heterosis
Carcass/end product Skeletal measurements Mature weight	High	Low (0 to 5%)
Growth rate Birth weight Weaning weight Yearling weight Milk production	Medium	Medium (5 to 10%)
Maternal ability Reproduction Health Cow longevity Overall cow productivity	Low	High (10 to 30%)

[a]Adapted from Kress and MacNeil. 1999.

Improvements in cow-calf production due to heterosis are attributable to having both a crossbred cow (maternal heterosis) and a crossbred calf (individual heterosis). Differing levels of heterosis are generated when various breeds are crossed. Similar levels of heterosis are observed when members of the *Bos taurus* species, including the British (e.g. Angus, Hereford, Shorthorn) and Continental European breeds (e.g. Charolais, Gelbvieh, Limousin, Maine-Anjou, Simmental), are crossed. Much more heterosis is observed when *Bos indicus,* or Zebu, breeds like Brahman, Nelore and Gir, are crossed with *Bos taurus* breeds. The increase in heterosis observed in British by *Bos indicus* crosses for a trait is usually 2-3 times as large as the heterosis for the same trait observed in *Bos taurus* crossbreds (Koger, 1980). The large increase is especially true with heterosis observed in the crossbred cow. The increase in heterosis is sensible as there are more genetic differences between species than within a species. Table 6 below details the individual (crossbred calf) heterosis and Table 7 describes the maternal (crossbred cow) heterosis observed for various important production traits in *Bos taurus* crossbreds. These heterosis estimates are adapted from a report by Cundiff and Gregory, 1999, and summarize crossbreeding experiments conducted in the Southeastern and Midwest areas of the US. Table 8 describes the expected individual heterosis of *Bos taurus* by *Bos indicus* crossbred calves, while

Table 9 details the estimated maternal (dam) heterotic effects observed in *Bos taurus* by *Bos indicus* crossbred cows. *Bos taurus* by *Bos indicus* heterosis estimates were derived from breeding experiments conducted in the southern US.

Table 6. Units and percentage of heterosis by trait for *Bos taurus* crossbred calves.

	Heterosis	
Trait	**Units**	**Percentage (%)**
Calving Rate, %	3.2	4.4
Survival to Weaning, %	1.4	1.9
Birth Weight, lb.	1.7	2.4
Weaning Weight, lb.	16.3	3.9
Yearling Weight, lb.	29.1	3.8
Average Daily Gain, lb./d	0.08	2.6

Table 7. Units and percentage of heterosis by trait for *Bos taurus* crossbred dams.

	Heterosis	
Trait	**Units**	**Percentage (%)**
Calving Rate, %	3.5	3.7
Survival to Weaning, %	0.8	1.5
Birth Weight, lb.	1.6	1.8
Weaning Weight, lb.	18.0	3.9
Longevity, years	1.36	16.2
Lifetime Productivity		
Number of Calves	.97	17.0
Cumulative Weaning Wt., lb.	600	25.3

Table 8. Units and percentage of heterosis by trait for *Bos taurus* by *Bos indicus* crossbred calves.[1]

	Heterosis
Trait	**Units**
Calving Rate, %[1]	4.3
Calving Assistance, %[1]	4.9
Calf Survival, %[1]	-1.4
Weaning Rate, %[1]	1.8
Birth Weight, lb. [1]	11.4
Weaning Weight, lb. [1]	78.5

[1]Adapted from Franke et al., 2005; numeric average of Angus-Brahman, Brahman-Charolais, and Brahman-Hereford heterosis estimates.

Table 9. Units and percentage of heterosis by trait for *Bos taurus* by *Bos indicus* crossbred dams.[1,2]

Trait	Heterosis Units	Heterosis Percentage (%)
Calving Rate, %[1]	15.4	--
Calving Assistance Rate, %[1]	-6.6	--
Calf Survival, %[1]	8.2	--
Weaning Rate, %[1]	20.8	--
Birth Weight, lb. [1]	-2.4	--
Weaning Weight, lb. [1]	3.2	--
Weaning Wt. per Cow Exposed, lb.[2]	91.7	31.6

[1]Adapted from Franke et al., 2005; numeric average of Angus-Brahman, Brahman-Charolais, and Brahman-Hereford heterosis estimates.
[2]Adapted from Franke et al., 2001.

The heterosis adjustments utilized by multi-breed genetic evaluation systems are another example of estimates for individual (due to a calf) and maternal (due to a crossbred dam) heterosis. These heterosis adjustments are presented in Table 10 below and illustrate the differences in expected heterosis for various breed-group crosses. In general the Zebu (Bos indicus) crosses have higher levels of heterosis than the British-British, British-Continental, or Continental-Continental crosses.

Table 10. Individual (calf) and maternal (dam) heterosis adjustments for British, Continental European, and Zebu breed groups for birth weight, weaning weight and post weaning gain.

	Birth Weight (lb)		Weaning Weight (lb)		Postweaning Gain (lb)
Breed Combinations	Calf Heterosis	Dam Heterosis	Calf Heterosis	Dam Heterosis	Calf Heterosis
British x British	1.9	1.0	21.3	18.8	9.4
British x Continental	1.9	1.0	21.3	18.8	9.4
British x Zebu	7.5	2.1	48.0	53.2	28.2
Continental x Continental	1.9	1.0	21.3	18.8	9.4
Continental x Zebu	7.5	2.1	48.0	53.2	28.2

(Wade Shafer, Am. Simmental Association, personal communication)

Why is it so important to have crossbred cows?

The production of crossbred calves yields advantages in both heterosis and the blending of desirable traits from two or more breeds. However, the largest economic benefit of crossbreeding to commercial producers comes from the crossbred cow. Dam heterosis improves both the environment a cow provides for her calf as well as improves her longevity and durability. The improvement of the maternal environment a cow provides for her calf is manifested in improvements in calf survivability to weaning and increased weaning weight. Crossbred cows exhibit improvements in calving rate of nearly 4% and an increase in longevity of more than one year due to heterotic effects. Heterosis results in increases in lifetime productivity of approximately one calf and 600 pounds of calf weaning weight over the lifetime of the cow. Crossbreeding can have positive effects on a ranch's bottom line by not only increasing the quality and gross pay weight of calves produced but also by increasing the durability and productivity of the cow factory.

The effects of dam heterosis on the economic measures of cow-calf production have been shown to be very positive. The added value of maternal heterosis ranges from approximately \$50/cow/year to nearly \$100/cow/year depending on the amount of maternal heterosis retained in the cowherd (Ritchie, 1998). The value of increased productivity for crossbred cows to a weaning endpoint using current calf prices is estimated to be \$150 per cow-calf pair per year. Heterosis expressed by dams accounted for an increase in net profit per cow of nearly \$75/cow/year (Davis et al., 1994). Their results suggested that the benefits of dam heterosis on profit were primarily the reduced cost per cow exposed. Crossbred cows had higher reproductive rates, longer productive lives, and required fewer replacements than straightbred cows in their study. All of these factors contribute to reduced cost per cow exposed. Further, they found increased outputs, including growth and milk yield, were offset by increased costs.

Crossbreeding's impact on profit

Enhanced profit is likely one of the strongest motivators for producers to implement effective structured crossbreeding systems. The substantial improvements in production efficiency measured as weaning weight per cow exposed supports improved profit and operational sustainability. Improved profit potential is realized through the simultaneous improvement in gross revenue stream to the ranch while decreasing costs of production through reduced replacement female requirements. Enhanced reproductive efficiency, especially in harsh environments, favorably decreases breakeven unit cost of production. Getting more calves to market endpoint, marketing heavier calves and selling a larger percentage of the calf crop through the benefits of individual and maternal heterosis, enhances gross revenue. Increasing revenue while decreasing or maintaining costs improves profit assuming constant inventories.

While most producers sell calves at weaning, this endpoint doesn't describe the total economic benefit to either an integrated beef producer that retains ownership to harvest and sells animals on a value based marketing grid or, if calves are marketed at weaning, describing the value of crossbred animals to downstream participants in the beef value chain. In an era of expanding demand for premium quality beef and declining fed cattle and cow herd inventories, it is essential that profit minded producers develop a clear understanding of the economic tradeoffs of concentrating the percentage of one breed in a breeding system and the corresponding decreased heterosis and associated reduced production efficiency. System or operation profit should be the metric by which breeding systems are evaluated. Relying on the value (revenue) per hundred weight of calves or carcasses sold or 'premiums' as indicators of profit is naïve. A number of simulation studies have been conducted to evaluate the value of breed differences and heterosis to integrated beef production systems. These projects (Notter et al, 1979; Tomson et al., 2001) concluded that breeding systems which used breed complementarity and individual and maternal heterosis are the most profitable. Mating systems that produced individual heterosis were shown to be more economically efficient than straight-breeding systems. Likewise systems that utilize maternal heterosis were more economically efficient than the use of straight bred dams (Notter et al., 1979).

What are the keys to successful crossbreeding programs?

If you implement a crossbreeding system, do not be fooled into the idea that you no longer need to select and purchase quality bulls or semen for your herd. Heterosis cannot overcome low quality genetic inputs. The quality of progeny from a crossbreeding system is limited by the quality of the parent stock that produced them. Conversely, do not believe that selection of extremely high quality bulls or semen or choosing the right breed will offset the advantages of effective crossbreeding system. Crossbreeding and sire selection are complementary and should be used in tandem to build an optimum mating system in commercial herds. (Bullock and Anderson, 2004)

Many of the challenges that have been associated with crossbreeding systems in the past are the result of undisciplined implementation of the system. With that in mind, one should be cautious to select a mating system that matches the amount of labor and expertise available to appropriately implement the system. Crossbreeding systems range in complexity from very simple programs such as the use of composite breeds, which are as easy as straight breeding, to elaborate rotational crossbreeding systems with four or more breed inputs. The biggest keys to success are the thoughtful construction of a plan and then sticking to it! Be sure to set attainable goals. Discipline is essential.

Crossbreeding Systems

Practical crossbreeding systems implemented in a commercial herd vary considerably from herd to herd. A number of factors determine the practicality and effectiveness of crossbreeding systems for each operation. These factors include herd size, market target, existing breeds in the herd, the level of management expertise, labor availability, grazing system, handling facilities and the number of available breeding pastures. It should be noted that in some instances the number of breeding pastures required can be reduced through the use of artificial insemination. Additional considerations include the operator's decision to purchase replacement females or select and raise replacements from the herd. Purchasing healthy, well developed replacement females of appropriate breed composition can be the simplest and quickest way for producers, especially small operators, to maximize maternal heterosis in the cowherd. Regardless of the crossbreeding system selected, a long-term plan and commitment to it is required to achieve the maximum benefit from crossbreeding. A variety of crossbreeding systems are described on the following pages. These systems are summarized in Table 11 by their productivity advantage measured in percentage of pounds of calf weaned per cow exposed. Additionally the table includes the expected amount of retained heterosis, the minimum number of breeding pastures required, whether purchased replacements are required, the minimum herd size required for the system to be effectively implemented, and the number of breeds involved. A more thorough discussion of various crossbreeding systems may be found in the *NBCEC Beef Sire Selection Manual, 2nd Edition* (http://www.nbcec.org/producers/sire.html).

A primary concern of many commercial producers is the increase in phenotypic variation and thus discounts for lack of uniformity in crossbred calf crops. As Table 1 illustrates, the coefficients of variation (variation standardized by the mean) have been shown to be very similar between composites and purebreds. Although the thought that a single breed, and even individuals within a breed, must be suited for all scenarios is common, this common thought leads to gross inefficiency of beef production. A much more progressive paradigm would include utilizing, and some in cases reestablishing, maternal breeds/composites that excel in maternal traits that are moderate in mature size. Within these populations, individuals exceling in breed strengths would be utilized as dams in terminal commercial beef production. Terminal sires would then be developed from terminal breed crosses that excel in growth and carcass merit. This simple, yet elusive thought process is a giant leap forward from the pervasive thought that one breed fits all and that a "good" bull must excel in all economically relevant traits. As producers seek to produce environmentally adapted crossbred cows and market targeted progeny, separation in sire selection decisions for dams that will produce replacements and dams that produce terminal progeny is encouraged.

Table 7. Summary of crossbreeding systems by amount of advantage and other factors.[a]

Type of System	% of Cow Herd	% of Marketed Calves	Advantage (%)[b]	Retained Heterosis (%)[c]	Minimum # of Breeding Pastures	Minimum Herd Size	Number of Breeds
2-Breed Rotation							
A*B Rotation	100	100	16	67	2	50	2
3-Breed Rotation							
A*B*C Rotation	100	100	20	86	3	75	3
2-Breed Rotational / Terminal Sire							
A*B Rotational	50	33			2		
T x (A*B)	50	67			1		
Overall	100	100	21	90	3	100	3
Terminal Cross with Straightbred Females[d]							
T x (A)	100	100	8.5	0[e]	1	Any	2
Terminal Cross with Purchased F1 Females							
T x (A*B)	100	100	24	100	1	Any	3
Rotate Bull every 4 years							
A*B Rotation	100	100	12-16	50-67[f]	1	Any	2
A*B*C Rotation	100	100	16-20	67-83[f]	1	Any	3
Composite Breeds							
2-breed	100	100	12	50	1	Any	2
3-breed	100	100	15	67	1	Any	3
4-breed	100	100	17	75	1	Any	4
Rotating Unrelated F_1 Bulls							
A*B x A*B	100	100	12	50	1	Any	2
A*B x A*C	100	100	16	67	1	Any	3
A*B x C*D	100	100	19	83	1	Any	4

[a]Adapted from Ritchie et al.,1999
[b]Measured in percentage increase in lb. of calf weaned per cow exposed,
[c]Relative to F_1 with 100% heterosis,
[d]Gregory and Cundiff, 1980.
[e]Straightbred cows are used in this system which by definition have zero (0) percent maternal heterosis; calves produced in this system exhibit heterosis which is responsible for the expected improvement in weaning weight per cow exposed.
[f]Estimates of the range of retained heterosis. The lower limit assumes that for a two breed system with stabilized breed fractions of 50% for each breed; three breed rotation assumes animals stabilize at a composition of 1/3 of each breed. Breed fractions of cows and level of maternal heterosis will vary depending on sequence of production.

Two- or Three-Breed Rotation:

A two-breed rotation is a simple crossbreeding system requiring two breeds and two breeding pastures. The two-breed rotational crossbreeding system is initiated by breeding cows of breed A to bulls of breed B. The resulting heifer progeny (A*B) chosen as replacement females would then be mated to bulls of breed A for the duration of their lifetime. Note the service sire is the opposite breed of the female's own sire. These progeny are then ¼ breed A and ¾ breed B. After several generations the amount of retained heterosis stabilizes at about 67% of the maximum calf and dam heterosis, resulting in an expected 16% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds (Ritchie et al., 1999). This system is sometimes called a crisscross. A three-breed rotational system achieves a higher level of retained heterosis than a two-breed rotational crossbreeding system does. After several generations the amount of retained heterosis stabilizes at about 86% of the maximum calf and dam heterosis, resulting in an expected 20% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds (Ritchie et al., 1999).

Considerations: For a two-breed rotation, the minimum herd size is approximately 50 cows with each half being serviced by one bull of each breed. Scaling of herd size should be done in approximately 50 cow units to make the best use of service sires, assuming 1 bull per 25 cows. Replacement females are mated to herd bulls in this system so extra caution is merited in sire selection for calving ease to minimize calving difficulty. Resources (pastures and cows) increases proportionally as the number of breeds in the rotation increases.

Breeds used in rotational systems should be of similar biological type to avoid large swings in progeny phenotype due to changes in breed composition. The breeds included have similar genetic potential for calving ease, mature weight and frame size, and lactation potential to prevent excessive variation in nutrient and management requirements of the herd. Using breeds of similar biological type and color pattern will produce a more uniform calf crop which is more desirable at marketing time. If animals of divergent type or color pattern are used additional management inputs and sorting of progeny at marketing time to produce uniform groups may be required.

Terminal Cross with Purchased F_1 Females

The terminal cross system utilizes crossbred cows and bulls of a third breed. This system is an excellent choice as it produces maximum heterosis in both the calf and cow. As such, calves obtain the additional growth benefits of hybrid vigor while heterosis in the cows improves their maternal ability. The terminal-cross system is one of the simplest systems to implement and achieves the highest use of heterosis and breed complementarity. All calves marketed will have the same breed composition. A 24% increase in pounds of calf weaned per cow exposed is expected from this system when compared to the average of the parent breed. The terminal cross system works well for herds of any size if high quality replacement females are readily available from other sources. Only one breeding pasture is required. No special identification of cows or groups is required.

Considerations: Since replacement females are purchased care should be given in their selection to ensure that they are a fit to the production environment. Their adaptation to the production environment will be determined by their biological type, especially their mature size and lactation potential. Through an added two-breed rotational component, the ranch could produce their own replacements (two-breed rotational/ terminal sire; see *NBCEC Beef Sire Selection Manual*), this option requires additional resources, adds complexity, and produces two different types of calves to market: one set from the maternally focused rotational system and one from the terminal sire system. With the availability of sexed semen, there exists the potential to alleviate this issue. Admittedly the cost is currently a deterrent for most, but the pairing of advanced reproductive technologies with breeding systems allows for greater efficiencies and is worth consideration

Success of the purchased F_1 female system is dependent on being able to purchase a bull of a third breed that excels in growth and carcass traits. If virgin heifers are selected as replacements, they should be mated to an easy calving sire to minimize dystocia problems, although purchasing 3-year old females alleviates this issue.. Some producers become concerned over the purchase price of replacement females. Although the return on investment should be careful determined, it should be fairly compared against what the individual producer's true costs of developing replacements heifers is and the opportunity cost associated utilizing bulls that are expected to produce replacement females and terminal offspring, likely exceling in neither. Disease issues are always a concern when introducing new animals to your herd. Be sure that replacement heifers are from a reputable, disease-free source and that appropriate bio-security measures are employed. Johne's, brucellosis, tuberculosis, bovine viral diarrhea (BVD) are diseases you should be aware of when purchasing animals. Another consideration and potential advantage of the terminal-cross system is that replacement females do not need to be purchased each year depending on the age stratification of the original cows. In some cases replacements may be added every 2-5 years providing an opportunity to purchase heifers during periods of lower prices or more abundant supplies. Heifers could also be developed by a professional heifer development center or purchased bred to easy calving bulls.

Composite Breeds

The use of composite populations in beef cattle has seen a surge in popularity recently. Aside from the advantages of heterosis retention and breed complementarity, composite population breeding systems are as easy to manage as straightbreds once the composite is formed. The simplicity of use has made composites popular among very large, extensively managed operations and small herds alike. When two-, three- or four-breed composite are formed they retain 50%, 67%, and 75% of maximum calf and dam heterosis and improve productivity of the cowherd by 12%, 15%, and 17%, respectively. Thus, these systems typically offer a balance of convenience, breed complementarity and heterosis retention.

A large herd (500 to 1000 cows) to form your own composite or a source of composite bulls or semen is required. In closed populations inbreeding must be avoided as it will decrease heterosis. To help minimize inbreeding in the closed herd where cows are randomly mated to sires the foundation animals should represent 15-20 sire groups per breed and 25 or more sires should be used to produce each subsequent generation (Ritchie et al., 1999). Similar recommendations would be made to seedstock breeders wishing to develop and merchandize bulls of a composite breed.

In small herds, inbreeding may be avoided through purchase of outside bulls that are unrelated to your herd. F_1 bulls provide a simple alternative to the formulation of composite breeds. Additionally, the F1 systems may provide more opportunity to incorporate superior genetics as germplasm can be sampled from within each of the large populations of purebreds rather than a smaller composite population. The use of unrelated F_1 bulls, each containing the same two breeds, in a mating system with cows of the same breeds and fractions will result in retention of 50% of maximum calf and dam heterosis and an improvement in weaning weight per cow exposed of 12%. A system that uses F_1 bulls that have a breed in common with the cow herd (A*B x A*C) results in heterosis retention of 67% and an expected increase in productivity of 16%. While the use of F_1 bulls that don't have breeds in common with cows made up of equal portion of two different breeds (A*B x C*D) retains 83% of maximum heterosis and achieves productivity gains of 19%. This last system is nearly equivalent to a three breed rotational system in terms of heterosis retention and productivity improvement, but much easier to implement and manage.

The use of F_1 bulls requires a seedstock source from which to purchase. The bulls will need to be of specific breed combinations to fit your program. These programs fit a wide range of herd sizes. The use of F_1 bulls on cows of similar genetic make-up is particularly useful for small herds as they can leverage the power of heterosis and breed complementarity using a system that is as simple as straight breeding. Additionally, they can keep their own replacement females.

Considerations: The inclusion of a third or fourth breed in the systems takes more expertise and management. To prevent wide swings in progeny phenotype, breeds B and C should be similar in biological type, while breeds A and D should be similar in biological type.

Crossbreeding Challenges

Although crossbreeding has many advantages, there are some challenges to be aware of during your planning and implementation as outlined by Ritchie et al., 1999.

1. **More difficult in small herds**
   Crossbreeding can be more difficult in small herds. Herd size over 50 cows provides the opportunity to implement a wider variety of systems. Small herds can still benefit through utilization of terminal sire, composite or F_1 systems.

2. **Requires more breeding pastures and breeds of bulls**
   Purchasing replacements and maximum use of A.I. can reduce the number of pastures and bulls. However, most operations using a crossbreeding system will expand the number of breeding pastures and breeds of bulls.

3. **Requires more record keeping and identification of cows**
   Cow breed composition is a determining factor in sire breed selection in many systems.

4. **Matching biological types of cows and sire**
   Breed complementarity and the use of breed differences are important advantages of cross breeding. However, to best utilize them care must be given in the selection of breeds and individuals that match cows to their production environment and sires to market place. Divergent selection of biological type can result in wide swings in progeny phenotype in some rotational systems. These swings may require additional management input, feed resources, and labor to manage as cows or at marketing points.

5. **System continuity**
   Replacement female selection and development is a challenge for many herds using crossbreeding systems. Selection of sires and breeds for appropriate traits (maternal or paternal traits) is dependent of ultimate use of progeny. Keeping focus on the system and providing labor and management at appropriate times can be challenging. Discipline and commitment are required to keep the system running smoothly.

Summary

Without question, at the individual firm level, errors have been made in correct breed utilization and in the development of crossbreeding systems. Simply mating animals of different breeds does not constitute a breeding program. However, the movement towards straightbreeding in an attempt to simplify breeding systems assumes that somehow firms that made incorrect decisions in breed selection and individual animal selection when crossbreeding immediately make more educated decisions when choosing animals with a single breed. Point being, incorrect selection decisions are made by those that crossbreed and those that straightbreed. Judicious breed selection and animal selection within breeds is critical. However, the economic benefits of crossbreeding are clear and the production system efficiencies that can be gained are tremendous, ranging from improved longevity, fertility, disease resistance, and growth. Every breed has strengths and weaknesses relative to an individual commercial operation's production and marketing goals. That is the benefit of crossbreeding, blending strengths from various breeds to meet production goals while fitting within environmental constraints, and heterosis becomes the reward for having done so. Climatic conditions are an important consideration when choosing breeds to utilize in a crossbreeding program and caution should be used to ensure environmental fitness is addressed. It is important to remember that successful crossbreeding programs focus on optimums, not maximums or minimums, to achieve breeding and marketing goals that fit within the production environment.

Moving forward there are researchable questions related to crossbreeding and heterosis that need to be addressed. One is updated estimates of global heterosis, or heterosis pooled across several breed pairings, and another is breed specific estimates of heterosis, or the heterotic benefit of pairing breed A with Breed B as opposed to breed C. Global estimates of heterosis will need to be estimated for "novel" traits that we are just now collecting phenotypes for (feed intake, susceptibility to certain diseases, microbial community, etc.). As most breeds now have, or will shortly, included genomic predictors into NCE we have surely just scratched the surface of what genomic information can do to aid in beef cattle breeding and management. Some loci no doubt influence the phenomenon of heterosis more than others, and the use of this in breeding systems holds tremendous benefits in the pairing of breeds and individuals. Finally, from a more applied perspective, the coupling of advanced reproductive technologies with the design and implementation of breeding systems holds tremendous advantages from a beef industry efficiency perspective. The ability to produce composite females, selected from maternal lines, and mated to terminal sires for the production of market bound progeny is a general concept that has eluded the beef industry while our animal protein competitors have mastered it. If we can then avoid the undesirable sex (heifers in the terminal system and bulls in the maternal system) the advantages become even greater.

While these possibilities are exciting, the fundamentals still hold. Pair breeds to take advantage of breed complementarity when possible, utilize heterosis, and select animals within the chosen breeds using EPD and Bio-economic index values. Without these fundamentals, advancing technology has no chance of success.

Literature cited:

Bullock, D. and L. Anderson. 2004. *Crossbreeding for the commercial beef producer.* ASC-168. Cooperative Extension Service, University of Kentucky, Lexington, KY.

Cundiff, L. V., and K. E. Gregory. 1999. *What is systematic crossbreeding?* Paper presented at Cattlemen's College, 1999 Cattle Industry Annual Meeting and Trade Show, National Cattlemen's Beef Association. Charlotte, North Carolina, February 11, 1999.

Cundiff, L. V., F. Szabo, K. E. Gregory, R. M. Koch, M. E. Dikeman, and J. D. Crouse. 1993. *Breed comparisons in the Germplasm Evaluation Program at MARC.* Pages 124-136 in Proc. 25th Annual Research Symposium and Annual Meeting, Beef Improvement Federation, Asheville, North Carolina..

Cundiff, L. V., R. M. Thallman, L. D. Van Vleck, G. L. Bennett and C. A. Morris. 2007. *Cattle Breed Evaluation at the U.S. Meat Animal Research Centre and implications for commercial beef farmers.* Proceedings of the New Zealand Society of Animal Production 2007, Vol. 67, p 9-17.

Davis, K. C., M. W. Tess, D. D. Kress, D. E. Doornbos, and D. C. Anderson. 1994 *Life cycle evaluation of five biological types of beef cattle in a cow-calf range production system: II. Biological and economic performance*. J. Anim. Sci. 72: 2591-2598.

Davis, K. C., M. W. Tess, D. D. Kress, D. E. Doornbos, and D. C. Anderson. 1994. *Life cycle evaluation of five biological types of beef cattle in a cow-calf range production system: I. Model development.* J. Anim. Sci. 72: 2585-2590.

Franke, D. E., S. M. DeRouen, A. R. Williams, and W. E. Wyatt. 2005. *Direct and maternal breed additive and heterosis genetic effects for reproductive, preweaning, and carcass traits.* Pages 204-209 in Proc. of Symposium on Tropically Adapted Breeds, Regional Project S-1013, American Society of Animal Science, Southern Section Meeting, Little Rock, Arkansas.

Franke, D. E., O. Habet, L. C. Tawah, A. R. Williams, and S. M. DeRouen. 2001. *Direct and maternal genetic effects on birth and weaning traits in multibreed cattle data and predicted performance of breed crosses.* J Anim. Sci. 79: 1713-1722.

Gregory, K. E. and L. V. Cundiff. 1980. *Crossbreeding in beef cattle: evaluation of systems.* J. Anim. Sci. 51:1224-1242.

Gregory, K. E., L. V. Cundiff, L. D. Van Vleck. 1999. *Composite breeds to use heterosis and breed differences to improve efficiency of beef production.* Technical Bulletin Number 1875. ARS-USDA. Washington, DC.

Greiner, S. P. 2002. *Beef cattle breeds and biological types.* Virginia Cooperative Extension Publication 400-803. Virginia Polytechnic Institute and Stat University. Blacksburg.

Gosey, J. 1994. Composites: *A beef cattle breeding alternative.* Proc. Beef Improvement Federation Annual Meeting. June 1-4, W. Des Moines, IA. P. 93.

Gosey, J. 2005. *Heterosis and crossbreeding.* Proc. Range Beef Cow Symposium XIX, Rapid City, SD, December 2005.

Koger, M. 1980. *Effective crossbreeding systems utilizing Zebu cattle.* J. Anim. Sci. 50:1215.

Kress, D. D., and M. D. MacNeil. 1999. *Crossbreeding Beef Cattle for Western Range Environments.* 2nd ed. WCC-1 Publ. TB-99-1. Samuel Roberts Noble Foundation, Ardmore, OK.

Kuehn, L. A. and R. M. Thallman. 2012a. *Mean EPDs Reported By Different Breeds.* Proc., Beef Improvement Federation 44th Research Symposium and Annual Meeting, Houston, TX. April 18-21, 2012. pp. 147-151.

Kuehn, L. A. and R. M. Thallman. 2012b. *Across-Breed EPD Tables for the Year 2012 Adjusted to Breed Differences for Birth Year 2010.* Proc., Beef Improvement Federation 44th Research Symposium and Annual Meeting, Houston, TX. April 18-21, 2012. pp. 147-151.

Notter, D. R., J. O. Sanders, G. E. Dickerson, G. M. Smith, and T. C. Cartwright. 1979. *Simulated Efficiency of Beef Production for a Midwestern Cow-Calf-Feedlot Management System. III. Crossbreeding Systems.* J. Anim. Sci. 49:92-102

Ritchie, H. D., 1998. *Role of Composities in Future Beef Production Systems.* http://www.msu.edu/~ritchieh/papers/BEEF201.ppt. Accessed October 2, 2005.

Ritchie, H., D. Banks, D. Buskirk, and J. Cowley. 1999. *Crossbreeding systems for beef cattle.* Michigan State University Extension Bulletin E-2701.

Tomsen, U. Jon; Darnell, D. Kirk; and Nielsen, Merlyn K., 2001. *A Comparison of Beef Cattle Crossbreeding Systems Assuming Value-Based Marketing.* Nebraska Beef Cattle Reports. Paper 322. (http://digitalcommons.unl.edu/animalscinbcr/322)

Breed Utilization and Production Efficiency

Merlyn Nielsen[1]
[1]*University of Nebraska-Lincoln*

Introduction

Maximizing production efficiency, or perhaps more specifically economic efficiency, is a goal of any beef enterprise. Maximizing production/economic efficiency, with minimal effect on natural resources, also addresses an even larger goal of sustainability. Although individual owners would and should be focused on their own enterprise and its efficiency, total industry efficiency and sustainability become the global goal for the beef industry. Thus utilization of breed resources is of interest as we address the various segments of the beef industry ranging from seed stock production to providing products for consumers of beef.

In this paper and presentation, production efficiency and its significant components will be addressed first. Then the decision processes and opportunities for utilization of our various breed and population resources, as they contribute positively to production efficiency, will be discussed. Descriptions and discussion will not be in full depth nor full completeness that might be possible, but generalities will emerge.

Production Efficiency

Production/economic efficiency can be expressed as output:input ratio or as the value of output relative to, or divided by, the costs of production. Value of output is the sum of the "amount x value" of the various outputs on a ranch or feedlot or processing plant, etc. Costs of production are those realized by the ranch, feedlot, processing plant, etc. The greater the ratio, the greater the efficiency of the enterprise, or if measured as final output of beef products to total costs, the greater the efficiency of the beef industry. As cycles in supply and demand of cattle and beef, and in production costs occur, efficiency of the enterprise can vary across industry segments, but these are temporal. In the long term, all segments of the industry, will need to have an economic efficiency ratio greater than one to be sustainable.

Biological characteristics of cattle that express variation and have an impact on production efficiency should receive our focus, whether we are evaluating breed variation for making choices in breed utilization and possible crossing systems, or we are developing breeding objectives for selection within populations. The latter would vary depending on intended use of the population (or breed group) in commercial beef production, either as a sire breed or dam breed or both. These characteristics may have variation arising from 1) direct breed differences (due to the genetic makeup of the animal measured), 2) maternal breed differences (due to the genetic makeup of the dam), 3) direct (arising from the genotype of the calf) heterosis, 4) maternal (arising from the genotype of the cow) heterosis, or 5) various combinations of these.

Let's look at a limited number of studies aimed at identification of biological characteristics influencing efficiency of production of calves through slaughter. MacNeil et al. (1994) developed relative economic values for sire and dam lines fitting the Canadian beef industry, and thus very similar to the U.S. industry. Variation in feedlot gain had important economic value in both sire and dam lines as did calf survival; variation in female fertility was important for dam lines and male fertility for sire lines. MacNeil (2005) presented a further look at terminal sires and variation in economic value of characteristics. He demonstrated the importance of increasing calf survival, weight gain, dressing percentage and marbling score while decreasing feed intake and fatness (yield grade).

Barron Lopez (2013) recently examined relative economic values of component characteristics contributing to a breeding objective for a totally integrated system. His results point to the importance of increasing marbling score, muscle, and post-weaning daily gain while decreasing feed intake (through indicator traits – decreasing milk production and cow mature size) and carcass fat. Feed requirement to meet maintenance is positively related to level of milk production potential in both cows and calves (Montano-Bermudez et al., 1990) and probably to locomotor activity level, as has been shown for mice (Sojka et al., 2013).

Being able to utilize breed differences, as they contribute to a system, is warranted for growth rate, marbling and carcass fatness, fertility and calf survival, and feed intake, especially for maintenance. For systems where a breed or composite is used both as a sire and a dam, then all these characteristics are important in making choices between breeds to use. In systems where a breed is used as a terminal sire, then calf survival, growth rate, carcass marbling and fatness, and feed intake are important to consider. For systems where a breed contributes as a dam, then add in female fertility and increase the emphasis on reducing feed intake for maintenance because annual cow costs are large in the system. Montano-Bermudez and Nielsen (1990) and van Oijen et al. (1993) demonstrated that lower milk level, and its accompanying lower feed energy requirement for maintenance throughout the life cycle, enhanced economic efficiency. In addition, being able to capitalize on heterosis for dam, and perhaps sire, fertility, calf survival, and growth rate (MacNeil et al., 1994) will also contribute to increased production efficiency.

Need for Multiple Breeds

Breeds and variation between breeds open up possibilities for innovative genetic applications. Breeds differ because frequencies of alleles for many genes differ between the breeds. These differences in frequencies of alleles are the result of different selection histories, both artificial as well as natural selection, and different mutation histories that have occurred in reproductively isolated populations. Because breeds differ in allelic frequencies for many genes, we create more heterozygosity in crossbred individuals than in the average of the parental breed populations. The greater the difference in frequency of alleles for a gene, the greater the increase in heterozygosity when we cross breeds. Increased heterozygosity, along with some degree of desirable dominance, is a cause of heterosis. And magnitude of heterosis effect is defined based on the difference between a first cross and the average of the contributing pure breeds, whether in a calf or a cow or a bull.

Breeds, as noted above, will differ in at least some characteristics for direct (g^d) and/or maternal (g^m) genetic effects. In evaluating a breed for use as a dam role in commercial production, we would wish to know how the breed ranks among those available for both g^d and g^m effects. In fact, in the manner that a potential dam breed would contribute to commercial production, it is ½ $g^d + g^m$ that becomes the critical knowledge. For a breed with possible use as only a sire role in commercial production, then we would only need to evaluate the breed's strengths and weaknesses for g^d, or ½ g^d as it contributes to the system. And, if we wish to choose among breeds which will contribute both from a sire and a dam role, across generations, then the important knowledge is $g^d + g^m$ for critical characteristics contributing to production efficiency.

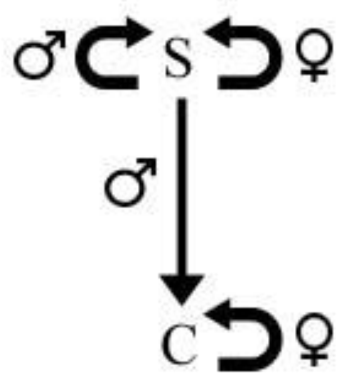
Complimentarity, or combining breeds of differing strengths, is realized in different ways with different combinations or utilization of breeds. For rotational crossing systems, because each breed will, in time, contribute equally to the other breeds as both a sire and a dam, then $g^d + g^m$ is the knowledge we need for making selections of breeds to include. Likewise, if we wish to create a new composite breed or wish to utilize an "open composite" with varying infusions of existing breeds over generations, then again, because contributions are equal in both sire and dam roles, $g^d + g^m$ is again the important knowledge to gather and evaluate for potential breeds to include in the composite. In these situations, where a breed contributes equally as both a sire and a dam, our goal is to combine breeds with varying strengths where each breed complements the other by bringing some strength to form the whole.

In the case of terminal crossing where some breed(s) fill the role of the sire breed and other breed(s) fill the role of the dam in the final, desired cross, then complimentarity has an even greater role to contribute positive attributes to the cross. Crossing smaller, lower feed intake dam breeds or crossbred dams to larger, greater growth and less waste-fat sire breeds demonstrates complimentarity at its greatest impact on production efficiency. Making use of breeds that can differ greatly in many characteristics can capitalize on significant complimentarity through "sire breed vs dam breed" strengths; we might also call this sire breed x dam breed complimentarity. Cundiff et al. (1986) presented an early comprehensive comparison of breeds for beef production based on the Germ Plasm Evaluation (GPE) project at US MARC. More recently, Cycle VII of the GPE evaluated the seven breeds with the greatest registration numbers. Wheeler et al. (2005) and Cushman et al. (2007) provided several breed comparisons from Cycle VII. Weaber (2010b) discussed many concepts on breed strengths and heterosis in detail.

For breeds being considered for use as a dam breed, fitting the breed to the environment (temperature, feedstuffs, parasite challenges, etc.) adds a further challenge. *Bos Taurus* breeds are better adapted for temperate zones, whereas inclusion of *Bos indicus* breeds in crossing or in composite breeds has value in the hot and humid portions of the US. Weaber (2010b) provides elaboration on matching breed characteristics to varying production environments.

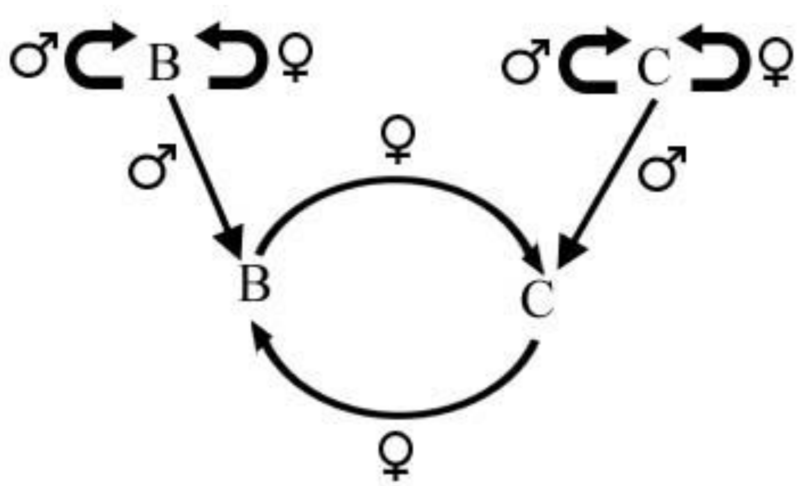
Breed Utilization

For a totally sustaining system of producing calves, multiple breeding groups are the norm. Even in the case of producing a pure breed or line of cattle, or a pure "composite" that has a defined composition of contributing breeds (e.g., ½ each of 2 breeds or ¼ each of 4 breeds), the system of breeding would have both seed stock, or bull source, and commercial sectors. We can minimize costs involved in practicing selection for the system by concentrating selection efforts in the seed stock group. Selection response in the seed stock (seed stock population shown below as “S”) portion of the system are fully realized, at the same rate in the long run, in the commercial portion (shown below as “C”) of the system. Arrows in the diagram below depict flow of breeding males and females from their source of production to their use in reproduction. For example, group S produces sons that become replacement bulls in both group S and group C. For cattle and their low female reproductive rate, commercial replacement females are born in the commercial portion. As noted above, in this type of system, a breed or composite would be chosen based on $g^d + g^m$ for the combination of important characteristics affecting production efficiency.



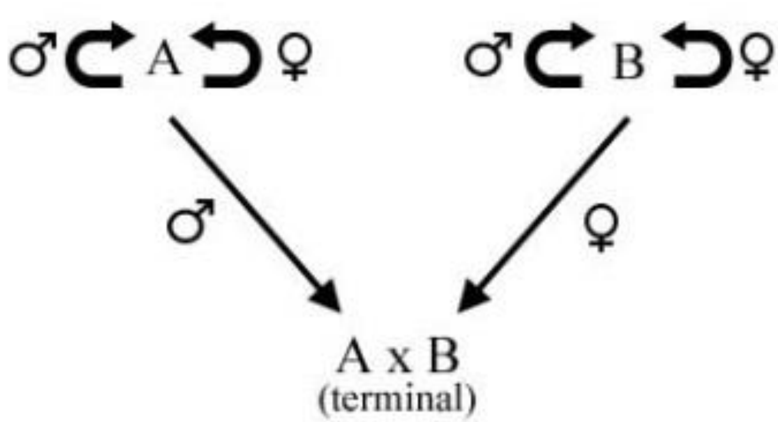
There is a large number of cattle breeds available for US producers to sample. Realistically, there are a limited number though that might play a major role in contributing to crossing systems. For ease here, let’s assume we wish to make choices among 10 breeds for use in building new composites. For composites developed from two breeds, there are 45 different combinations, and these composites would capitalize on ½ the possible calf, dam and sire heterosis. For those using four breeds, there are 210 different combinations, and based on ¼ contribution of each breed, these composites would express ¾ of the possible calf, dam and sire heterosis.

An alternative to a composite that would also capitalize on heterosis is a rotational cross. The simplest form is a two-breed rotation, and the total system for sustaining this system is depicted in the diagram below. Breeds B and C are used as purebred sires in the commercial portion of the system, given in the bottom half of the diagram. Daughters of B sires are mated to C sires throughout their life, and daughters of C sires are mated to B sires. Purebred seed stock groups are shown at the top of the diagram. Like the composite and the pure breed examples above, the two breeds are again chosen based on $g^d + g^m$ for characteristics affecting production efficiency. We would choose breeds to be compatible in birth weight to minimize dystocia in first-calf dams. Weaber (2010a) describes rotational as well as other crossing programs for beef production.



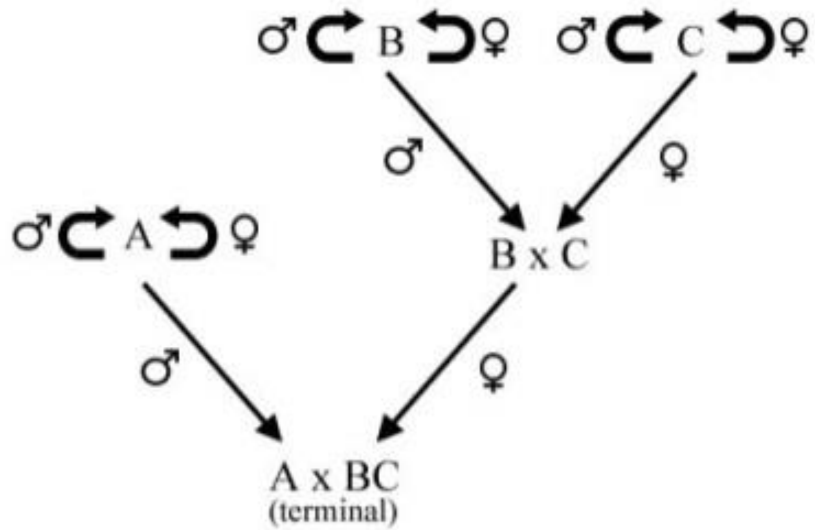
Again, imagining 10 different breeds to select from, there are 45 unique two-breed rotations, and these capitalize on ⅔ of the possible calf and dam heterosis. With three-breed rotations, there would be 120 unique rotational systems, making use of $^{6}/_{7}$ of the possible calf and dam heterosis.

The easiest crossing system to design that makes use of sire breed x dam breed complimentarity is a two-breed cross. One simply crosses the best sire breed by the best dam breed. All progeny are intended for slaughter, hence a terminal cross. Full call heterosis is realized. In the diagram below, "A" is the sire breed and "B" is the dam breed, each breed chosen for their strengths in their unique roles. Under a fully sustainable system, we would need the two purebred groups (A and B) to generate replacement breeding stock for the commercial, terminal cross as well as replacing breeding stock in the purebred populations. And, B females would probably not be mated to A sires for their first calves, if A is a greater birth weight, high growth breed. Given the low female reproductive rate in cattle, it would be difficult to realize 50% of the total system in the terminal cross, thus giving up production efficiency, including the lack of capitalizing on dam heterosis.

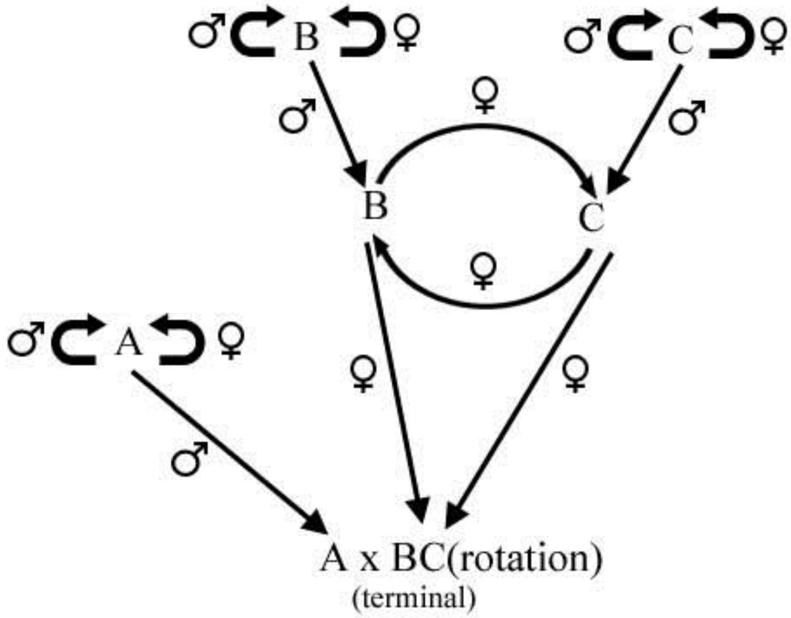


But, what if breed "B" in the diagram above were a maternal composite of two (or four or ?) breeds that had been identified with strengths in female fertility, smaller cow size and lower feed intake, etc.? Then, 50% (for a maternal composite of equal parts of two breeds, or 75% if a maternal composite of equal parts of four breeds) of the dam heterosis would be realized in a large (93+%) portion of the total system, thus enhancing production efficiency.

Most commercial swine production capitalizes on full dam heterosis as well as full offspring heterosis. Relatively high female reproductive rate in swine opens the door for realizing a high (~90%) of the system production in the commercial, terminal cross. This is depicted in the diagram below for a totally sustaining system with supporting purebred and first-cross female production (B x C). Full dam heterosis is used because the females are first crosses of lines that excel as females. When natural service was the norm, first-cross boars of two terminal sire lines were used in the terminal cross. But, as artificial insemination has become the least costly method for breeding sows, and as single, best-sire lines have been identified, the terminal three-breed cross (A x BC) now dominates the swine industry. So, why not use the same system in cattle if we can identify two dam breeds and a terminal sire breed, and thus capitalize on full dam heterosis in addition to full calf heterosis? Unfortunately, on a totally sustaining industry basis, we still have a very large portion of the system as purebred dams in the purebred C and the B x C groups as dictated by the low reproductive rate of females. And, we would probably need to avoid breeding BC crossbred heifers to A sires for their first calf.



The alternative to the three-breed cross, shown above that is working well in swine production, is the rota-terminal cross for cattle. With rotational crossing to generate replacement females, the large overhead of purebred females required in a three-breed cross is avoided. Shown in the diagram below is a two-breed rotation that generates replacement females for the rotation (breeds B and C) as well as replacement females for terminal crossing (these would be older cows, not heifers for first breeding, again to avoid calving difficulty) to sire breed A, capitalizing on sire breed x dam breed complimentarity. Here the dam breeds are represented in the rotational crosses of two dam breeds. Given the low reproductive rate of cows that can not be overcome, we still achieve much less than half the total system in the terminal cross, but all commercial cows are now two-breed rotation and contributing $^{2}/_{3}$ dam heterosis, and the terminal cross has full calf heterosis. Reflecting back to our selection from 10 different breeds to develop such a system, there are 360 unique combinations!



Simulation research by Tomsen et al. (2001) compared total-system (all purebred plus crossing groups) profitability (income – expenses) for beef production using literature data on 14 breeds of cattle. All systems were simulated for a fixed amount of grazing resource and with slaughter of young animals at a constant level of fat (0.3 inch over the rib). Because there were many crossing systems with 14 breeds, the 10 best for various crossing systems were averaged and compared to the average of the best 3 pure breeds. The average of the best 10 two-breed rotation systems was 32% greater in profitability than the average of the best 3 purebred systems. The 10 best rota-terminals (two-breed rotation dams) averaged 55% better and the 10 best composites, all composed of four breeds, averaged 51% better for profitability than the average of the best 3 purebred systems. Being able to capitalize on calf and cow heterosis plus utilize breed strengths through complimentarity explains these results.

Due to differing strengths of breeds and desirable effects of heterosis, planned crossing systems can utilize breed resources to improve production/economic efficiency of beef production. Wisely engineered crossing systems will have greater production efficiency than purebreeding for commercial beef production.

Literature Cited

Barron Lopez, J.A. 2013. Selection objective for improving efficiency of beef cattle. Ph.D. Dissert. *U. Nebraska Library*. 160 pp.

Cushman, R.A., M.F. Allan, R.M. Thallman and L.V. Cundiff. 2007. Characterization of biological types of cattle (Cycle VII): Influence of postpartum interval and estrous cycle length on fertility. J. Anim. Sci. 85:2156-2162.

Cundiff, L.V. K.E. Gregory, R.M. Koch, and G.E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. 3rd World Cong. Appl. Live. Prod. Lincoln, NE IX:271-291.

Kuehn, L. and M. Thallman. 2012. Across-breed EPD table. Beef Improvement Federation Ann. Mtg. Proc. Houston, TX. http://www.beefimprovement.org/PDFs/2012/Across-Breed-EPD-Factors.pdf

MacNeil, M.D., S. Newman, R.M. Enns and J. Stewart-Smith. 1994. Relative economic values for Canadian beef production using specialized sire and dam lines. Can. J. Anim. Sci. 74:411-417.

MacNeil, M.D. 2005. Breeding objectives for terminal sires for use in U.S. beef production systems. Beef Improvement Federation Ann. Mtg. Proc. Billings, MT. p. 82-87.

Montano-Bermudez, M. and M.K. Nielsen. 1990. Biological efficiency to weaning and to slaughter of crossbred beef cattle with different genetic potential for milk. *J. Anim. Sci.* 68:2297-2309.

Montano-Bermudez, M., M.K. Nielsen and G.H. Deutscher. 1990. Energy requirements for maintenance of crossbred beef cattle with different genetic potential for milk. *J. Anim. Sci.* 68:2279-2288.

Sojka, P.A., R.S. Greiss and M.K. Nielsen. 2013. Locomotor activity and body temperature in selected mouse lines differing greatly in feed intake. J. Anim. Sci. 91: (accepted).

Tomsen, U. Jon, D. Kirk Darnell, and Merlyn Nielsen. 2001. A comparison of beef cattle crossbreeding systems assuming value-based marketing. *Nebraska Beef Report.* MP 76-A:3-7.

van Oijen, M., M. Montaño-Bermudez and M.K. Nielsen. 1993. Economical and biological efficiencies of beef cattle differing in level of milk production. *J. Anim. Sci.* 71:44-50.

Weaber, Bob. 2010a. Crossbreeding for commercial beef production. NBCEC. *Beef Sire Selection Manual*. p. 50-57.

Weaber, Bob. 2010b. Breed and composite selection. NBCEC. *Beef Sire Selection Manual*.

p. 58-64.

Wheeler, T.L., L.V. Cundiff, S.D. Shackelford and M. Koohmaraie. 2005. Characterization of biological types of cattle (Cycle VII): Carcass, yield and longissimus palatability traits. J. Anim. Sci. 83:196-207.

That's Nice – But I Raise Cows

David A. Daley, Ph.D.[1]

[1]*California State University, Chico*

Why do we continue to talk about crossbreeding?

I am somewhat disappointed that we are continually revisiting the topic of crossbreeding in commercial beef production—and actual debating the merits of the practice. Crossbreeding is not a new concept and frankly, BIF needs to move past this discussion towards practices which can take us to the next level of genetic improvement. Unfortunately, it seems that this topic continues to fester, simply because we refuse to look at the issue objectively.

The inherent problem with the discussion is we have proponents and opponents rather than a simple discussion of advantages and disadvantages—where it fits and where it doesn't. We can have outstanding straightbred or crossbred cattle. I find it simplistic and a waste of time to argue one is better than the other. We need to put our resources and energy into a more productive direction. As scientists, breed associations and beef producers, we should take a step back and approach the issue rationally. It seems to me we have three failures in this discussion: 1) a failure to actually understand what heterosis means, 2) a focus on the wrong traits to evaluate the impact of crossbreeding (we are chasing a red herring), and 3) a lack of understanding of the impact of environment on crossbreeding results.

What are the genetic results of crossbreeding? Hybrid vigor or heterosis—we all know the answer. However, based on what I see in the popular press, we may know the answer but we fail to understand the definition. Heterosis is the improvement in the crossbred progeny compared to the AVERAGE OF THE PARENTAL BREEDS. Proponents and opponents of crossbreeding alike—please take note—NO ONE SAID THE CROSSBRED PROGENY WERE SUPERIOR TO EITHER STRAIGHTBRED PARENT—JUST TO THE AVERAGE OF THE PARENTAL BREEDS. So, if we cross Holstein and Hereford, the progeny don't out milk Holstein! Heterosis is the improvement above the mean of the two parental breeds.

This lack of understanding of hybrid vigor was driven home to me clearly on a visit to Queensland in Bos Indicus country. One particular producer who raised straightbred Brahmans seemed delighted to show me crossbred animals that he had tried in his environment that looked absolutely miserable. His not so subtle point—crossbreeding doesn't work. "See, my Brahmans are better than the crossbreds!" That view represents a lack of understanding of heterosis. The fact that the Bos Indicus cattle are better adapted to that climate doesn't mean that crossbreeding failed. Heterosis, by definition (and in practice) would be the improvement in adaptability of the F1 (in this case Brahman X Angus) over the mean of the two breeds—not over Brahmans.

The biology of crossbreeding is clear and can't be changed regardless of the dialogue that occurs. The elegant research at the USMARC on germplasm evaluation will never be duplicated. The sheer numbers, classic design and life cycle analysis should provide irrefutable evidence of the impact of planned crossbreeding. I am always amazed at how people want to disagree with the data from USMARC. That usually occurs if we don't like the results. Careful study of the data will demonstrate what we know to be true with crossbreeding—small, net improvement in many traits, but a large increase in lifetime productivity, particularly when you evaluate longevity (Table 1.)

Table 1. Selected individual (direct) and maternal effect of heterosis (Cundiff et al., 1970; Gregory et al., 1965, 1978)

	Effect of Heterosis (%)	
Trait	Direct	Maternal
Calving rate	4.4	3.7
Survival to weaning	1.9	1.5
Weaning weight	3.9	3.9
Post-weaning ADG	2.6	.
Number of calves	.	17.0
Longevity	.	38.0

One thing that has changed since the completion of the life cycle analysis of germplasm evaluation and utilization at MARC is that our selection tools have improved. In particular, the advances in EPD technology (accuracy, numbers, techniques) have changed dramatically—and that doesn't even include the recent additions of genomics to the mix. So, clearly, we can change things like growth rate, feed efficiency and carcass merit more accurately and faster within a breed than ever before. Does that mean crossbreeding is less valuable? No. You shouldn't be using crossbreeding to change growth rate, feed efficiency and carcass merit anyway. Those are highly heritable, easily measured traits that we have excellent tools available. That's not why you crossbreed!

On the other hand, what about the lowly heritable (e.g. reproduction and general fitness) traits where you receive the greatest benefit from crossbreeding? What tools do we have for pregnancy rate, embryo survival, calf livability and lifetime productivity? NONE. In terms of the economic bottomline from crossbreeding, we shouldn't focus on short term individual traits like gain and growth, but long term profitability. That is where crossbreeding will make the greatest difference.

One of the reasons we seem to have difficulty focusing on the issue is because of our varying experiences in vastly different environments. The data is clear. Harsher environments see a greater benefit to crossbreeding. That is why large scale western ranches that may have harsh winters or summers and limited feed at certain times of the year, see the benefits of crossbreeding more directly. If you are from a softer, more intensively managed environment, the benefits may be less obvious.

This paper primarily focused on a basic discussion of understanding heterosis. I have not even explored the value of how two or three breeds may complement one another in a crossbreeding system. Since BIF has been kind enough to invite me to talk about this topic in 2006, 2009 and again in 2013, I thought it might be easier (and more efficient) to include my paper from '09. Things haven't changed that much.

So, that's nice, but I own cows. I have the unique opportunity to practice what I preach. I run both crossbred and purebred programs in similar, somewhat challenging environments. I could care less about weaning weight, quality grade or feedlot performance as a single measurement taken out of context. By necessity, I am interested in the bottomline, long term profitability. That includes looking at the entire system—labor, feed costs, replacement costs—every input and output that affects my return. Crossbreeding reduces inputs while increasing outputs. That adds value to my particular system.

Crossbreeding – Back to the Future (Adopted from Daley, 2009a)

Three years ago I was invited to address BIF regarding heterosis and how we have either ignored or forgotten the value of systematic crossbreeding to improve profitability in beef cattle production systems. In the interim period since that presentation, I am even more convinced that this incredible genetic resource has been under-utilized and devalued. At a time when all of our input costs have increased dramatically, and the value of cow efficiency is paramount, we continue to find arguments against using crossbreeding primarily centered on the concepts of consistency and marketability. Clearly, there are specific instances in the commercial cattle sector where heterosis has been used effectively used. I would argue, however, that the potential is far from realized. In fact, in the past few years, we seem to have drifted away from crossbreeding to more traditional straightbred programs that intend to focus on phenotypic consistency and end product, but not necessarily on profitability. Is there a rationale explanation for our unwillingness to take advantage of a proven technique to enhance economic return? In my previous paper I outlined the "top ten" reasons that we have failed to capitalize on this important genetic attribute:

1) **A cultural bias that clearly reflects "purebreds" are better!** If for no other reason than they have a registration paper. Society, at many levels, rewards purity. Is your dog registered? Does your quarter horse *gelding* have papers? How far can you trace your ancestry? Please don't misunderstand---there is certainly value associated with that record, particularly our ability to track performance and predict genetic potential of purebreds. But being purebred should not be a presumption of superiority.

2) **Our predilection for single trait selection focusing on "bigger is better".** The beef cattle industry seems to choose a trait of importance and then put an inordinate amount of pressure on that trait, ignoring genetic antagonisms. If a 90 pound yearling EPD is good, 100 must be better! It is intuitive! We have already done frame, growth (weight of all kinds), milk,

and carcass traits (both ribeye and marbling). I sometimes have to ask myself, “so what is the trait of the year this time?”. It is akin to the “flavor of the month” at the local ice cream shop. And because often have chosen relatively highly heritable traits, we have not needed to crossbreed to achieve those goals. The subtle, and cumulative improvement that heterosis provides does not lend itself to maximums.

3) **We have decided that measuring outputs is more meaningful than measuring inputs**, as well as easier to do. It is certainly easier to measure calf performance on an individual basis, rather than all costs associated with that production. “I can weigh them at weaning quicker than I can determine differences in treatment costs over time.”

4) **Uniform phenotypes for qualitative traits (color) have a distinct and real marketing advantage that is difficult to ignore**. That does not mean you cannot have uniformity of color within a crossbreeding program, but the widespread and indiscriminate planning (or lack thereof) of many crossbreeding programs certainly gave us some interesting marketing challenges. Generally, it is easier to produce a uniform color in straightbred programs.

5) **Heterosis is very difficult to visualize and even more difficult to measure**. Because heterosis is expressed as a small net positive in many traits we do not know it when we see it. Slight changes in morbidity, age at puberty, conception rate and significant changes in longevity are not easily observed. However, we all know when calves gain faster in the feedlot.

6) **The presentation of complicated crossbreeding systems as a “normal practice” to diverse cattle operations, especially the countless small beef herds in the United States**. Many of the systems that we teach as part of standard animal breeding or beef production courses have very limited application in the real world. Most beef herds are too small to implement the “standard systems”.

7) **Our penchant for telling people how to modify their environment in order to “get heavier calves, higher percent calf crop and more total pounds”,** rather than how to increase net return. How many new supplementation programs can you develop in order to get your heifers bred or wean bigger calves? In fact, we can recommend programs for non-cycling females…..you just have to pay for it and then pass those genetics to the next generation! Heterosis provides some improvement in traits at relatively little cost. However, we have obscured the opportunity for producers to focus on those traits, because they are so busy masking differences with artificial environments.

8) **Historically, there has been active resistance to crossbreeding from some traditional marketing outlets, some purebred producers and (in some cases) breed associations.** I would like to commend many of the associations who, quite recently, have taken the risk of suggesting where their animals fit most effectively in crossbreeding programs.

9) **Inappropriate use of breed diversity.** Nothing undermines crossbreeding more quickly than the unplanned "Heinz 57" or "Breed of the Month Club" approach. For those who were willing to experiment in crossbreeding, there was often very poor planning of the combination of breeds and the selection within those breeds.

10) **Our industry and University systems have focused on individual trait measurement for over fifty years.** We have done a very poor job of incorporating real world economics into our models. We have EPD's for a plethora of traits ….and we are adding more! Economic indices are starting to catch up, but we are still behind. Has anyone thought about measuring return per acre or return on investment? We have had a disconnect between agricultural economists and animal science that has not been well bridged. We tend to think lineally rather than laterally, which has reduced the application of innovative crossbreeding.

As I review this list, I am convinced that the primary drawback (among all of the others), is #3…the focus on measuring outputs rather than inputs. With a few notable exceptions, all of the individual animal traits we measure reflect "bigger, faster, more". And certainly, the glamour traits of yearling weight, ribeye area, marbling---have accelerated at a rapid pace. You can make very rapid genetic progress in these highly heritable traits by direct selection within a breed. Therefore, many people fail to see the value of crossbreeding. The value in crossbreeding is often underestimated because it has a small positive effect on many different traits that are lowly heritable and difficult to measure. Frequently, maternal heterosis (the value of the crossbred cow) is about decreasing inputs as much as it is about increasing output. For example, longevity, livability and disease resistance are traits that impact the input side of the equation as much as the output. Our industry has been on a mission to improve product quality and quantity, focusing on carcass traits. We finally were paying attention to our consumers---a good thing! Unfortunately, that effort has been on a per animal basis rather than per unit of input. Do we ever ask ourselves how our long term selection programs affect the profitability of commercial producers?

When EPD's became a marketing tool rather than a genetic improvement tool, a great deal was lost from beef cattle breeding. There was a decision to chase numbers in order to have the "latest and best", and function was often ignored. Purebred breeders were constantly looking for the newest genetics. We utilized lightly proven sires throughout the breeds, before we tested them carefully. And now look……how many genetic defects are we tracking in each major beef breed? A quick check of most of the major breeds websites are somewhere between five and ten! And we discouraged crossbreeding, while we simultaneously narrowed the genetic base of many of the major breeds. Does that make sense? Our current "trait of the month/selection effort" moves us in the direction of genomics. I applaud the scientists who do the work and I see the eventual long term value. But as a commercial cattleman, if I am not capitalizing on crossbreeding---a simple, inexpensive tool to make genetic progress---should I really be worrying about gene markers? Do I really want to select for a marker that may only explain a very small part of the variation of a complex trait ---a trait significantly influenced by genotypic/environmental interactions. If I had a goal for gene markers it would not be for markers that identify highly heritable traits. I can make progress with those traits based on good old fashioned selection programs. The gene markers that I would like to see are for things like disease resistance, fertility, longevity---those traits that make the biggest difference in profitability. Let's not get sidetracked on what determines maximum sustained profit for all segments of the industry. It is not the amount of pounds of product per head. It is amount of product per unit of input cost. Every few years we seem to find another EPD or measurement to chase. When are we going to focus on maximum sustained profit per unit of input?

Three years ago we began a study/field trial (Daley and Earley, 2009b) evaluating the impact of crossbreeding in a vertically coordinated beef system, where premiums are paid for carcass merit. Approximately 600 predominantly Angus based cows were exposed to either Angus or Hereford bulls under extensive range conditions. DNA was used to determine parentage at weaning, and only those calves that could be definitively matched to a single sire were used in the data analysis. Collaborators included Harris Ranch Beef Company (Coalinga, CA); Lacey Livestock of Independence, CA and the American Hereford Association.

Presently we are close to collecting the third year of feedlot/carcass data and the final report should be completed by summer, 2009. However, preliminary results are not surprising. As we measured direct heterosis (heterosis of the calf), there was a small positive advantage in most traits. In particular, crossbred (F1) calves were slightly heavier at weaning, had a slight advantage in feedlot gain and feed efficiency and a lower cost of gain. The crossbred calves had lower quality grades, partially offsetting the economic advantage in the other segments. However, in the first two years of the study, there was a consistent economic advantage to crossbreeding, even factoring the reward for differences in quality grade to the Angus sired calves. The data is not surprising and mirrors decades of research.

Although direct heterosis (heterosis of the calf) is important, we must remember that the true value is maternal hybrid vigor—the incredible value of the crossbred cow. If the data in year three is consistent, it appears there will be an economic advantage in vertically coordinated beef production systems from direct heterosis of the F1. However, the most important economic return will be when the crossbred cow enters the production system. In particular, the potential increase in lifetime productivity and longevity are key to maximum sustained profit per unit of input.

In academia, it seems that we tend to want to make the simple complex. The commercial beef business is faced with a very difficult challenge to maintain long term profitability and viability. There are countless battles (unrelated to cattle breeding) in order to survive and be profitable in the long term. We need to keep cattle breeding simple. We have wonderful within breed selection tools (EPD's). We have the ability to capitalize on breed differences and capture both heterosis and breed complementarity through crossbreeding. Designing simple, long term breeding programs to capture direct and maternal heterosis, while capitalizing on maternal and terminal lines, is a significant step in attempting to maximize sustained profit.

Literature Cited

Cundiff, L V (1970). *Experimental results on crossbreeding cattle for beef production.* J. Anim. Sci 30:694.

Daley, D. A. 2009. *Crossbreeding – Back to the Future.* Proc. Beef Improvement Fed. Sacramento, CA. pp 132-136.

Daley, D.A. and S. P. Earley. 2009. *Impacts of crossbreeding on profitability in vertically coordinated beef industry marketing system (Final Report).* http://www.hereford.org/static/files/HarrisHeterosisReport.pdf. Accessed 30 May 2013.

Gregory, K E, Swiger, L A, Koch, R M, Sumption, L J. Rowden, W W and Ingalls, J. J. E. (1965). *Heterosis in preweaning traits of beef cattle.* J. Anim. Sci 24:21.

Gregory, K E, Koch, R M, Laster, DB, Cundiff, L V and Smith, G M (1978d), *Heterosis and breed maternal and transmitted effects in beef cattle 3: Growth traits in steers.* J. Anim. Sci 47:1054.

Ritchie, H.D., B.D. Banks, D.D. Buskirk, J.D. Cowley and D.R. Hawkins. 1999. *Crossbreeding systems for beef cattle.* Michigan State Univ. Extension Bulletin E-2701.

Taylor, R E, Field T G. *Beef Production and Management Decisions.* Upper Saddle River, New Jersey. Prentice Hall. 1994.

ADDRESSING COWHERD EFFICIENCY IN A WORLD OF MIXED MESSAGES FOR PRODUCERS: MATCHING PRODUCTION LEVELS TO ENVIRONMENTAL CONDITIONS

David Lalman[1], Megan Rolf[1], Robert Kropp[1], Mike Brown [2], Dillon Sparks[1], and Sara Linneen[1]

[1]Oklahoma State University, [2]USDA Grazinglands Research Laboratory

Introduction

Weaned calf prices have set all-time records in recent years. However, escalating land, fertilizer, feed, fuel and labor costs have more than offset increased income for many commercial cow/calf operations (Figure 1, Bevers 2012). Consequently, profit-motivated commercial operations must become more cost-efficient to maintain or improve profit margins. From another perspective, recent appreciation in weaned calf prices provides tremendous financial opportunity for commercial cow/calf enterprises that can minimize and control their cost of production without sacrificing reproductive efficiency.

Grazed forage remains the least expensive source of nutrients to maintain a beef cow herd (Doye and Sahs, 2013). Therefore, a long-term stated goal of ranchers and academicians has been to match cow size and milk production potential to forage resources in order to optimize forage utilization and reproductive efficiency. This statement is logical enough although may not sufficiently emphasize the importance of the possible interaction between the genetic production potential of the cows and stocking rate along with other management factors. Grazing management, forage quality, and stocking rate likely have as much or more impact on this interaction than does the genetic makeup of the cows.

For example, a set of cows with nutrient requirements lower than that supplied annually by a grazed forage system would ostensibly maximize reproductive performance due to excessive nutrient intake (over conditioned cows), but would waste forage resources and potentially produce lower weaning weights (less saleable product). This outcome assumes that stocking rate is set at some point lower than carrying capacity of the forage system given typical environmental conditions. Minimal adjustment in stocking rate would be required during years of drought or other forage production hazards resulting in minimal enterprise risk during those times. Overall ranch productivity could be increased by increasing the stocking rate with more of the same type of cows. However, the enterprise would effectively be more sensitive to risk associated with intemperate environmental conditions.

A cow herd with nutrient requirements above that supplied annually by a grazed forage system would become thin resulting in low fertility and potentially, disappointing calf weaning weights. This situation could lead to overgrazed pasture or rangeland potentially causing permanent damage to the forage resource unless stocking rate is adjusted accordingly. Depending on the degree of mismatch, a reduction in stocking rate may or may not allow the cows to select a diet higher enough in quality to overcome their nutrient deficiencies. If not, a common adjustment is to modify the production environment with purchased or harvested feed in hopes of avoiding depressed reproductive performance and perhaps to boost weaning weights.

Accomplishing equilibrium in this matching process requires consideration of not only genetic production potential and forage resources, but also timing of calving, marketing end point, and numerous other management factors. Because many of the factors involved in this balancing act cannot be measured directly, matching cows and management to forage resources is not a simple task. In this paper, we will consider fundamental animal, forage and management factors along with industry trends that are driving equilibrium or perhaps amplifying imbalance of forage nutrient supply and beef cow requirements.

Industry Trends

Selection for increased weaning and yearling growth has been steady since 1990 according to most breeds' genetic trend data. Similarly, milk EPD in some breeds has consistently increased while other breeds' genetic trend is negative or static. Most breeds with a negative or static genetic trend had a relatively high capacity for milk yield when they entered the U.S. beef industry.

Selection for increased growth through weaning and increased milk should lead to increased weaning weights in commercial operations unless genetic expression for milk and growth is limited by the environment. Interestingly, there is no evidence of sustained increases in weaning weights in commercial cow/calf operations according to Standardized Performance Analysis (SPA) data from New Mexico, Texas and Oklahoma (Figure 2; Bevers, 2012). Benchmarking data from the North Dakota Cow Herd Appraisal Performance Software (CHAPS: Dr. Kris Ringwall, personal communication) program indicates a steady increase in weaning weights from 1996 through 2006 followed by stable weaning weights since 2006 (Figure 3). Is it possible that genetic potential in cattle has surpassed the capacity of forage to provide increased nutrients that must accompany increased production? Although the cause is not immediately clear, we submit that the number of cases where this phenomenon is occurring may be GROWING in commercial cow/calf operations.

When environment and available forage resources are not considered in making selection decisions, the potential exists for dramatic effects on reproductive performance. While reproductive efficiency in the CHAPS benchmarking data shows weaning rates above 90%, which would be considered excellent, there is no indication of sustained improvement in that trait (Figure 4). Similarly, the Southwest SPA data suggests no improvement in weaning rates since the benchmarking program was initiated in the early 1990's (Figure 5). However, comparing these data does emphasize a glaring difference in reproductive efficiency among the two regions. There is an obvious challenge and great opportunity for the development of technology, beef cattle genetics, or production systems to improve reproductive capacity of beef cattle in the South.

Maternal Effects on Weaning Weight (Milk)

Increased milk production requires increased nutrient intake (NRC 1996). We executed a simple calculation considering the efficiency of conversion of additional milk production to additional calf weight gain (Clutter and Nielsen, 1987; Fox et al., 1988; Mallinckrodt, 1993), the energy required to produce a pound of milk (NRC, 1996), and estimated cost per mega calorie of net energy for maintenance (Northcutt, 2013). Average cost per additional pound of calf weight gain from additional milk averaged $1.13. The value of additional weight in U.S. medium and large framed #1 feeder cattle at Oklahoma National Stockyards on Monday, May 22, 2013 averaged $0.85. Obviously, there are many factors that will have dramatic impacts on this cost of added gain calculation; however, this simple calculation shows that there may be a limit to the amount of money that should be invested into generating calf weight through additional pounds of milk production.

One of the most influential factors driving cost of added weaning weight is grazing and feed cost at a given ranch and point in time. The other is conversion of added milk to added calf gain. Regarding the latter point, efficiency of conversion of added milk to added calf gain is improved (around 20:1) with lower yielding cows and considerably exacerbated (around 40:1) with higher yielding cows (Clutter and Nielsen, 1987; Fox et al., 1988; Mallinckrodt, 1993). Declining efficiency of milk utilization with increased genetic potential for milk production given a limited nutritional environment appears to be relatively clear in the literature.

Another important factor that is only occasionally acknowledged is the positive relationship between increased genetic capacity for milk production and year-long maintenance requirements in beef cows (Ferrell and Jenkins, 1984; Montano-Bermudez et al., 1990). Increased maintenance requirements have direct implications for overall feed costs and stocking rate. Higher nutrient requirements associated with increased genetic potential for milk production can be linked to increased size of visceral organ mass (heart, liver, kidney, rumen, small and large intestine) relative to live weight (Ferrell and Jenkins, 1988). Evans et al. (2005) developed an EPD for maintenance energy requirements using these relationships for milk production potential and mature body weight.

Little advancement has been made in terms of improving native rangeland or introduced forage characteristics from a nutritional perspective. Therefore, it is logical that continued selection for increased milk within breeds, whether these breeds are used in a straight or crossbreeding program with other high-milk breeds, may lead to excessive milk that could result in the expression of this trait being limited by the forage system and not by the genetic capacity of the cattle (Figure 6: Brown et al., 2005, Brown and Lalman, 2010). We submit that in many cases in recent years, the environment has been artificially modified to match or surpass the genetic potential of the cattle, rather than discontinuing selection for milk yield in an effort to minimize input costs. Broadly stated, “artificial” modifications to the environment tend to be expensive modifications. Given the dramatic acceleration in input costs seen in recent years, it would seem that downward pressure on milk yield would better fit many cow herds to their respective forage resources from a moderate to low input commercial cow/calf operation’s perspective.

Growth

A similar link could be made with continued selection for growth. The positive relationship between growth and mature weight has long been recognized and debated relative to the potential impact on the commercial cow/calf enterprise. However, perhaps a less debated potential impact is the positive genetic and phenotypic correlation between post weaning growth and feed intake (Arthur et al., 2001). Increased feed intake and gut capacity are related to increased visceral organ mass relative to live body weight (Wang, 2009). Digestive tract tissue and the liver use about 40 to 50% of total energy expenditure in the beef cow, even though these tissues make up less than 10% of the animal’s body mass (Ferrell, 1988). Consequently, variation in mass of these organs is likely related to variation in energy expenditures. Continued selection for growth and “capacity” may be a contributing factor to the high cost of keeping a beef cow in today’s expensive production environment. Moreover, from a commercial cow/calf perspective (low input production system), continued selection for cattle with extreme appetite and a larger digestive tract may expose an enterprise depending primarily on grazed forage to more risk. For example, could these cattle be negatively affected to a greater extent during times of intensified environmental restriction such as drought? It would seem that continued development of residual feed intake technology and selection tools may serve the commercial cow/calf sector well in this regard. Moreover, a planned crossbreeding program utilizing breed complementarity and heterosis would appear to represent “low hanging fruit” from the perspective of developing beef cow herds with moderate to low maintenance requirements, high fertility and finished beef carcasses with optimal retail product yield.

Conclusions

Perhaps the dramatically higher input costs and competition for grazing land has effectively narrowed the range of cow type that “fits” production environments in the U.S. From a low to moderate input commercial cow/calf operation perspective, failure to effectively utilize planned mating systems to maintain moderation in the cowherd while producing desirable calves for sale within the beef value chain may be leading us to a cow herd that is more expensive to maintain, while actual production within the commercial sector may not be improving. The lack of improvement in reproductive efficiency in the South is of particular concern. Emphasizing moderation in growth, mature size, and milk for replacement females, combined with a modification in ranch stocking rate would seem to better fit more cattle to existing forage resources given current industry trends. Commercial cow/calf producers are encouraged to emphasize new selection tools designed to minimize maintenance requirements of cows while maintaining or improving reproductive efficiency. Additionally, use of mating systems designed to maximize cowherd efficiency while maintaining high consumer acceptability in beef should aid producers in managing risk and increasing profitability.

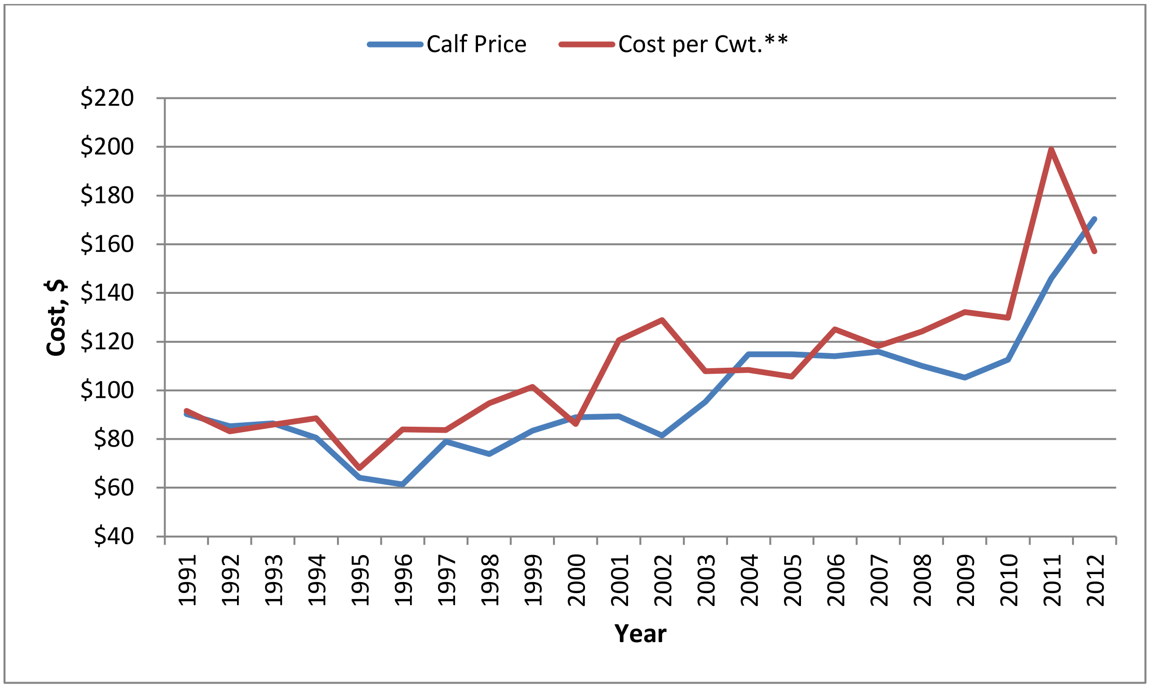


Figure 1. Calf price versus cost per unit of production in New Mexico, Oklahoma and Texas commercial cow/calf operations (Bevers, 2012).

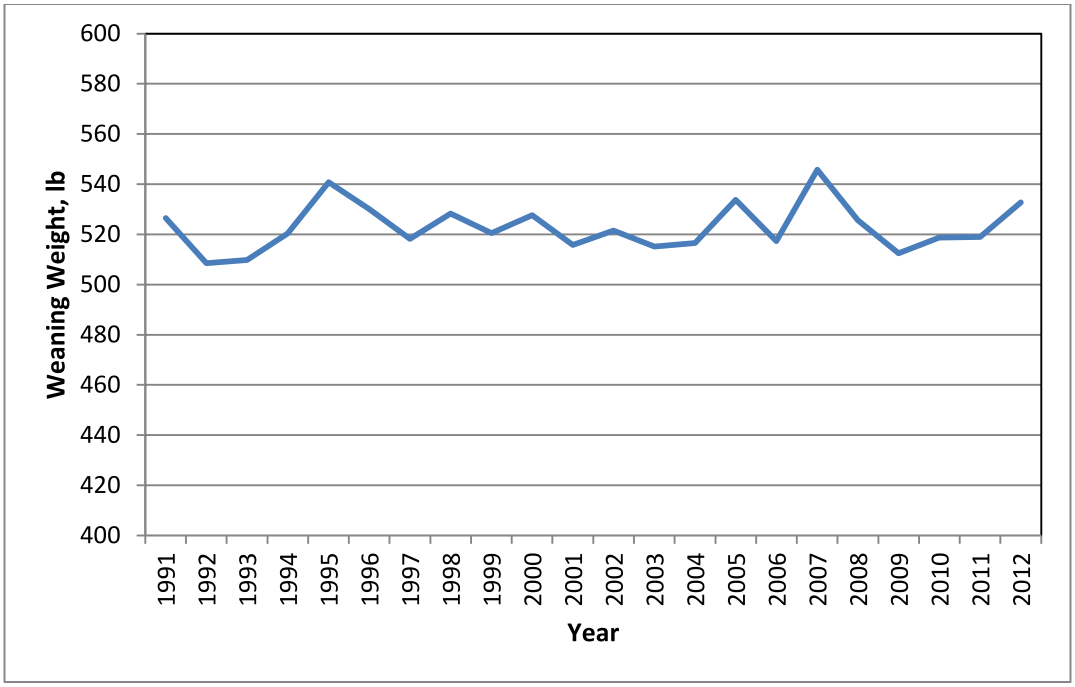


Figure 2. Average weaning weights in New Mexico, Oklahoma and Texas commercial cow/calf operations (Bevers, 2012).

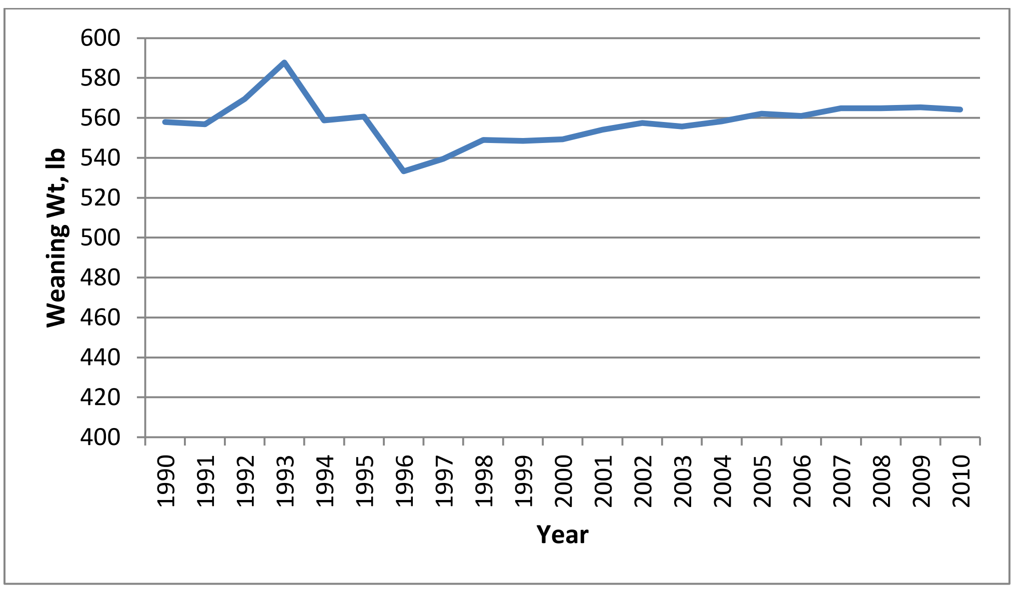


Figure 3. Average weaning weights in North Dakota commercial cow/calf operations (Cow Herd Appraisal Performance Survey (CHAPS), Dr. K. Ringwall, 2013).

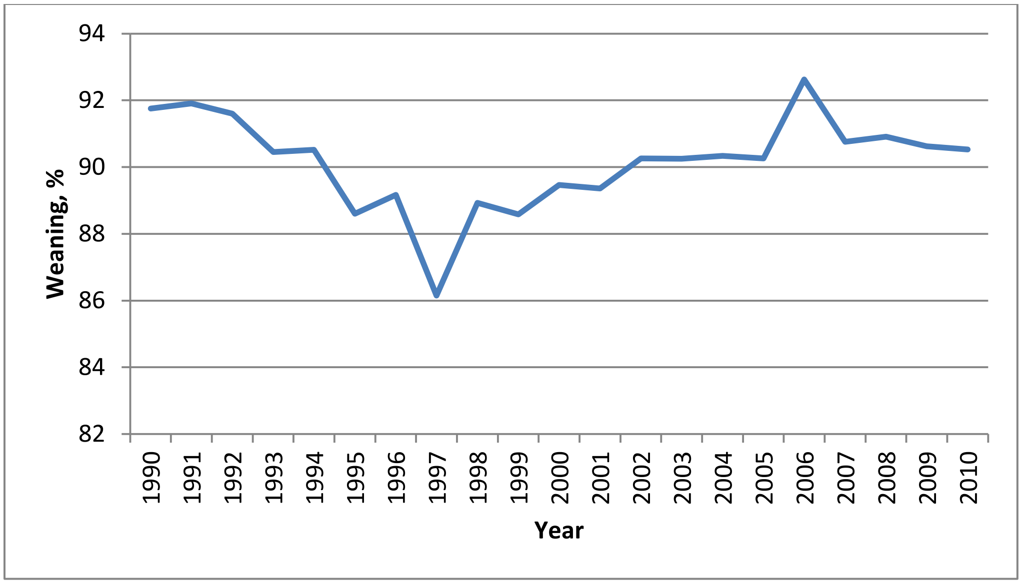


Figure 4. Average weaning percent in North Dakota commercial cow/calf operations (Cow Herd Appraisal Performance Survey (CHAPS), Dr. K. Ringwall, 2013).

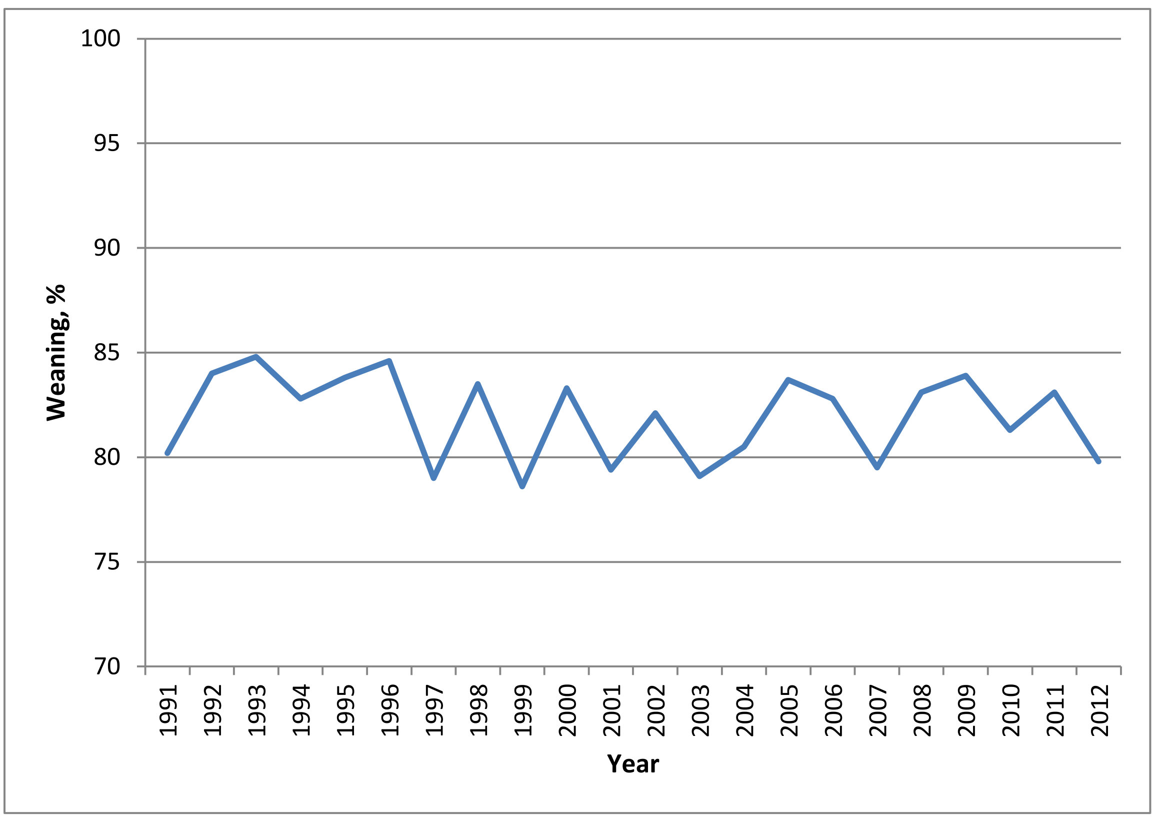


Figure 5. Average weaning percent in New Mexico, Oklahoma and Texas commercial cow/calf operations (Bevers, 2012).

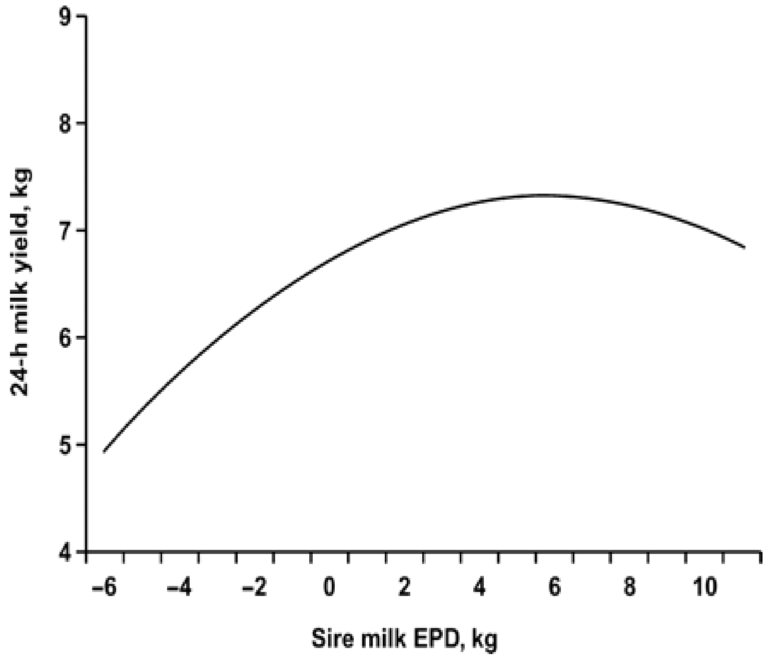


Figure 6. The relationship of sire milk EPD and 24-h milk yield in Brangus cows grazing tall grass prairie in Oklahoma (Brown et al., 2005).

Literature Cited

Arthur, P.F., J.A. Archer, D.J. Johnson, R.M. Herd, E.C. Richardson, and P.F. Parnell. 2001. *Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle.* J. Anim. Sci. 79:2805-2811.

Bevers, S.J. 2012. *Standardized performance analysis (SPA) for decision making.* 2012 Beef Cattle Short Course, August 8, 2012. Available at: http://agrisk.tamu.edu/files/2012/05/SPA-Informing-Decision-Makers.pdf

Brown, M.A., S.W. Coleman, and D. L. Lalman. 2005. *Relationship of sire expected progeny differences to milk yield in Brangus cows.* J. Anim. Sci. 83: 1194-1201.

Brown, M.A. and D.L. Lalman. 2010. *Milk yield and quality in cows sired by different breeds.* 2010. Prof. Anim. Sci. 26:393-397.

Clutter, A. C. and M. K. Nielsen. *Effect of level of beef cow milk production on pre- and postweaning calf growth.* 1987. J. Anim. Sci. 64:1313-1322.

Doye, D.G. and R. Sahs. 2013. *Oklahoma pasture rental rates 2012-2013.* Available at: http://agecon.okstate.edu/faculty/publications_results.asp?id=4532&submit2=1&page=1

Evans, J.L., B.L. Golden, B.L. Hough. 2002. *A new genetic prediction for cow maintenance energy requirements.* Proceedings: Beef Improvement Federation available at: http://www.beefimprovement.org/proceedings.html.

Ferrell, C.L. 1988. *Contribution of visceral organs to animal energy expenditures*. J. Anim. Sci. 66:23-34.

Ferrell, C.L. and T.G. Jenkins. 1984. *Energy utilization by mature, nonpregnant, nonlactating cows of different types.* J. Anim. Sci. 58:234-243.

Fox, D.G., C.J. Sniffen, and J.D. O'Connor. 1988. *Adjusting nutrient requirements of beef cattle for animal and environmental variations*. J. Anim. Sci. 66:1475:1495.

MacNeil, M.D., L.V. Cundiff, C.A. Dinkel, and R.M. Koch. 1984. *Genetic correlations among sex-limited traits in beef cattle.* J. Anim. Sci. 58:1171-1180.

Mallinckrodt, C. H., R. M. Bourdon, B. L. Golden, R. R. Schalles and K. G. Odde. 1993. *Relationship of maternal milk expected progeny differences to actual milk yield and calf weaning weight.* J. Anim. Sci. 71:355-362.

Northcutt, S.L. 2013. Angus $ Values. Available at: http://www.angus.org/Nce/ValueIndexes.aspx:

NRC. 1996. *Nutrient requirements of beef cattle.* 7th rev. ed. Natl. Acad. Press, Washington, DC.

Wang, Y.J., M. Ko, S. Holligan, B.W. McBride, M.Z. Fan, and K.C. Swanson. 2009. *Effect of dry matter intake on visceral organ mass, cellularity, and protein expression of ATP synthase, Na+/K+-ATPase, proliferating cell nuclear antigen and ubiquitin in feedlot steers.* Can J. Anim Sci. 89:253-262.

BAD NEWS: THEY'RE ALL CARRIERS OF SOMETHING – BROKEN GENES IN THE BEEF BUSINESS

Dorian Garrick[1]

[1]*Department of Animal Science, Iowa State University, Ames IA 50011*

Background

Cattle typically have 30 pairs of chromosomes, comprising 29 pairs of autosomes and XX or XY sex chromosomes. Chromosomes are made from DNA which consists of a sequence of bound paired chemical compounds, known as nucleotides, which are made up of a nitrogenous base, a sugar, and some phosphate groups. There are four kinds of nucleotides; adenine (A), guanine (G), thymine (T) and cytosine (C), and the sequence of these four compounds dictate the genetic characteristics of an individual. A typical cattle chromosome consists of 100 million base pairs, and occurs in two versions, one inherited from the sire and the other inherited from the dam. Accordingly, the genome consists of 3 billion base pairs inherited from one parent, and a similar number inherited from the other. After fertilization, these 6 billion base pairs must be copied every time a cell divides, in a process known as mitosis. An adult contains something like 50-100 trillion cells, and any error that occurred during the copying of the chromosomes or their division into daughter cells will be propagated in subsequent divisions of the cell. During development, cells specialize to form around 200 different cell types, including those different types found in muscle, fat, skin, blood and various organs. Most errors that occur in DNA replication are not passed on to offspring - only those cells that form parts of the testicular or ovarian tissue can contribute to the genomes of future generations.

Changes in genomic sequence such as those that arise from DNA copying errors are known as mutations. There are a number of different kinds of mutations that can arise. Sometimes one base pair (A, G, T or C) is mistakenly copied for an alternate base pair. This is known as a single nucleotide polymorphism (SNP). Other mutations might involve the accidental duplication of a piece of DNA, an accidental deletion of a piece of DNA, or an inversion whereby the sequence is partially reversed. Errors in copying DNA are very common, perhaps 1 in every 100 base pairs, but the cell has DNA repair mechanisms that identifies and repairs almost all of the errors. The typical error rate remaining after the repairs is something like 1 in every 30 million nucleotides each generation, or a little over 3 mutations per chromosome per generation.

Most of the genome does not code for genes. Genes comprise a promoter region, coding regions known as exons, and regions between exons that are known as introns. The sequence between the locations of genes are known as intergenic regions. Perhaps only 2-3% of the genome comprises exons, and only half of these code for proteins. Accordingly, the impact of mutations on performance depends largely upon which part of the genome is mutated. Mutations in intergenic regions between genes, or in introns are less likely to be damaging than mutations in exons. It is now possible to have exonic regions captured and individually sequenced for less than $2,000, or a whole genome sequenced for less than $10,000, although these prices are likely to erode markedly over the next decade. Sequence information is believed to be useful in personalized human medicine, and in assessment of risk for certain diseases such as heart disease, diabetes or cancer.

The fact that chromosomes occur in pairs means that except for some genes on the sex chromosomes an individual inherits two copies of every gene, one from their sire and the other copy from their dam. A mutation in one copy of the gene may not be very serious provided the other copy is functional. Due to the presence of historical mutations, every individual inherits a number of dysfunctional genes from its sire, and a number of other dysfunctional genes from its dam. On average, half of these will be passed on to the offspring, along with half the 100 or so new mutations, mostly not in genes, that are new (*de novo*) to the sperm or egg, or occurred in the individual between the time of its conception and the time it becomes a parent. Many mutations inherited by the offspring will not be passed on because the offspring is harvested without becoming a parent, or because of chance sampling when a parent has few offspring. There develops from a population perspective a balance between the creation of new mutations and the loss of existing mutations. Widely used sires are likely to pass on all their mutations to some of their progeny and in this manner the frequency of certain rare mutations can increase markedly in just one generation of widespread use.

Loss-of-function mutations

Mutations in genes may or may not be problematic. Proteins consist of sequences of amino acids. There are 20 different amino acids, and each is specified at DNA level by a triplet sequence of base pairs. Since each base pair can be one of four options, there are $4\times4\times4=64$ different possible triplets to represent the 20 amino acids or a stop codon which is the signal to terminate the protein. This means that more than one triplet sequence can represent the same amino acid. Accordingly, some mutations can change the triplet code but have no impact on the amino acid sequence. These are known as synonymous mutations. Other mutations will result in substitution of one amino acid for another and are known as non-synonymous or misssense mutations. Such mutations may or may not have serious impacts, depending upon the extent they change the shape or other properties of the resultant protein. Some mutations will result in the gene being dysfunctional or “broken” and these are known as loss-of-function mutations. This includes some non-synonymous mutations that seriously impact the protein properties, as well as mutations that disrupt the start or the stop information, known as nonsense mutations. Mutations can prevent the protein forming at all, or can make it too short or too long. Some loss-of-function mutations are of particular concern because they can impact the viability or productivity of the resulting offspring.

Even loss-of-function mutations are not a real problem in an outbreeding population because the mutations carried by any particular sire are likely to be rare in its unrelated mates.

However, the same cannot be said in the presence of inbreeding, as occurs to a mild extent when animals of the same breed are mated together. In these circumstances, a mutation that an ancestral sire passed on down through its daughters and subsequent maternal lineages is also likely to be carried by one or more of its paternal lineage. In that case we would expect one-quarter of matings between sires that carried the mutation and dams that carried the same mutation to exhibit the recessive genetic defect.

Serious defects may prevent normal completion of the pregnancy, and may go unnoticed, except perhaps by a slight reduction in reproductive performance. In other cases the defect may be apparent in the new-born offspring. In a performance recorded setting, particularly with single-sire mating, such occurrences can often be easily detected. This is the case in the dairy industry where sires are routinely used simultaneously across many herds. Sadly, the track record for early detection of genetic defects in the beef industry has been much poorer, and presence of a visual deformity has sometimes been associated with the three s's – shoot, shovel and shut up. That is, a bull breeder observing a defective newborn might destroy the evidence and eliminate the further use of the sire and dam and other close relatives, rather than communicating the finding at the risk of developing a reputation for genetic defects that may lose them market share. This approach may sometimes be successful, but in many cases has simply delayed the recognition of the genetic defect while it becomes more widely propagated in the industry.

Identifying loss-of-function mutations

There are several approaches that have been successfully used to identify loss-of-function mutations. The oldest method is based on the appearance of defective offspring, such as dwarfs. Not all defective offspring represent inherited genetic abnormalities. Matings between parents of defective offspring (i.e. carriers) should produce 1 out of 4 defective offspring for a recessive condition.

Prior to methods for comprehensively genotyping the entire genome, genetic defects had to be managed by progeny testing. An effective method was to mate a potential carrier sire to dams that were known to carry the defect. This required carrier animals to be maintained, and also resulted in delays in waiting for progeny test results before the sire could be confidently used. Half a century ago in the US, it had been a common occurrence by some Hereford breeders to mate a sire to a few of his daughters and to delay the wide use of the sire until the results of the inbred matings had been observed to confirm the absence of defective offspring.

Mannisidosis was one such recessive disease not uncommon in Angus cattle until Dr. Bob Jolly at Massey University in New Zealand identified a blood test to distinguish apparently normal carrier animals from animals that were free of the defect. The blood test took advantage of the fact that animals with only one functional copy of the α-mannosidase enzyme had lower (i.e. about half) blood concentrations of the enzyme than animals with two functional copies.

Screening animals to detect carriers based on a blood test was much easier than progeny testing and was rapidly adopted by industry.

Nowadays, the availability of high-density genotyping panels in most livestock species has made it possible to identify carrier animals by inspecting their DNA. In order to develop a test for the disease, the genomic region responsible for the defect must first be identified. This can be very easily done with the DNA from 10-15 affected offspring, or less, provided the condition really is due to a homozygous recessive condition. The analysis simply involves genotyping the affected animals, and identifying any regions where they are all homozygous for the same SNP alleles. We have recently undertaken such an approach with three different recessive conditions in sheep. The results of the experiments showed that the disease was contained within a genomic region whose size ranged between 1-10% length of one chromosome. A similar approach was used to find the cause of osteopetrosis in Red Angus cattle (Meyers *et al.*, 2010), arthrogryposis multiplex (AM) in Angus cattle (http://www.angus.org/NAAB_release.pdf), and many recessive diseases in dairy cattle (e.g. Charlier *et al.*, 2008; Charlier *et al.*, 2012).

Sequencing technology allows the actual sequence of nucleotides to be readily determined in each of the homozygous genomic regions that were common to all the affected animals. Within 12 months we were able to identify what we believe to be the actual causal mutation in three sheep diseases. One was due to a nonsense mutation that altered one base pair so that the protein encoded by the gene was prematurely terminated. Another was due to a base pair change that resulted in the protein that comprises a sequence of amino acids, having one different amino acid in its sequence that changed the shape of the protein and therefore its biological properties. The third disease had a single base pair missing, known as a frameshift mutation, resulting in a complete change in the amino acids that form the protein from the point of mutation onwards. The cause of osteopetrosis in Red Angus cattle was the deletion of 2,800 base pairs that removed exon 2 and nearly half of exon 3 (Meyers *et al.*, 2010). The cause of AM is the deletion of a significant genome fragment (http://www.freepatentsonline.com/y2011/0151440.html).

Genomic technologies have now provided two additional methods for detecting loss-of-function mutations, and these will lead to a marked increase in the number of such mutations discovered over the next few years. The increase in mutation discovery rate reflects the fact that the conventional approach based on observing defects has two shortcomings. First, the conventional approach cannot easily detect defects that cause fertilization failure or embryonic loss. Second, the conventional approach relies on breeders noticing and reporting the defects. Rare defects may only be apparent in individual cases within any particular herd, and not be recognized as having a genetic origin. Many recently discovered defects in cattle have now been shown to have been present but undetected for several decades or longer. The two new methods for finding defects don’t rely on the use of phenotypes in the first instance, but instead rely either on the use of SNP marker panels across a subset of the population, or on whole genome (or exome) sequencing of one or more individuals.

Unlike most cells, gametes such as sperm or eggs contain only one copy of each of the 30 pairs of chromosomes. These single copies typically represent a chromosome that is not the same as either the paternal or maternal chromosome of the parent, but represents a new variant created from a crossover between the two parental chromosomes in the pair. This means that DNA is not inherited one base pair at a time, but in large units. Accordingly, many base pairs and therefore alleles are inherited together in a chunk of chromosome that forms a small unit known as a haplotype. Although SNP marker panels only identify the genotype of an individual (i.e. A_1A_1, A_1B_1 or B_1B_1 at a particular locus, say 1), population data allows haplotypes to be identified. Suppose an animal was heterozygous (i.e. A_1B_1 and A_2B_2) at two adjacent loci. This means that at either locus one chromosome carries the A allele and the other chromosome carries the B allele. However, these genotypes do not tell us unambiguously which haplotypes are carried by the individual. Animals that are heterozygous at two adjacent loci might represent two different haplotype combinations. One haplotype combination is known as coupling and would comprise one chromosome carrying the two adjacent A alleles (i.e. A_1A_2), and the other chromosome carrying the two adjacent B alleles (i.e. B_1B_2). An alternative haplotype combination is known as repulsion and it involves one chromosome carrying the A_1 allele next to the B_2 allele (i.e. A_1B_2), while the other chromosome would carry the B_1 allele next to the A_2 allele (i.e. B_1A_2). Bot these haplotype combinations would results in the same genotypes. Using population data, it is possible to reconstruct haplotypes from the SNP genotypes. This would normally be undertaken for much larger regions than just 2 loci. A sequence of 20 consecutive SNP markers could produce over 1 million different haplotypes, but in a typical beef cattle population we are likely to only observe about 20 common haplotypes.

If a common haplotype contains a deleterious mutation such as one causing loss of function, we would not observe the expected proportion of individuals that were homozygous for that haplotype. Scientists at USDA AIPL have used this concept in the US dairy population (VanRaden *et al.*, 2011) to find haplotypes in 5 regions of the genome that should have been observed if they had no detrimental effects, but have never been seen. Similar studies in France using the same approach found some of the same regions and confirmed another 9 mutations (Fritz *et al.*, 2013). This approach has yet to be applied to US beef cattle populations.

Genomic sequencing of individual animals involves the comparison of their sequence to the bovine reference genome based on the Line 1 Hereford cow Dominette. Inspection of the sequence of known genes can identify potentially serious missense mutations as well as nonsense mutations, splice site variants and damaged start regions. Every animal (and human) carries a number of such mutations. Most of these mutations will have been inherited from a parent and may have existed in the population for many generations whereas some may be *de novo* mutations that have just occurred in the most recent generation. Any candidate loss-of-function mutations can be individually screened in the population and/or added to the next generation of SNP chips.

In many species particularly humans, the study of affected individuals allows identification of mutations causing inherited diseases which adds to published knowledge as to the importance of particular genes. In model animal species such as mice, considerable research has been undertaken to "knock out" or deliberately create loss-of-function mutations in almost every known gene. Knowledge of the productive attributes of the resultant animals homozygous for the knock out provides valuable information as to the likely role or impact of that gene. Some genes can be knocked out without apparent effect, whereas others might impact production (e.g. muscularity or obesity), lactation, reproduction, longevity etc. Collectively, this information from naturally mutations and from knock out studies undertaken on a range of species allows the annotation of bovine genome sequence and automated identification of possible loss-of-function mutations.

Managing loss-of-function mutations

The immediate reaction of many farmers to the finding that one of their animals carries a genetic defect is to discard the animal and any descendants that inherited the defective mutation. However, this is not a good idea – every individual carries defective mutations – the sensible approach is to manage the matings in such a way as to avoid the pairing of carrier animals. A carrier animal may be a perfectly good terminal sire and will not result in defective offspring when used in an outcrossing program even when carrier offspring are retained for breeding to a terminal sire.

In a bull breeding herd carrier animals can still be used provided the offspring are screened for the mutation and only those that are free of the defect should be mated to animals that carry the defect. Mate selection software now being trialed by some breed associations can be usefully applied to minimize the impact of such mutations (e.g. Kinghorn, 2011).

Dr. Jerry Taylor at University of Missouri has obtained USDA funding for sequencing widely-used sires in a number of US beef breeds and a similar Genome Canada project at University of Alberta and University of Guelph in Canada has almost completed the sequencing of about 300 beef sires. An international effort in dairy and beef cattle is underway with a target of sequencing 1,000 bovine genomes (http://www.1000bullgenomes.com). That project represents a collaborative effort where approved contributors of 25 or more sequenced animals can gain access to the sequences on all the animals in the project.

Summary

Mutations are a natural occurring phenomenon that provide a mechanism for genetic variation. There are a number of kinds of mutations, and one common kind is represented by alterations in DNA that cause loss of function of the gene. All individuals carry loss-of-function mutations. Some have been identified as inherited diseases with obvious abnormalities (e.g. dwarfism). Most have gone undetected. Genomic technologies now allow loss-of-function mutations to be discovered through absence of homozygote haplotypes, or through annotation of individual genomic sequence. Some of these new discoveries will include those that impact embryonic mortality. The challenge for breeders in the future will be to manage known mutations in their herds.

Literature Cited

Charlier C, Coppieters W, Agerholm Js, Cambisano N, Carta E, Desmecht D, Divem, Fasquelle C, Frennet Jc, Hanset R, Hubin X, Jorgensen C, Karim L, Kent M, Harvey K, Pearce Br, Rollin F, Simon P, Tama N, Nie H, Vandeputte S, Lien S , Longeri M , Fredholm M , Harvey Rj, Georges M. 2008. *Highly effective SNP-based association mapping and management of recessive defects in livestock.* Nature Genetics, 40(4):449-54. Epub 2008 Mar 16.

Charlier C, Agerholm Js, Coppieters W, Karlskov-Mortensen P, De Jong G, Li W, Fasquelle C, Karim L, Cirera S, Cambisano N, Ahariz N, Mullaart E, Georges M, Fredholm M. 2011. *A deletion in the bovine FANCI gene compromises fertility by causing fetal death and brachyspina.* PLoS ONE 7(8):e43085.

Fritz S., Capitan A., Djari A., Rodriguez S.C., Barbat A., Baur A., Grohs C., Weiss B., Boussaha M., Esquerre D., Klopp C., Rocha D., Boichard D. 2013. *Identification of novel mutations associated with prenatal mortality in dairy cattle.* PAG 2013. http://www.intl-pag.org

Kinghorn BP. *An algorithm for efficient constrained mate selection.* 2011. Genetics, Selection, Evolution, 43:4.

Meyers S.N., McDaneld T.G., Swist S.L., Marron B.M., Steffen D.J., O'Toole D., O'Connell J.R., Beever J.E., Sonstegard T.S., Smith T.P.L. 2010. *A deletion mutation in bovine SLC4A2 is associated with osteopetrosis in Red Angus cattle.* BMC Genomics 11:337.

VanRaden P.M., Olson K.M., Null D.J., Hutchison J.L. 2011. *Harmful recessive effects on fertility detected by absence of homozygous haplotypes.* Journal Dairy Science 94:6153–6161.

Sexed Semen

Congratulations!
It's a Girl!

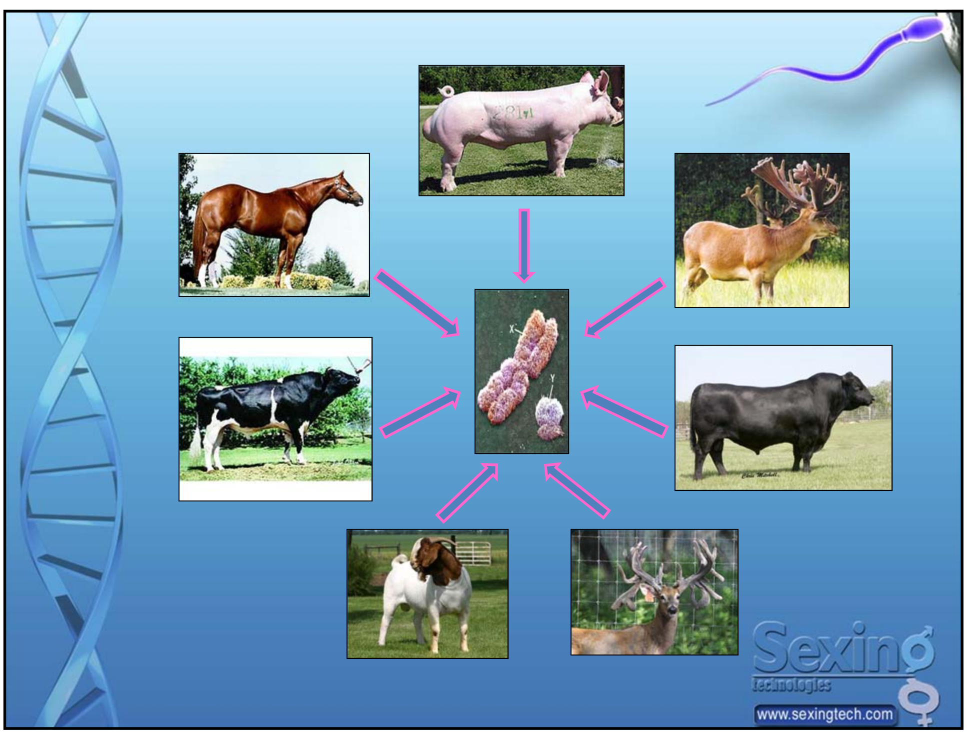
Dustin T. Dean, PhD
Director of Beef Programs
Sexing Technologies, Navasota TX

Sexing technologies
www.sexingtech.com

A Global
Livestock Services Company

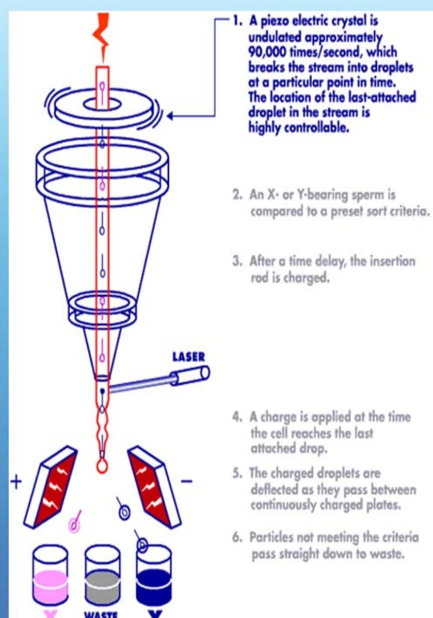
Sexing technologies
www.sexingtech.com


SELECT SIRES
gender SELECTed
SEMEX
semexx
ABS
ABS SEXATION
Accelerated Genetics
ACCESS
Sexed Semen
CRV
SiryX
SÊMEN Lagoa SEXADO
TWG
TRANS-WORLD GENETICS
SEXED
CRI Cooperative Resources International
GenChoice
UMOTEST
Sexumo
Alta
Alta 511 Fast Track Your Future
SEMEN ITALY
FOEMINA
Sexing technologies
Sexing technologies
www.sexingtech.com

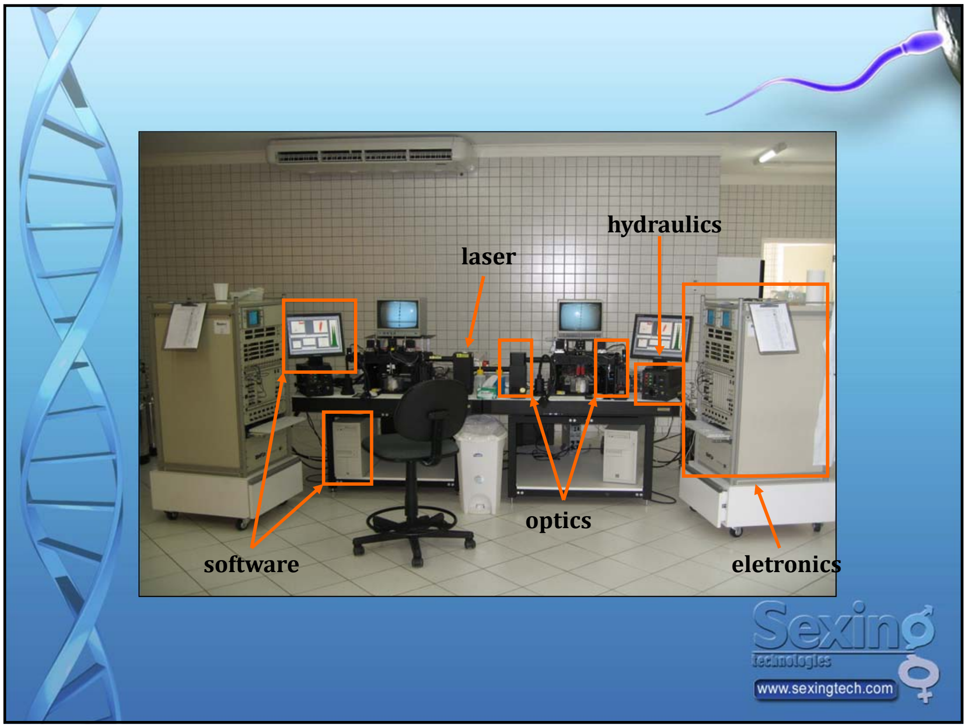

Sexing technologies
www.sexingtech.com

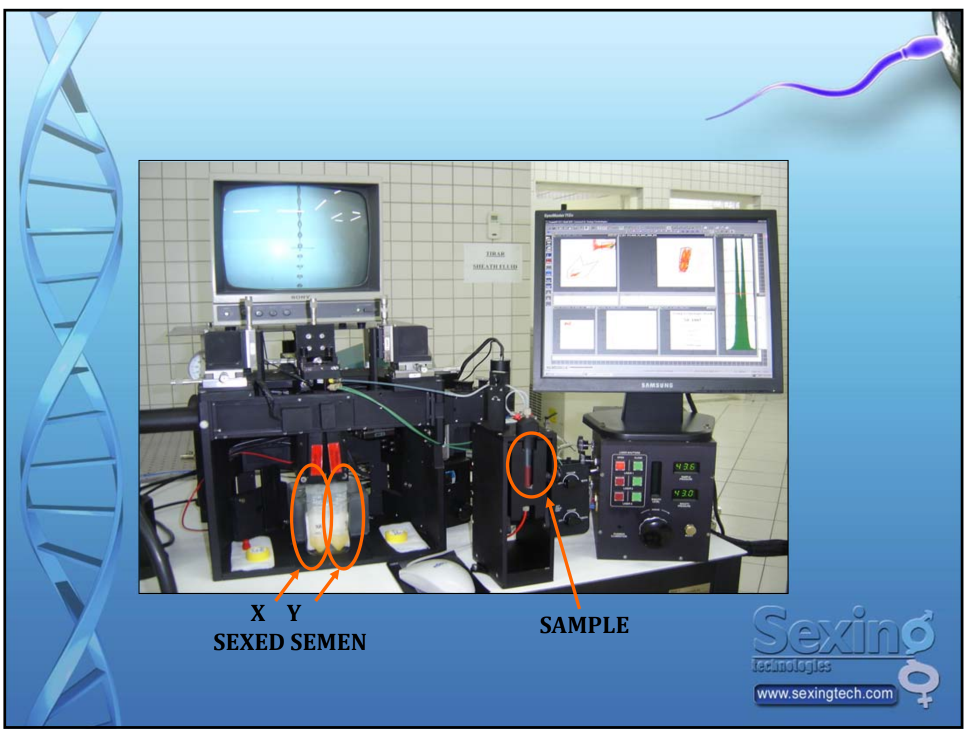
Pre-Sort Quality Control

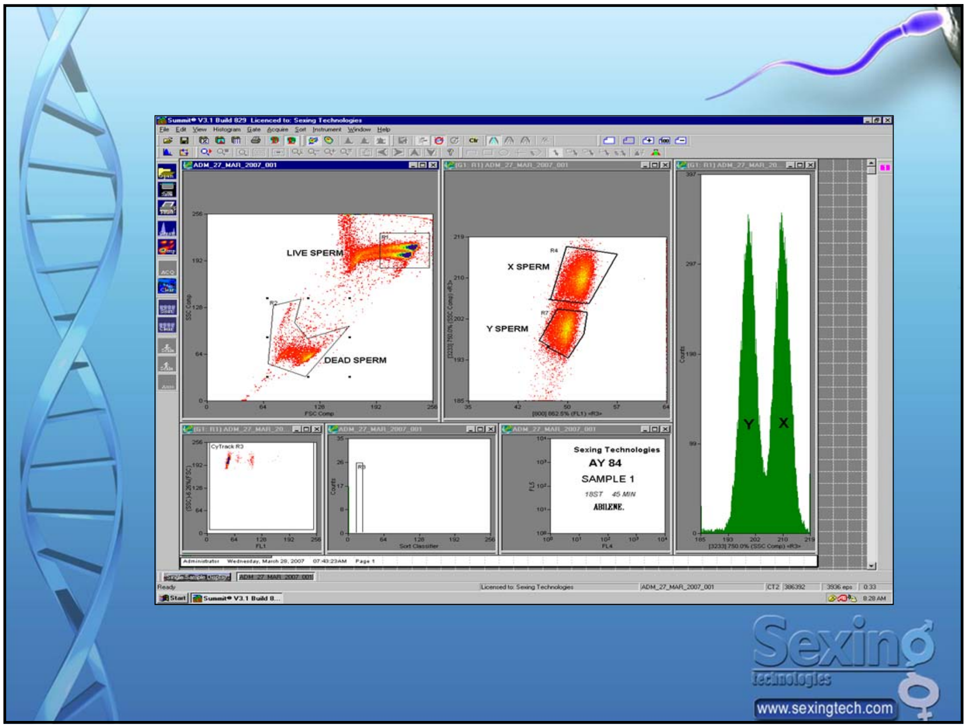
- Volume of 6 - 7 ml minimum
- Concentration of no less than 1.1 billion sperms per ml.
- Motility over 60%
- Less than 15% Primary Problems - Heads
- Less than 15% Secondary Problems - Tails
- Less than 25 - 30% Total Morphologic Problems

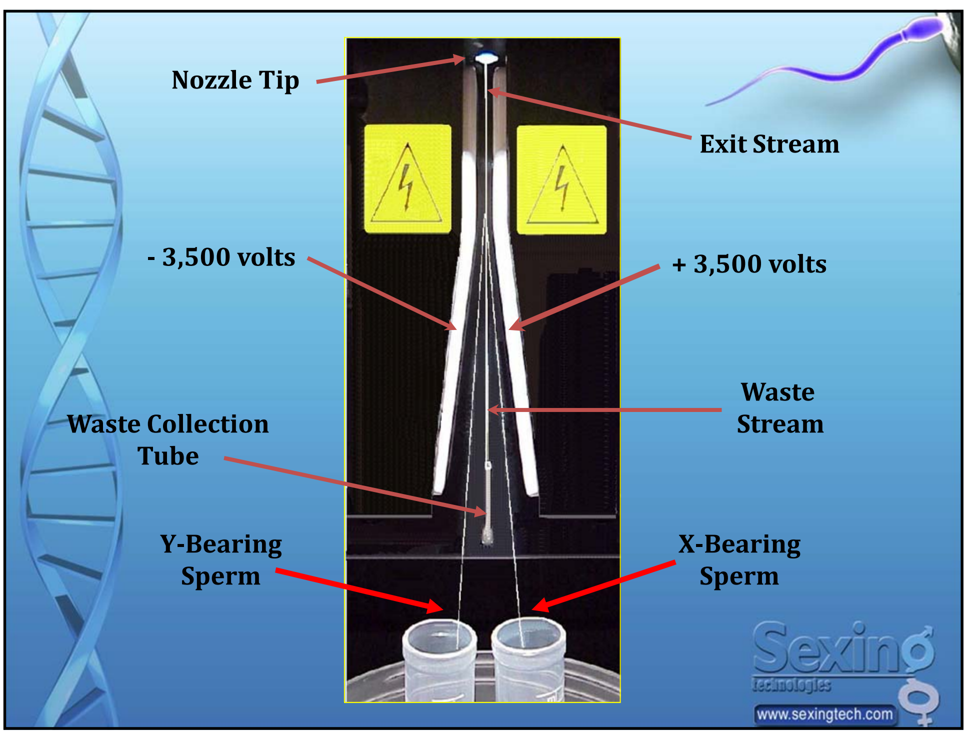


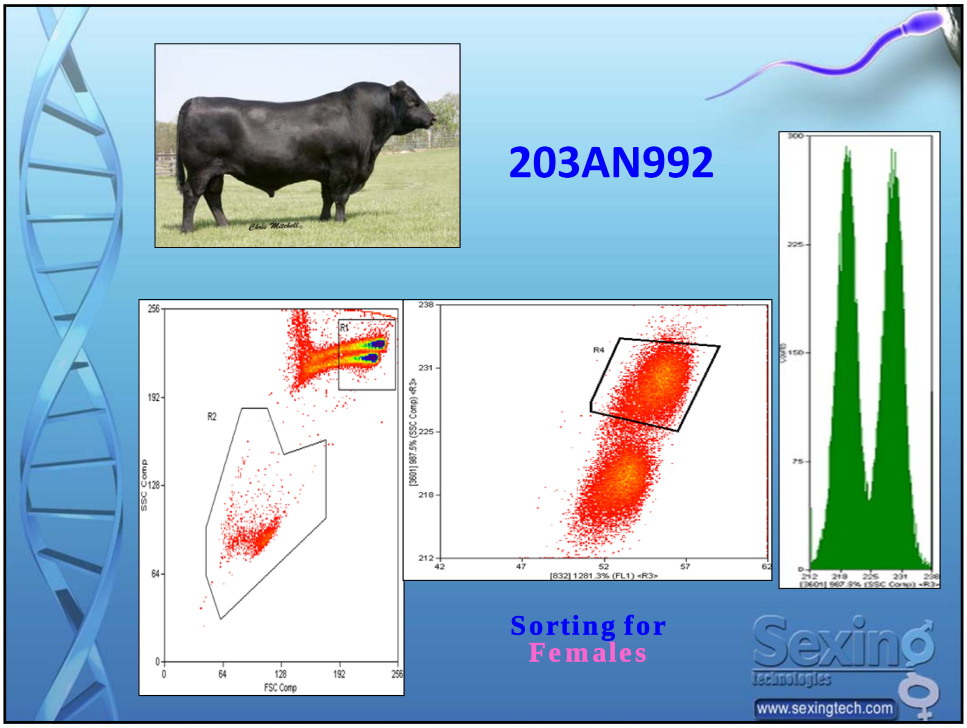
Sexing technologies
www.sexingtech.com

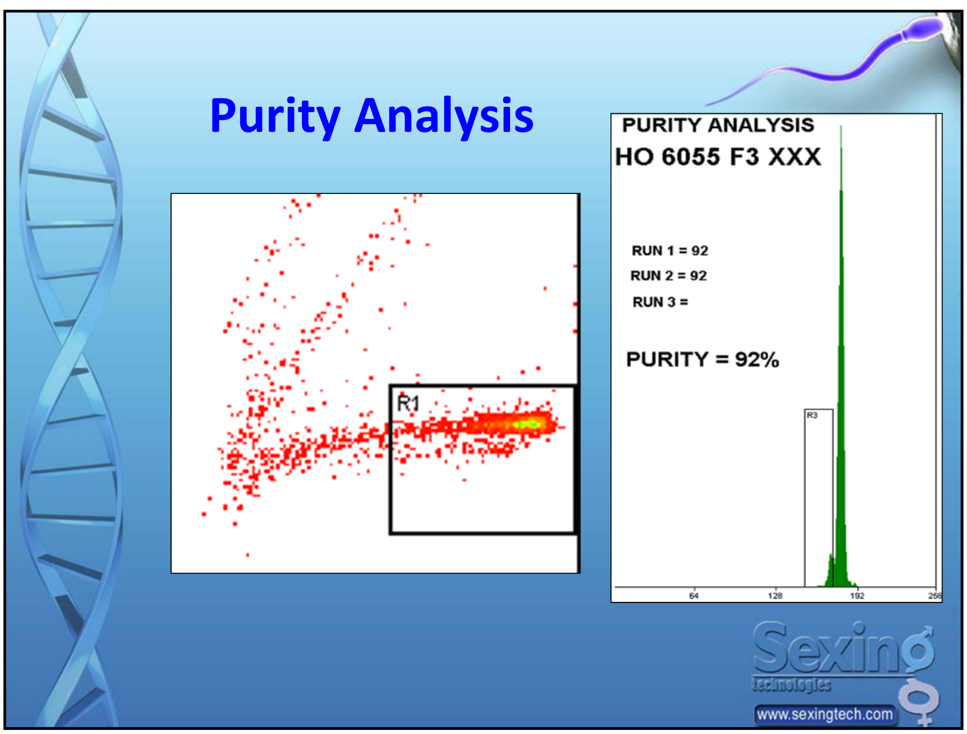

hydraulics
laser
software
optics
eletronics
Sexing technologies
www.sexingtech.com


X Y
SEXED SEMEN
SAMPLE
Sexing technologies
www.sexingtech.com


LIVE SPERM
DEAD SPERM
X SPERM
Y SPERM
Sexing Technologies
AY 84
SAMPLE 1
Y
X
www.sexingtech.com


Nozzle Tip
Exit Stream
- 3,500 volts
+ 3,500 volts
Waste Stream
Waste Collection Tube
Y-Bearing Sperm
X-Bearing Sperm
www.sexingtech.com


203AN992
R1
R2
R4
SSC Comp
FSC Comp
Sorting for
Females
Sexing
technologies
www.sexingtech.com


Purity Analysis
R1
PURITY ANALYSIS
HO 6055 F3 XXX
RUN 1 = 92
RUN 2 = 92
RUN 3 =
PURITY = 92%
R3
64
128
192
256
Sexing
technologies
www.sexingtech.com

What's the Economic Relevance?

Sexing Technologies
www.sexingtech.com

Sexed Semen Economics

"We shouldn't dismiss a technology just because of the added cost. We should also factor in the added value that it can provide"

"If someone is taking the time to perform AI or ET, they most likely prefer one gender over the other"

"The cost of the semen relative to the calf's value is very low, but seldom expressed in this way"

Sexing Technologies
www.sexingtech.com

Sexed Semen Economics

"The Return on Investment of Sexed Semen is very attractive with an increasing gender difference "

"Higher per straw cost and slightly lower conception rates are overcome by an increased percentage of the desired gender"

IVF
2.1 Dose Straws

Flushing
5.0 Dose Straws

AI
2.1 or 5.0 Dose Straws

Where do I use Sexed Semen?

Bring your bull to Sexing Technologies and have it custom produced.

Purchase from one of the major AI Stud companies.

Purchase from someone else who had it custom produced.

How do I get Sexed Semen?

Sexed Semen Myths and Facts

•**A bull produces more heifers or more bulls**—*That might be the case at home, but the percentage of bull sperm and heifer semen contained in a bull's ejaculate is never much more than 50/50.*

•**Male cells or Female cells swim faster than the other**—*Nope.*

•**Every bull's semen can be sorted**—*Most can, but a few can't due to inherent abnormalities in the sperm cells and sperm "vigorousness".*

•**Inherent conception rates associated with sexed semen are static**. *Nope. Conception rates with sexed semen are increasing through more effective management and technique, and also through indirect selection for bulls with higher quality semen.*

•**The technology isn't proven** —*That's not true. Dairy producers buying and using millions of units of sexed semen every year say so.*

Life-Cycle, Total-Industry Genetic Improvement of Feed Efficiency in Beef Cattle: Blueprint for the Beef Improvement Federation

M.K. Nielsen[1], M.D. MacNeil[2], J.C.M. Dekkers[3], D.H. Crews, Jr.[4], T.A. Rathje[5], R.M. Enns[4], and R.L. Weaber[6]

[1]University of Nebraska-Lincoln, [2]Delta G, [3]Iowa State University, [4]Colorado State University, [5]Danbred North America, [6]Kansas State University

Introduction

Beef, as a protein source for humans, has two major positive characteristics relative to pork and chicken: 1) consumers, on average, place greater preference for beef in its eating characteristics and 2) beef animals, on an industry-wide life-cycle basis, consume large amounts of lower-cost forages as compared to higher-cost concentrates. Although these positive characteristics exist, beef production still needs to improve cost per unit of product because it has greater cost per edible pound than chicken and pork. If one compares edible product per unit of feed energy input, beef production is ~1/3 as efficient as pork production and ~1/5 to 1/6 as efficient as broiler production (adapted from Dickerson, 1978). Greatly lower reproduction per breeding female is a major contributor, and adding the consumer-desired intramuscular fat in beef contributes to slaughter beef animals having greater total-carcass waste fat than slaughter pigs and broilers.

Implementing genetic programs and management changes that can improve efficiency of beef production requires answers to several questions. Some of these questions follow, and our goal in this paper is to provide answers to these questions, based on current knowledge. From an industry-wide perspective, what are the opportunities for improving efficiency of feed utilization? What can we learn from the pork and broiler industries in how they have approached genetic improvement of efficiency of feed utilization? Are there potential antagonisms between feed utilization/efficiency measurements and other economically relevant traits in beef cattle? What phenotypic and genomic data collections are warranted, and how will these be incorporated into National Cattle Evaluation programs? Where are the holes in our knowledge base, and what are the needs for future research to generate answers?

Do We Need to Measure Feed?

Efficiency has been conventionally expressed as the ratio of output per unit of input. However, expressing efficiency in a linear form as output minus input has better statistical properties and comes closer to economic measures such as net return (value of output minus cost of input). If we express feed efficiency of the beef life cycle on an average dam basis and in linear form, we have the following (adapted from Dickerson, 1970):

[Dam Weight*Lean Value of Dam + **No. Progeny***Progeny Weight*Lean Value of Progeny]
- [Dam Feed*Value of Feed for Dam + **No. Progeny***Progeny Feed*Value of Feed for Progeny].

Note, there is no requirement that the value terms be expressed in monetary units. They could equally well be expressed in biological units (e.g., kcal) to reflect biological efficiency.

In the positive, income component, we have the output from harvesting the dam (or fraction of the dam accounting for death loss) and from harvesting progeny (again, accounting for death loss); these are multiplied by different per unit prices to obtain the total value output. The negative, feed cost component, accounts for the input of feed energy, where we can account for different feed stuffs in the calculation of energy. The number of progeny per dam is in both components and, thus, increasing number of progeny will increase efficiency. By simply increasing number of progeny per dam through either selection, heterosis from crossing, or better management, we will increase efficiency of production. We do not need to measure feed to get this improvement in feed efficiency.

If we look at feed efficiency of a single animal, we also find that there are possible improvements in efficiency that can be achieved again without measurement of feed. To visualize this, first imagine that we can separate feed intake, at least conceptually, into: 1) feed required to meet maintenance requirements (**M**, basal metabolism, tissue repair, thermal regulation, locomotor activity, etc.) or the energy required for keeping body weight constant; 2) feed required to create new product (**P**, e.g., growth, milk, new offspring); and 3) feed that goes unused (**U**, waste products). For a growing calf, efficiency can be shown simply as:

$$\text{Calf Weight Gain} * \text{Calf weight value} - [\text{Feed}_M + \text{Feed}_P + \text{Feed}_U] * \text{Feed value}$$

For a pair of calves with the **<u>same</u>** start and end weights but with one animal gaining weight more quickly, thus requiring fewer days and less **<u>maintenance</u>** to reach market weight, the faster growing calf would be more efficient. This can occur with <u>no</u> difference in efficiency of feed use for either maintenance or creation of new product; it is “All Mathematical”. Similarly, with an improvement in reproduction, there is no need to measure feed to capitalize on methods to improve efficiency. The same would be true for an individual cow; if there is more output per day and no difference in cow size and in partial costs for maintenance and for production, then the cow with a greater rate of output will be the more efficient one.

For a reproducing cowherd, we can express efficiency based on the weight of calf and cull cow as the summed outputs, and total feed intake for the two production components as the feed costs. This gets a bit more complicated compared to the growing calf example above. But, we can express this as:

$$\begin{gathered}[\text{Calf Weight*Calf Weight Value} + \{\text{Culling Rate * Cull Cow Weight*Cow Weight Value}\}] \\ - \{\text{Feed}_M(\text{cow}) + \text{Feed}_P(\text{cow}) + \text{Feed}_U(\text{cow})\}\text{*Cow Feed Value} \\ - \{\text{Feed}_M(\text{calf}) + \text{Feed}_P(\text{calf}) + \text{Feed}_U(\text{calf})\}\text{*Calf Feed Value} \\ - \{\text{Feed}_M(\text{heifer}) + \text{Feed}_P(\text{heifer}) + \text{Feed}_U(\text{heifer})\}\text{*Heifer Feed Value}\end{gathered}$$

So again, there is 1) feed for maintenance, 2) feed for production, and 3) feed that is wasted. So, one goal for improving efficiency of feed utilization, whether with a growing calf in a feedlot or with a reproducing cow and calf in our cowherds, must be to reduce the feed being used for maintenance, while not reducing output. This also means that we could lose efficiency if we reduce rate of output, and hence reduce feed above maintenance required to produce output. Thus, instead of focusing on single traits, yearling bull buying decisions must consider the multiple-trait associations of feed intake and the implications of making selection decisions in the multiple-trait sense based mainly on data collected from growing bulls, especially with regard to the replacement daughters of selected bulls.

So, if the size of animals, rates of product formation (growth, milk), and reproduction, are known, then why is it necessary to measure feed intake? Feed measurement is costly due to the need for special facilities and equipment and due to labor. To complicate matters, this costly measurement is amenable for high-energy diets but not for low-energy, high-roughage diets, in particular in pasture-based systems. The reproducing cow herd, including calves to weaning, consumes the greater fraction of annual feed energy required in for beef production, as compared to calves grown from weaning to slaughter. The reproducing cow herd consumes mostly roughages, thus any measurement of cow herd intake is not very feasible at this time. We can, however, use research results to formulate appropriate multiple-trait index tools that account for synergisms and antagonisms that may exist among feed intake and other economically relevant traits.

The reason why we might consider measuring feed intake is because we cannot explain all the variation in individual-animal intake from simply knowledge of body weight maintained and level of production. Animals differ in their ability to digest feedstuffs and ability to transform feed energy to meet these needs. Within these, the main deficiency in being able to explain feed intake is in predicting the cost of meeting maintenance requirements, adjusted for body size. As noted above, maintenance includes all energy costs to hold body weight and body energy content constant in the particular production situation. During extremely cold ambient conditions, maintenance for a given animal will be greater than for more moderate ambient conditions. Maintenance in an extensive, open grazing situation will be greater than in a confined feeding situation. From a total life-cycle perspective, energy costs for maintenance are estimated to be about 70% of the total energy intake in the beef production system.

Thus, reducing energy for maintenance, while accounting for possible negative effects on other performance characteristics, becomes a clear target for genetic improvement programs. **The focus of these programs is not be to define a single measurement of efficiency which may lead to inappropriate use of single-trait selection**, but to define optimal measures which conform to the marketing practices (e.g., profitability) in the industry.

We can write an expression for feed intake that is unique for each animal in a defined production scenario: Feed Intake = Feed for Maintenance + Feed above Maintenance for Production. This expression can be expanded to:

$$\text{Feed Intake} = b_M \cdot (\text{Body Weight})^{0.75} + b_P \cdot (\text{Amount of Production}) + e.$$

Both b_M and b_P are partial efficiencies, as they represent the amount of feed required per unit of metabolic body size (b_M) or per unit of production (b_P). The error term (e) denotes the feed not used for either maintenance or producing products. If desired, production can be further subdivided into fat and lean gain in the case of a growing calf, or into lactation and fetal growth in the case of a lactating or pregnant cow.

Differences between animals in b_M, including those due to genetics or breeding value that can be changed via selection, have been demonstrated following selection in mice (Nielsen et al., 1997). And, the magnitude of these differences is relatively large enough to lead us to believe that reductions of 15-20% in maintenance costs would be achievable through long-term selection. Less clear is whether there are differences between animals in b_P, and if so, what amount might be due to underlying genetic causes. Work by Eggert and Nielsen (2006), using selected lines of mice, did not reveal genetic differences in b_P.

Selection Practices in Swine and Broiler Production

The general characteristics of broiler and swine selection programs are fairly similar and quite different from beef cattle. Due in part to intensive production, lower value of individual animals, and perhaps most importantly, much shorter generation intervals, broiler and swine selection programs are controlled and directed by a small number of companies. In broiler breeding, only a handful of multi-national companies control the genetic improvement programs Both broiler and swine breeding programs are centered around a limited number of nucleus herds or flocks and multiple sets of contemporary groups occur each year to make for more cost-effective year-round utilization of data collection technology. Costs of implementation in breeding companies are balanced against predicted genetic change and its value recovery to make decisions on implementation of selection programs, including methods, traits, population sizes, phenotypic and genomic data collected, etc.

In beef cattle, the breeding pyramid structure is less fully defined, and thus, evaluation of costs of implementation and value recovery are not easily done. The long generation interval sets a long horizon for recovery of costs in selection programs. With many breeders trying to contribute at a nucleus level, inefficiencies become evident, as compared to the industrial organization that exists in swine and broiler breeding companies.

Broiler breeding programs emphasize feed conversion as the most important trait for improvement. An example of the importance placed on measurement and subsequent selection for decreasing feed needs is that by Aviagen (D. Emmerson, personal communication), an international leader in broiler breeding. This company annually collects feed intake data on more than 150 thousand birds in individual pens for selection decisions, and in addition, collects another 50 thousand feed records, measured on full-sib families, to assess response under commercial conditions. Adjusted feed conversion has been the trait of focus for selection, although feed efficiency selection in egg-laying populations has used RFI as the trait of focus. Because the commercial goal is to reduce feed required to grow birds to a constant, defined market weight, emphasis has long been placed on selecting faster growing birds. Yet for a feed measurement program, a fixed age schedule is employed, and thus, adjustments for body weight are required when using feed conversion as the primary selection trait (Emmerson, 1997).

Data collection of feed intake is for 7 to 14-day periods, starting in the last phase of production (~35 days of age) before market weight is attained. As noted above, in a broiler system, hatches throughout the year keep new birds in queue for use of feed measurement equipment. Aviagen also uses their own proprietary technology for individual bird measurement of feeding behavior (number of visits, length of visits, size of meals, etc.; Howie, et al., 2011). Estimated genetic correlations between feeding behavioral traits and feed intake have not been large, thus behavioral indicators of feed intake have not been uncovered.

The swine industry has increasingly adopted a structure similar to the broiler industry. The largest 25 producers in the United States manage ~3 million sows which represent just less than 50% of the sow inventory. The vast majority of genetics provided to this market originate from a small number of 3-4 suppliers. As in poultry, feed conversion is the dominant trait in the selection objective for terminal lines, and increasingly for maternal lines.

Swine breeding companies leverage unique selection objectives within specialized populations to create commercial sows (maternal lines) and market pigs (terminal lines). Historically, litter size has been the dominant trait in the selection objective of maternal lines. However, as litter size has increased, the incremental value of each additional pig decreases relative to the other traits in the selection objective. Recent changes in the cost of feed, and the performance level achieved for litter size, has increased the relative emphasis on feed conversion in maternal lines. Today, feed efficiency would account for slightly over 50% of the selection objective in a terminal line and between 30 and 40% of the objective in a maternal line.

In general, feed conversion is measured only in the growing pig, specifically during the finishing period. The Danbred breeding program is a typical example that would be representative of most companies. In this program, feed intake is recorded during the period between 11 and 22 weeks of age. Pigs are maintained in pens of 12-15 animals that are equipped with a feeding station designed to record feed intake. Each pig is equipped with an electronic ear tag that identifies the pig as it enters the feeding station. The number of visits to the feeder, the amount of time spent at the feeder and the amount of feed consumed is recorded for each individual pig. These data are recorded on a sample of males that originate from the highest indexing litters resulting in the accuracy for the FCR breeding value being the highest for those animals most likely to be selected to produce the next generation.

Adjusted feed conversion (FCR, adjusted to a fixed end weight) is used as the trait in the selection index. Feed conversion data from the boars is combined with information on growth rate and body composition (percent lean) from the boars and all remaining males and females that undergo the same performance test less feed intake information. A breeding value for FCR is predicted on all animals in the population and weighted by its economic value in the overall index.

The use of feed intake measures in swine has, as in broilers, been used to improve the efficiency of the market pig, which represents the largest cost of producing pork. There is increasing interest in modifying these programs, particularly in maternal lines, to more directly (or perhaps reliably) impact the maintenance energy requirements of sows while maintaining progress in feed utilization by market pigs. It is particularly important that sows are able to maintain high levels of feed intake during the lactation period in order to maintain body condition, support high levels of milk production and prepare for the next reproductive cycle. At the same time, the ideal sow has relatively low maintenance energy requirements during the gestation period. Selection for RFI is one method to address these needs in a more direct manner compared with the current emphasis on FCR during the finishing phase.

Improving Efficiency of Beef Production

As noted earlier in this paper, simply reducing feed intake is not the sole goal for a selection program. Emphasis must be placed in order to not reduce production or output while we attempt to reduce feed intake for maintenance. Thus, selection program with ranking criteria for selection and culling decisions that maximizes efficiency will include multiple traits that include both output(s) and input(s). A selection index that considers both cow/calf performance and postweaning growth and carcass merit characteristics in the definition of net merit breeding value will be optimum.

The efficiency with which an animal utilizes feed can be expressed in different ways. For growing animals, traditional ratio measures are feed efficiency (FE = gain/feed) and feed conversion ratio (FCR = feed/gain). Although FE and FCR are often used in production settings, these traits are problematic because they are the ratio of two traits (Gunsett 1984). Koch et al. (1963) introduced the concept of using residuals for expression of efficiency. Residual feed intake (RFI), defined as the amount of feed that the animal consumed adjusted for expected consumption based on requirements for maintenance and growth. Residual gain (RG), defined as the amount of gain adjusted for feed intake. Thus, animals with negative RFI consume less than expected and are deemed more efficient, and animals with positive RG grow more rapidly than is expected and are thus deemed more efficient. Further elaboration on RG has been given by MacNeil et al. (2011) and Crowley et al. (2010). Arthur et al. (1996), Arthur et al. (2001), and

Crews (2005) further elaborate on RFI. For the purpose of improving production efficiency, it is recommended that RFI and(or) RG be computed using genetic regression coefficients based on estimates of genetic (co)variances (Kennedy et al., 1993), preferably from a single multiple-trait mixed model analysis. Both RFI and RG have been found to be moderately heritable.

From a genetic improvement perspective, it is important to recognize that selection for feed efficiency does not require an explicit measure of feed efficiency to be computed. Instead, selection for feed efficiency can be accomplished by selection on a linear index of traits that measure components of output (e.g. gain,) and input (i.e. feed intake), with output traits receiving positive weights and input traits negative weights. Further, Kennedy et al. (1993) showed the equivalence of selection indexes that incorporated intake or RFI, when the economic weights were calculated correctly.

One of the challenges, and a lingering question and need for further research, is to assess and understand the genetic correlation between feed energy requirement for maintenance per unit size (the b_M coefficient described above) in a growing calf in a feedlot, which consumes a high proportion of grain or grain co-products from ethanol production, versus in a reproducing cow, which consumes mostly forages in a range/pasture environment. Basarab et al. (2007) was unable to detect any significant antagonisms among feed intake and reproductive merit or lifetime productivity of dams that were the mothers of calves with different efficiency. Future results from a project nearing completion at the US Meat Animal Research Center with collection of cow feed intake, combined with growing calf data (Rolfe et al., 2011) will provide further insights. In addition, data from the USDA-supported National Program for Genetic Improvement of Feed Efficiency project (http://www.beefefficiency.org) will add clarification to this question.

Past work using breed differences as a method to infer possible genetic correlations, has pointed to strong, positive genetic relationships between growing calf and reproducing cow energy requirements, per unit body size, for maintenance (b_M; Montaño-Bermudez et al., 1990). In addition, Archer et al. (2002) found a strong and positive genetic correlation between RFI of growing calves in a feedlot and RFI of cows in a feedlot. The data on feed intake and utilization on heifers, prior to making replacement selection decisions, is lacking. Therefore, more study is needed to appropriately account for the associations of feed intake and other economically relevant traits in the female.

All of the measures of efficiency discussed above are favorably related to life-cycle production efficiency. Feed conversion ratio is used in many broiler and swine breeding company programs as the measure of "feed efficiency". Measurement is done over a fairly well defined weight and age interval within each company. Because new hatches/farrowings occur frequently, with new birds/animals ready for feed measurement at the starting weight and age, feed conversion is measured in a narrowly defined window and new batches enter and use the feed measurement equipment year-round. Statistical adjustments for weight range are still made to fine-tune the measurement, but the level of adjustment is relatively small. With the annual calving interval of beef cattle, many young cattle are ready for feed measurement at the same time, which results in expensive equipment then sitting idle for much of the year.

Especially for broiler production, but also for swine production, the magnitude of total feed consumption that is used by the reproducing female flock/herd is much smaller than what we observe with cattle. Low reproductive rate (<1 calf/cow/year) and long time between successive reproductive cycles (1 year) result in almost 65% of the feed energy in total-system/life-cycle being used by the reproducing cowherd, as opposed to the growing calf to slaughter. Although we cannot easily measure feed intake for grazing cows, improving the efficiency of feed utilization of cows is still of paramount importance. Thus, either protocols for measuring intake at grazing, or indicator traits indicative of intake at grazing need to be identified in order to maximize improvement in production system efficiency.

Data Recording

Given the desirability of recording feed intake in order to enhance improvement in efficiency relative to that attainable from output traits alone, protocols for data recording take on increased importance. Archer et al. (1997) have demonstrated that a measurement period of 70 d will provide adequate precision in measurement of relevant performance traits in growing calves. The main limitation and need for a minimum of 70 d is precision in measurement of weight gain, rather than feed intake. At this point, protocols for data collection from reproducing females are less well established. However, historical studies of factors affecting life-cycle efficiency considered individually fed cows and calves for an entire production cycle (e.g., Davis et al., 1983; Kirkpatrick et al., 1985).

To make effective use of expensive feed measurement equipment, at least a couple of groups from the same calving season will have data collected in the system. These calves are likely to be more variable in age and weight than what happens in swine and broiler breeding programs. Opportunities to use central testing facilities, where animals from multiple herds can have feed intake data collected can also reduce cost of collection of individual feed intake. However, variation in age and weight at the time of data collection will likely remain.

A National Cattle Evaluation Program

National cattle evaluation seeks to provide producers with information regarding the genetic basis for economically relevant traits (ERT). To the extent that feed costs money, feed intake is an ERT. Alternative measures, derived from feed intake and performance, provide no additional information beyond that contained in the traits used in their calculation (Kennedy et al., 1993). Therefore, it is recommended that NCE analyze feed intake.

Conditions vary between different contemporary groups (Beef Improvement Federation, 2010), potentially affecting not only the mean but also the variance of observations. Across testing facilities, different equipment may be employed, with ramifications for the observed variance in feed intake. Even in the same herd, the variance of feed intake may be altered due to environmental conditions and perhaps diets fed. Finally, differences in sophistication in operating the test may result in feed intake being reported in different units (as fed, DM, ME, etc), which can be assumed to differ only by unobserved multiplicative constants. Further, contemporary groups in which feed intake is recorded tend to be fairly large. Thus, standardization/normalization of data, as proposed by MacNeil et al. (2011), has the desired result that measurement of feed intake within a contemporary group will have mean 0 and standard deviation 1.

Feed intake is known to be genetically and phenotypically correlated with other phenotypes that are more easily obtained, for instance postweaning growth. Including these indicator trait phenotypes in NCE for feed intake has potential for increasing accuracy in the evaluation of feed intake and extending the evaluation of feed intake to many animals beyond those for which feed intake was observed.

Due to reliance on relatively expensive testing facilities, with limited capacity for collection of data on feed intake, only a selected sample of animals may be evaluated. Thus, to overcome selection bias, a NCE for feed intake should also contain correlated trait(s) recorded for all animals in the contemporary groups from which the evaluated animals were selected.

MacNeil et al. (2011) provide concepts and then an example for a NCE program where measures of feed intake plus “more easily measured” indicator traits are incorporated to predict EPD for feed intake requirements. The genetic relationship matrix, in addition, greatly aids in prediction of breeding value for animals that have no measurement of feed intake on them.

Due to the cost of measurement, feed intake (hence, efficiency of feed utilization) will benefit from further development of genomic predictors to enhance prediction of breeding value in a national cattle evaluation system. In a multi-breed population of steers at the US Meat Animal Research Center, the best 96 SNPs drawn from the BovineSNP50 Chip explained approximately three-fourths of the breeding value variance in genetic RFI (Snelling et al., 2011). Similarly, Rolf et al. (2011) found 55-65 SNPs explained approximately 55% of the additive genetic variance of feed intake in growing Angus steers. A continuing requirement, for the use of genetic markers to enhance the evaluation of feed intake, is an ongoing commitment to collection of phenotypic data for training marker prediction panels. Ideally, these data are collected on animals from different breeds and crossbreds to yield robust predictions across many genetic types.

A number of opportunities exist to derive genetic predictors of merit and efficiency following the NCE analysis of feed intake. These include EPD for RG, RFI, and residual intake and gain (Berry and Crowley, 2012), as well as selection indexes. If the feed intake data were standardized prior to the NCE, then incorporation of the predicted genetic values into indexes or decision support systems may require back adjustment to a given diet formulation and environment, where the mean and standard deviation have estimated or assumed values.

The choice of which measure of feed intake or efficiency should be derived from the NCE of feed intake and provided to breeders in terms of an EPD, should be driven primarily by the goal to provide an EPD that promotes the proper use of the information provided by breeders in a multiple-trait setting. Thus, assuming that not all breeders use selection indexes and that many breeders are concerned about the impact of reducing feed intake capacity, it may be desirable to provide EPD for RG or RFI, rather than EPD for feed intake. While there are compelling reasons for phenotypic measures of efficiency in other contexts, selection decisions in genetic improvement programs should be based on genetic predictions from the multiple trait genetic evaluation of feed intake. The measure should also ensure that it addresses efficiencies both during the growing period and cow-calf phase of production.

Summary

Improvement of production system efficiency is important to the profitability and sustainability of beef production. Substantial improvement results solely from increasing rate of production, by reducing *per diem* costs associated with maintenance, as well as increasing reproduction by minimizing losses from feeding non-productive females. However, because there is variation between animals in utilization of feed energy, especially for maintenance, further improvement is possible through appropriate consideration of feed intake measurement in selection decisions. This consideration should be facilitated by NCE. Absent efficacious indicator traits for intake by reproducing females, difficulty in measuring feed intake of grazing animals compromises improvement of life-cycle efficiency. For the near term, measurement of feed intake will be centered in growing animals. Choosing which measure of feed intake or efficiency should be derived from the NCE of feed intake and provided to breeders as EPD, should be driven primarily by the goal to provide an EPD that promotes proper use of that information in a multiple-trait setting.

References

Archer, J.A., P.F. Arthur, R.M. Herd, P.F. Parnell, and W.S. Pitchford. 1997. *Optimum postweaning test for measurement of growth rate, feed intake, and feed efficiency in British breed cattle*. J. Anim. Sci. 75:2024-2032.

Archer, J.A., A. Reverter, R.M. Herd, D.J. Johnston, and P.F. Arther. 2002. *Genetic Variation in Feed Intake and efficiency of Mature Beef Cows and Relationships with Postweaning Measurements.* 7th World Cong. on Genet. Appl. to Livest. Prod. CD-ROM Comm. 10-07.

Arthur, P.F., R.M. Herd, J. Wright, G. Xu, K. Dibley, and E.C. Richardson. 1996. *Net feed conversion efficiency and its relationship with other traits in beef cattle.* Proc. Aust. Soc. Anim. Prod. 21:170-110.

Arthur, P.F., J.A. Archer, D.J. Johnston, R.M. Herd, E.C. Richardson, and P.F. Parnell. 2001. *Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle*. J. Anim. Sci. 79:2805-2811.

Basarab, J.A., D. McCartney, E.K. Okine, and V.S. Baron. 2007. *Relationships between progeny residual feed intake and dam lifetime production efficiency traits.* Can. J. Anim. Sci. 87:489-502.

Beef Improvement Federation. 2010. *Guidelines for Uniform Beef Improvement Programs.* 9th Edition. www.beefimprovement.org.

Berry, D.P. and J.J. Crowley. 2012. *Residual intake and body weight gain: A new measure of efficiency in growing cattle.* J. Anim. Sci. 90:109-115.

Crews, D.H. Jr. 2005. *Genetics of Efficient Feed Utilization and National Cattle Evaluation: A Review.* Genet. and Mol. Res. 4 (2):152-165.

Crowley, J.J., M. McGee, D.A. Kenny, D.H. Crews Jr., R.D. Evans, and D.P. Berry. 2010. *Phenotypic and genetic parameters for different measures of feed efficiency in different breeds of Irish performance-tested beef bulls.* J. Anim. Sci. 88: 885-894.

Davis, M. E., J. J. Rutledge, L. V. Cundiff, and E. R. Hauser. 1983. *Life-cycle efficiency of beef production. 1. Cow efficiency ratios for progeny weaned.* J. Anim. Sci. 57:832-851.

Dickerson, G. 1970. *Efficiency of Animal Production – Molding the Biological Components.* J. Anim. Sci. 30:849-859.

Dickerson, G.E. 1978. *Animal size and efficiency: Basic concepts.* Anim. Prod. 27:367-379.

Eggert, D.L., and M.K. Nielsen. 2006. *Comparison of feed energy costs of maintenance, lean deposition, and fat deposition in three lines of mice selected for heat loss.* J. Anim. Sci. 84:276-282.

Emmerson, D. 1997. *Commercial Approaches to Genetic Selection for Growth and Feed Conversion in Domestic Poultry*. Poul. Sci. 76:1121-1125.

Gunsett, F.C. 1984. *Linear index selection to improve traits defined as ratios.* J. Anim. Sci. 58: 1185-1193.

Howie, J.A., S. Avendano, B.J. Tolkamp, and I. Kyriazakis. 2011. *Genetic Parameters of Feeding Behavior Traits and Their Relationship with Live Performance Traits in Modern Broiler Lines.* Poul. Sci. 90:1197-1205.

Kennedy, B.W., J.H.J. van der Werf and T.H.E. Meuwissen. 1993. *Genetic and Statistical Properties of Residual Feed Intake.* J. Anim. Sci. 71:3239-3250.

Kirkpatrick, B. W., C. A. Dinkel, J. J. Rutledge, and E. R. Hauser. 1985. *Prediction equations of beef cow efficiency*. J. Anim. Sci. 60:964-969.

Koch, R.M., L.A. Swiger, D. Chambers and K.E. Gregory. 1963. *Efficiency of Feed Use in Beef Cattle*. J. Anim. Sci. 22:486-494.

MacNeil, M.D., N. Lopez-Villalobos and S.L. Northcutt. 2011. *A Prototype National Cattle Evaluation for Feed Intake and efficiency of Angus Cattle.* J. Anim. Sci. 89:3917-3923.

Montaño-Bermudez, M., M.K. Nielsen and G.H. Deutscher. 1990. *Energy requirements for maintenance of crossbred beef cattle with different genetic potential for milk.* J. Anim. Sci. 68:2279-2288.

Nielsen, M. K**.**, B.A. Freking, L.D. Jones, S.M. Nelson, T.L. Vorderstrasse and B.A. Hussey. 1997. *Divergent selection for heat loss in mice. II. Correlated responses in feed intake, body mass, body composition, and number born through fifteen generations.* J. Anim. Sci. 75:1469-1476.

Rolf, M.M., J.F. Taylor, R.D. Schnabel, S.D. McKay, M.C. McClure, S.L. Northcutt, M.S. Kerley, and R.L. Weaber. 2011. Anim. Genet. 43:367-374.

Rolfe, K.M.,, W.M. Snelling, M.K. Nielsen, H.C. Freetly, C.L. Ferrell, and T.G. Jenkins. 2011. *Genetic and Phenotypic Parameter Estimates for Feed Intake and Other Traits in Growing Beef Cattle and Opportunities for Selection.* J. Anim. Sci. 89: 3452-3459.

Snelling, W.M., M.A. Allan, J.W. Keele, L.A. Kuehn, R.M. Thallman, G.L. Bennett, C.L. Ferrell, T.G. Jenkins, H.C. Freetly, M.K. Nielsen, and K.M. Rolfe. 2011. *Partial-genome evaluation of postweaning feed intake and efficiency of crossbred beef cattle.* J. Anim. Sci. 89: 1731-1741.

ACROSS-BREED EPD TABLES FOR THE YEAR 2013 ADJUSTED TO BREED DIFFERENCES FOR BIRTH YEAR OF 2011

L. A. Kuehn[1] and R. M. Thallman[1]

[1]Roman L. Hruska U.S. Meat Animal Research Center, USDA-ARS, Clay Center, NE 68933

Summary

Factors to adjust the expected progeny differences (EPD) of each of 18 breeds to the base of Angus EPD are reported in the column labeled 6 of Tables 1-7 for birth weight, weaning weight, yearling weight, maternal milk, marbling score, ribeye area, and fat thickness, respectively. An EPD is adjusted to the Angus base by adding the corresponding across-breed adjustment factor in column 6 to the EPD. It is critical that this adjustment be applied only to Spring 2013 EPD. Older or newer EPD may be computed on different bases and, therefore, could produce misleading results. When the base of a breed changes from year to year, its adjustment factor (Column 6) changes in the opposite direction and by about the same amount.

Breed differences are changing over time as breeds put emphasis on different traits and their genetic trends differ accordingly. Therefore, it is necessary to qualify the point in time at which breed differences are represented. Column 5 of Tables 1-7 contains estimates of the differences between the averages of calves of each breed born in year 2011. Any differences (relative to their breed means) in the samples of sires representing those breeds at the U.S. Meat Animal Research Center (USMARC) are adjusted out of these breed difference estimates and the across-breed adjustment factors. The breed difference estimates are reported as progeny differences, e.g., they represent the expected difference in progeny performance of calves sired by average bulls (born in 2011) of two different breeds and out of dams of a third, unrelated breed. In other words, they represent half the differences that would be expected between purebreds of the two breeds.

Introduction

This report is the year 2013 update of estimates of sire breed means from data of the Germplasm Evaluation (GPE) project at USMARC adjusted to a year 2011 basis using EPD from the most recent national cattle evaluations. The 2011 basis year is chosen because yearling records for weight and carcass traits should have been accounted for in EPDs for progeny born in 2011 in the Spring 2013 EPD national genetic evaluations. Factors to adjust Spring 2013 EPD of 18 breeds to a common base were calculated and are reported in Tables 1-3 for birth weight (BWT), weaning weight (WWT), and yearling weight (YWT) and in Table 4 for the maternal milk (MILK) component of maternal weaning weight (MWWT). Tables 5-7 summarize the factors for marbling score (MAR), ribeye area (REA), and fat thickness (FAT).

The across-breed table adjustments apply **only** to EPD for most recent (spring, 2013) national cattle evaluations. Serious errors can occur if the table adjustments are used with earlier or later EPD which may have been calculated with a different within-breed base.

The following describes the changes that have occurred since the update released in 2012 (Kuehn and Thallman, 2012):

New samplings of sires in the USMARC GPE program continued to increase progeny records for all of the breeds. Numbers of progeny added ranged from 23 in Salers to 93 in Angus. The GPE program has entered a new phase in which more progeny are produced from breeds with higher numbers of registrations. However, all of the breeds will continue to produce progeny in the project and sires continue to be sampled on a continuous basis for each of the 18 breeds in the across-breed EPD program.. These additional progeny improve the accuracy of breed differences estimated at USMARC (column 3 in Tables 1-7) particularly for breeds with less data in previous GPE cycles (e.g., South Devon, Tarentaise, Santa Gertrudis, Chiangus). Progeny born in 2012 from South Devon and Tarentaise have begun to impact birth weight and weaning weight results. For the first time, there are enough daughters of Chiangus and Santa Gertrudis sires to estimate maternal milk (Table 4) breed of sire differences and factors.

Other significant changes were largely due to changes in national cattle evaluations for individual breeds. The primary change occurred as a result of the multi-breed analysis conducted by Simmental causing base shifts (columns 1 and 2, Tables 1-7) for Simmental, Red Angus, and Gelbvieh. In general base shifts only affect the adjustment factors (column 6, Tables 1-7). Part of the goal of this new multi-breed cooperation among the three breeds was to place their EPDs on the same base and scale across all three breeds. This should have the effect of making their adjustment factors (to an Angus base) similar for all traits. For weight traits, Gelbvieh and Red Angus did consistently have similar adjustment factors. For carcass traits (Tables 5-7), Gelbvieh and Simmental had similar adjustment factors. Refinement in both the multi-breed evaluation and the USMARC database should bring adjustment factors close for all three breeds in the future.

Materials and Methods

All calculations were as outlined in the 2010 BIF Guidelines. The basic steps were given by Notter and Cundiff (1991) with refinements by Núñez-Dominguez et al. (1993), Cundiff (1993, 1994), Barkhouse et al. (1994, 1995), Van Vleck and Cundiff (1997–2006), Kuehn et al. (2007-2011), and Kuehn and Thallman (2012). Estimates of variance components, regression coefficients, and breed effects were obtained using the MTDFREML package (Boldman et al., 1995). All breed solutions are reported as differences from Angus. The table values of adjustment factors to add to within-breed EPD are relative to Angus.

Models for Analysis of USMARC Records

An animal model with breed effects represented as genetic groups was fitted to the GPE data set (Arnold et al., 1992; Westell et al., 1988). In the analysis, all AI sires (sires used via artificial insemination) were assigned a genetic group according to their breed of origin. Due to lack of pedigree, dams mated to the AI sires and natural service bulls mated to F_1 females were also assigned to separate genetic groups (i.e., Hereford dams were assigned to different genetic groups than Hereford AI sires). Cows from Hereford selection lines (Koch et al., 1994) were used in Cycle IV of GPE and assigned into their own genetic groups. Through Cycle VIII, most dams were from Hereford, Angus, or MARCIII (1/4 Angus, 1/4 Hereford, 1/4 Pinzgauer, 1/4 Red Poll) composite lines. In order to be considered in the analysis, sires had to have an EPD for the trait of interest. All AI sires were considered unrelated for the analysis in order to adjust resulting genetic group effects by the average EPD of the sires.

Fixed effects in the models for BWT, WWT (205-d), and YWT (365-d) included breed (fit as genetic groups) and maternal breed (WWT only), year and season of birth by GPE cycle by age of dam (2, 3, 4, 5-9, >10 yr) combination (241), sex (heifer, bull, steer; steers were combined with bulls for BWT), a covariate for heterosis, and a covariate for day of year at birth of calf. Models for WWT also included a fixed covariate for maternal heterosis. Random effects included animal and residual error except for the analysis of WWT which also included a random maternal genetic effect and a random permanent environmental effect.

For the carcass traits (MAR, REA, and FAT), breed (fit as genetic groups), sex (heifer, steer) and slaughter date (245) were included in the model as fixed effects. Fixed covariates included slaughter age and heterosis. Random effects were animal and residual error. To be included, breeds had to report carcass EPD on a carcass basis using age-adjusted endpoints, as suggested in the 2010 BIF Guidelines.

The covariates for heterosis were calculated as the expected breed heterozygosity for each animal based on the percentage of each breed of that animal's parents. In other words, it is the probability that, at any location in the genome, the animal's two alleles originated from two different breeds. Heterosis is assumed to be proportional to breed heterozygosity. For the purpose of heterosis calculation, AI and dam breeds were assumed to be the same breed and Red Angus was assumed the same breed as Angus. For purposes of heterosis calculation, composite breeds were considered according to nominal breed composition. For example, Brangus (3/8 Brahman, 5/8 Angus) × Angus is expected to have 3/8 as much heterosis as Brangus × Hereford.

Variance components were estimated with a derivative-free REML algorithm with genetic group solutions obtained at convergence. Differences between resulting genetic group solutions for AI sire breeds were divided by two to represent the USMARC breed of sire effects in Tables 1-7. Resulting breed differences were adjusted to current breed EPD levels by accounting for the average EPD of the AI sires of progeny/grandprogeny, etc. with records. Average AI sire EPD were calculated as a weighted average AI sire EPD from the most recent within breed genetic evaluation. The weighting factor was the sum of relationship coefficients between an individual sire and all progeny with performance data for the trait of interest relative to all other sires in that breed.

For all traits, regression coefficients of progeny performance on EPD of sire for each trait were calculated using an animal model with EPD sires excluded from the pedigree. Genetic groups were assigned in place of sires in their progeny pedigree records. Each sire EPD was 'dropped' down the pedigree and reduced by ½ depending on the number of generations each calf was removed from an EPD sire. In addition to regression coefficients for the EPDs of AI sires, models included the same fixed effects described previously. Pooled regression coefficients, and regression coefficients by sire breed were obtained. These regression coefficients are monitored as accuracy checks and for possible genetic by environment interactions. The pooled regression coefficients were used as described in the next section to adjust for differences in management at USMARC as compared to seedstock production (e.g., YWT of males at USMARC are primarily on a slaughter steer basis, while in seedstock field data they are primarily on a breeding bull basis). For carcass traits, MAR, REA, and FAT, regressions were considered too variable and too far removed from 1.00. Therefore, the regressions were assumed to be 1.00 until more data is added to reduce the impact of sampling errors on prediction of these regressions. However, the resulting regressions are still summarized.

Records from the USMARC GPE Project are not used in calculation of within-breed EPD by the breed associations. This is critical to maintain the integrity of the regression coefficient. If USMARC records were included in the EPD calculations, the regressions would be biased upward.

Adjustment of USMARC Solutions

The calculations of across-breed adjustment factors rely on breed solutions from analysis of records at USMARC and on averages of within-breed EPD from the breed associations. The basic calculations for all traits are as follows:

USMARC breed of sire solution (1/2 breed solution) for breed i (USMARC (i)) converted to an industry scale (divided by b) and adjusted for genetic trend (as if breed average bulls born in the base year had been used rather than the bulls actually sampled):

$$M_i = \text{USMARC (i)/b} + [\text{EPD(i)}_{YY} - \text{EPD(i)}_{USMARC}].$$

Breed Table Factor (A_i) to add to the EPD for a bull of breed i:

$$A_i = (M_i - M_x) - (\text{EPD(i)}_{YY} - \text{EPD(x)}_{YY}).$$

where,

USMARC(i) is solution for effect of sire breed i from analysis of USMARC data,

EPD(i)_{YY} is the average within-breed 2013 EPD for breed i for animals born in the base year (YY, which is two years before the update; e.g., YY = 2011 for the 2013 update),

$EPD(i)_{USMARC}$ is the weighted (by total relationship of descendants with records at USMARC) average of 2013 EPD of bulls of breed i having descendants with records at USMARC,

b is the pooled coefficient of regression of progeny performance at USMARC on EPD of sire (for 2013: 1.17, 0.84, 1.01, and 1.14 BWT, WWT, YWT, and MILK, respectively; 1.00 was applied to MAR, REA, and FAT data),

i denotes sire breed i, and

x denotes the base breed, which is Angus in this report.

Results

Heterosis

Heterosis was included in the statistical model as a covariate for all traits. Maternal heterosis was also fit as a covariate in the analysis of weaning weight. Resulting estimates were 1.41 lb, 13.09 lb, 19.04 lb, -0.007 marbling score units (i.e. 4.00 = Sl^{00}, 5.00 = Sm^{00}), 0.26 in^2, and 0.038 in for BWT, WWT, YWT, MAR, REA, and FAT respectively. These estimates are interpreted as the amount by which the performance of an F_1 is expected to exceed that of its parental breeds. The estimate of maternal heterosis for WWT was 11.12 lb.

Across-breed adjustment factors

Tables 1, 2, and 3 (for BWT, WWT, and YWT) summarize the data from, and results of, USMARC analyses to estimate breed of sire differences on a 2011 birth year basis. The column labeled 6 of each table corresponds to the Across-breed EPD Adjustment Factor for that trait. Table 4 summarizes the analysis of MILK. Tables 5, 6, and 7 summarize data from the carcass analyses (MAR, REA, FAT). Because of the accuracy of sire carcass EPDs and the greatest percentage of data being added to carcass traits, sire effects and adjustment factors are more likely to change for carcass traits in the future.

Column 5 of each table represents the best estimates of sire breed differences for calves born in 2011 on an industry scale. These breed difference estimates are reported as progeny differences, e.g., they represent the expected difference in progeny performance of calves sired by average bulls (born in 2011) of two different breeds and out of dams of a third, unrelated breed. Thus, they represent half the difference expected between purebreds of the respective breeds.

In each table, breed of sire differences were added to the raw mean of Angus-sired progeny born 2008 through 2012 at USMARC (Column 4) to make these differences more interpretable to producers on scales they are accustomed to.

Figures 1-4 illustrate the relative genetic trends of most of the breeds involved (if they submitted trends) adjusted to a constant base using the adjustment factors in column 6 of Tables 1-7. These figures demonstrate the effect of selection over time on breed differences; breeders within each breed apply variable levels of selection toward each trait resulting in reranking of breeds for each traits over time. These figures and Column 5 of Tables 1-7 can be used to identify breeds with potential for complementarity in mating programs.

Across-breed EPD Adjustment Factor Example

Adjustment factors can be applied to compare the genetic potential of sires from different breeds. Suppose the EPD for yearling weight for a Hereford bull is +90.0 (which is above the year 2011 average of 86 for Hereford) and for a Limousin bull is +98.0 (which is above the year 2011 average of 84.2 for Limousin). The across-breed adjustment factors in the last column of Table 3 are -23.6 for Hereford and -35.9 for Limousin. Then the adjusted EPD for the Hereford bull is 90.0 + (-23.6) = 67.4 and for the Limousin bull is 98.0 + (-35.9) = 62.1. The expected yearling weight difference when both are mated to another breed of cow, e.g., Angus, would be 67.4 – 62.1 = 5.3 lb. The differences in true breeding value between two bulls with similar within-breed EPDs are primarily due to differences in the genetic base from which those within-breed EPDs are computed.

Birth Weight

The range in estimated breed of sire differences for BWT (Table 1, column 5) ranged from 0.8 lb for Red Angus to 7.5 lb for Charolais and 11.1 lb for Brahman. Angus continued to have the lowest estimated sire effect for birth weight (Table 1, column 5). The relatively heavy birth weights of Brahman-sired progeny would be expected to be offset by favorable maternal effects reducing birth weight if progeny were from Brahman or Brahman cross dams which would be an important consideration in crossbreeding programs involving Brahman cross females. Changes in breed of sire effects were generally small, less than 1.5 lb for all breeds relative to last year's update (Kuehn and Thallman, 2012).

Weaning Weight

With the exception of South Devon, all of the 17 breed differences (Table 2, column 5) were within 5 lb of the values reported by Kuehn and Thallman. (2012). The number of South Devon progeny with weaning weight increased by approximately 30%. South Devon and Tarentaise are the most likely to shift due to increasing data in future evaluations. Changes in breed effects for other breeds seem to be stabilizing since continuous sampling started in 2007.

Yearling Weight

Breed of sire effects for yearling weight were also similar to Kuehn and Thallman (2012) in general. All but two of the estimates were within 8 lb of last year's estimates. The estimated Santa Gertrudis breed difference increased by 12.7 lb and the Chiangus difference decreased by

10.7 lb likely due to increased sampling and progeny. Angus continued to have the greatest rate of genetic change for yearling weight, causing most breed of sire differences relative to Angus to decrease at least slightly.

Maternal Milk

Changes to the maternal milk breed of sire differences (Table 4, column 5) were generally small. All changes were less than 4 lb difference from those reported in 2012. However, the breed solution estimates (Table 4, column 3) are expected to change the most in future updates as GPE heifers from each of the 18 breeds being continuously sampled are developed and bred. Chiangus and Santa Gertrudis estimates and factors for maternal milk are presented here for the first time.

Marbling

Marbling score was again highest in Angus and South Devon. Most changes relative to last year's update were minor with the exception of Chiangus (USMARC breed solution; due to increased numbers of progeny sampled) and Gelbvieh (likely due to new genetic evaluation). Continental breeds continue in general to be lower for marbling score relative to Angus (most more than 0.5 score units lower).

Ribeye Area

Continental breeds had higher ribeye area estimates relative to the British breeds (Table 6, column 5) as would be expected. Continued selection for ribeye area in Angus led to a higher mean EPD (0.06 sq in larger) in 2011 for Angus and resulted in decreases for most breeds relative to Angus (Column 5) compared to last year's update.

Fat Thickness

Progeny of Continental breeds again had 0.1 to 0.2 in less fat at slaughter than British breeds (Table 7, Column 5) and other breeds were leaner than Angus. Charolais, Salers, Maine Anjou, and Simmental were predicted to be the leanest breeds among the 13 breeds analyzed for carcass traits. Limousin was not included in the FAT analysis because they do not report an EPD for FAT. Changes in breed of sire effects relative to Angus were all minor compared to the previous year (Kuehn and Thallman, 2012).

Accuracies and Variance Components

Table 8 summarizes the average Beef Improvement Federation (BIF) accuracy for bulls with progeny at USMARC weighted appropriately by average relationship to animals with phenotypic records. The sires sampled recently in the GPE program have generally been higher accuracy sires, so the average accuracies should continue to increase over the next several years.

Table 9 reports the estimates of variance components from the animal models that were used to obtain breed of sire and breed of MGS solutions. Heritability estimates for BWT, WWT, YWT, and MILK were 0.58, 0.17, 0.45, and 0.15, respectively. Heritability estimates for MAR, REA, and FAT were 0.49, 0.48, and 0.40, respectively.

Regression Coefficients

Table 10 updates the coefficients of regression of records of USMARC progeny on sire EPD for BWT, WWT, and YWT which have theoretical expected values of 1.00. The standard errors of the specific breed regression coefficients are large relative to the regression coefficients. Large differences from the theoretical regressions, however, may indicate problems with genetic evaluations, identification, or sampling. The pooled (overall) regression coefficients of 1.17 for BWT, 0.84 for WWT, and 1.01 for YWT were used to adjust breed of sire solutions to the base year of 2011. These regression coefficients are reasonably close to expected values of 1.0. Deviations from 1.00 are believed to be due to scaling differences between performance of progeny in the USMARC herd and of progeny in herds contributing to the national genetic evaluations of the 18 breeds. Breed differences calculated from the USMARC data are divided by these regression coefficients to put them on an industry scale. A regression greater than one suggests that variation at USMARC is greater than the industry average, while a regression less than one suggests that variation at USMARC is less than the industry average. Reasons for differences in scale can be rationalized. For instance, cattle at USMARC, especially steers and market heifers, are fed at higher energy rations than some seedstock animals in the industry. Also, in several recent years, calves have been weaned earlier than 205 d at USMARC, likely reducing the variation in weaning weight of USMARC calves relative to the industry.

The coefficients of regression for MILK are also shown in Table 10. Several sire (MGS) breeds have regression coefficients considerably different from the theoretical expected value of 1.00 for MILK. Standard errors, however, for the regression coefficients by breed are large except for Angus and Hereford. The pooled regression coefficient of 1.14 for MILK is reasonably close to the expected regression coefficient of 1.00.

Regression coefficients derived from regression of USMARC steer progeny records on sire EPD for MAR, REA, and FAT are shown in Table 11. Each of these coefficients has a theoretical expected value of 1.00. Compared to growth trait regression coefficients, the standard errors even on the pooled estimates are higher, though they have decreased from the previous year. While REA and FAT are both close to the theoretical estimate of 1.00, we continued to use the theoretical estimate of 1.00 to derive breed of sire differences and EPD adjustment factors. Pooled regression estimates for these two traits may be used in future updates.

Prediction Error Variance of Across-Breed EPD

Prediction error variances were not included in the report due to a larger number of tables included with the addition of carcass traits. These tables were last reported in Kuehn et al. (2007;

available online at http://www.beefimprovement.org/proceedings.html). An updated set of tables is available on request (Larry.Kuehn@ars.usda.gov).

Implications

Bulls of different breeds can be compared on a common EPD scale by adding the appropriate across-breed adjustment factor to EPD produced in the most recent genetic evaluations for each of the 18 breeds. The across-breed EPD are most useful to commercial producers purchasing bulls of two or more breeds to use in systematic crossbreeding programs. Uniformity in across-breed EPD should be emphasized for rotational crossing. Divergence in across-breed EPD for direct weaning weight and yearling weight should be emphasized in selection of bulls for terminal crossing. Divergence favoring lighter birth weight may be helpful in selection of bulls for use on first calf heifers. Accuracy of across-breed EPD depends primarily upon the accuracy of the within-breed EPD of individual bulls being compared.

Table 1. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – BIRTH WEIGHT (lb)

	Number		Ave. Base EPD		Breed Soln	BY 2011	BY 2011	Factor to
			Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2011	Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	131	1822	1.7	1.8	0.0	87.3	0.0	0.0
Hereford	140	2246	3.5	2.2	3.7	91.7	4.5	2.7
Red Angus	43	615	-0.9	-1.9	-0.3	88.1	0.8	3.4
Shorthorn	52	461	2.4	1.4	6.4	93.7	6.5	5.8
South Devon	25	195	2.6	2.1	4.1	91.4	4.1	3.2
Beefmaster	44	395	0.2	1.0	6.5	92.1	4.8	6.3
Brahman	56	672	1.8	0.6	11.5	98.3	11.1	11.0
Brangus	47	397	0.8	1.0	4.3	90.8	3.5	4.5
Santa Gertrudis	21	249	0.5	0.9	6.8	92.6	5.4	6.6
Braunvieh	30	430	2.4	4.1	5.0	89.9	2.6	1.9
Charolais	100	1070	0.6	0.2	8.2	94.7	7.5	8.6
Chiangus	24	247	3.1	3.2	4.3	90.9	3.6	2.2
Gelbvieh	73	980	1.4	2.7	4.2	89.6	2.4	2.7
Limousin	62	1053	1.5	0.9	3.4	90.8	3.6	3.8
Maine Anjou	38	435	2.0	3.3	6.7	91.8	4.5	4.2
Salers	50	428	1.7	2.5	2.9	89.0	1.8	1.8
Simmental	71	1011	2.3	3.2	6.0	91.5	4.3	3.7
Tarentaise	17	245	1.9	2.1	2.3	89.1	1.9	1.7

Calculations:

(4) = (3) / b + [(1) – (2)] + (Recent Raw Angus Mean: 87.3 lb) with b = 1.17

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 2. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – WEANING WEIGHT (lb)

Breed	Number: AI Sires	Number: Direct Progeny	Ave. Base EPD: Breed 2011 (1)	Ave. Base EPD: USMARC Bulls (2)	Breed Soln at USMARC (vs Ang) (3)	BY 2011 Sire Breed Average (4)	BY 2011 Sire Breed Difference[a] (5)	Factor to adjust EPD To Angus (6)
Angus	131	1682	47.0	26.2	0.0	577.0	0.0	0.0
Hereford	138	2082	45.0	27.3	-2.1	571.5	-5.5	-3.5
Red Angus	43	595	54.8	48.4	-0.9	561.5	-15.4	-23.2
Shorthorn	52	438	15.3	14.5	-0.4	556.5	-20.4	11.3
South Devon	25	176	40.9	26.1	-4.2	566.0	-10.9	-4.8
Beefmaster	44	382	10.0	13.3	19.1	575.6	-1.3	35.7
Brahman	56	584	15.0	7.8	20.5	587.7	10.8	42.8
Brangus	47	383	23.7	21.8	8.5	568.2	-8.7	14.6
Santa Gertrudis	21	241	4.3	8.5	15.5	570.5	-6.5	36.2
Braunvieh	30	403	41.1	45.0	-2.4	549.4	-27.5	-21.6
Charolais	99	972	24.4	14.0	21.7	592.4	15.5	38.1
Chiangus	24	228	36.8	40.3	-5.4	546.2	-30.7	-20.5
Gelbvieh	73	919	63.7	56.1	9.8	575.4	-1.5	-18.2
Limousin	62	971	46.5	30.4	2.0	574.7	-2.3	-1.8
Maine Anjou	38	404	39.4	39.4	-1.8	554.1	-22.9	-15.3
Salers	50	405	41.3	33.0	1.7	566.4	-10.5	-4.8
Simmental	70	923	62.1	57.0	20.9	586.1	9.2	-5.9
Tarentaise	17	237	16.0	-2.6	1.2	576.2	-0.7	30.3

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 556.2 lb) with b = 0.84

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 3. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – YEARLING WEIGHT (lb)

	Number		Ave. Base EPD		Breed Soln at USMARC	BY 2011 Sire Breed	BY 2011 Sire Breed	Factor to adjust EPD
	AI	Direct	Breed 2011	USMARC Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	128	1512	86.0	49.0	0.0	1045.3	0.0	0.0
Hereford	133	1926	74.0	45.7	-27.2	1009.7	-35.6	-23.6
Red Angus	42	543	81.6	67.1	-9.9	1013.0	-32.3	-27.9
Shorthorn	45	382	24.8	22.8	12.7	1022.9	-22.4	38.8
South Devon	15	134	77.2	50.4	-5.2	1030.0	-15.4	-6.6
Beefmaster	38	275	14.0	19.7	0.3	1002.9	-42.5	29.5
Brahman	55	517	24.1	12.9	-30.4	989.3	-56.0	5.9
Brangus	40	262	43.1	40.1	-2.8	1008.4	-36.9	6.0
Santa Gertrudis	21	210	6.3	11.0	10.4	1013.9	-31.4	48.3
Braunvieh	30	376	64.8	70.9	-20.6	981.8	-63.5	-42.3
Charolais	94	884	43.1	26.8	23.4	1047.7	2.4	45.3
Chiangus	24	201	67.9	70.5	-18.8	987.0	-58.3	-40.2
Gelbvieh	71	875	93.5	74.9	0.3	1027.1	-18.2	-25.6
Limousin	62	904	84.2	59.2	-25.8	1007.7	-37.7	-35.9
Maine Anjou	37	375	78.2	81.1	-4.6	1000.8	-44.5	-36.7
Salers	50	380	79.6	64.0	-4.5	1019.5	-25.9	-19.5
Simmental	65	829	90.3	83.1	23.5	1038.8	-6.5	-10.9
Tarentaise	7	189	28.6	-3.6	-32.6	1008.2	-37.1	20.3

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 1008.3 lb) with b = 1.01

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 4. Breed of maternal grandsire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – MILK (lb)

Breed	AI Sires	Number Direct Gpr	Direct Progeny	Ave. Base EPD Breed 2011 (1)	Ave. Base EPD USMARC Bulls (2)	Breed Soln at USMARC (vs Ang) (3)	BY 2011 Sire Breed Average (4)	BY 2011 Sire Breed Difference[a] (5)	Factor to adjust EPD To Angus (6)
Angus	123	2816	636	23.0	13.9	0.0	565.3	0.0	0.0
Hereford	123	3502	809	18.0	9.6	-24.4	543.2	-22.1	-17.1
Red Angus	35	767	216	19.9	16.6	-1.4	558.3	-7.0	-3.9
Shorthorn	38	369	145	2.3	4.2	12.0	564.8	-0.5	20.2
South Devon	14	347	69	22.9	19.1	5.6	564.9	-0.4	-0.3
Beefmaster	30	292	74	2.0	-0.9	-5.6	554.2	-11.1	9.9
Brahman	49	764	228	6.4	5.3	16.6	571.9	6.6	23.2
Brangus	26	280	59	11.3	4.9	-3.7	559.3	-6.0	5.8
Santa Gertrudis	19	114	74	0.7	-1.6	-3.5	555.4	-9.9	12.4
Braunvieh	24	589	147	34.0	33.6	22.6	576.4	11.1	0.1
Charolais	87	1460	358	6.9	5.3	-2.0	556.1	-9.2	6.9
Chiangus	19	107	72	10.9	5.5	-4.2	557.9	-7.4	4.7
Gelbvieh	65	1430	336	25.5	28.2	20.5	571.4	6.1	3.6
Limousin	57	1611	377	22.1	18.6	-4.6	555.7	-9.6	-8.7
Maine Anjou	35	559	136	19.7	22.1	1.5	555.2	-10.1	-6.8
Salers	43	449	150	19.5	20.9	10.5	564.0	-1.3	2.2
Simmental	63	1552	353	22.9	26.2	13.0	564.4	-0.9	-0.8
Tarentaise	6	341	78	0.6	5.3	17.7	567.0	1.7	24.1

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 556.2lb) with b = 1.14

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 5. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – MARBLING (marbling score units[a])

	Number		Ave. Base EPD		Breed Soln	BY 2011	BY 2011	Factor to
			Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2011	Bulls	(vs Ang)	Average	Difference[b]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	111	663	0.46	0.18	0.00	6.09	0.00	0.00
Hereford	128	877	0.05	-0.02	-0.52	5.36	-0.73	-0.32
Red Angus	40	176	0.38	0.44	-0.04	5.71	-0.38	-0.30
Shorthorn	43	201	-0.02	0.02	-0.32	5.45	-0.64	-0.16
South Devon	13	49	0.40	-0.10	-0.20	6.11	0.02	0.08
Santa Gertrudis	21	100	0.00	0.00	-0.84	4.96	-1.12	-0.66
Braunvieh	30	184	0.50	0.41	-0.43	5.46	-0.63	-0.67
Charolais	42	207	0.03	-0.04	-0.65	5.22	-0.87	-0.44
Chiangus	23	95	0.19	0.22	-0.41	5.37	-0.72	-0.45
Gelbvieh	68	373	0.04	-0.17	-0.76	5.26	-0.83	-0.41
Limousin	59	345	-0.02	-0.07	-0.96	4.90	-1.19	-0.71
Maine Anjou	37	191	0.21	0.20	-0.82	4.99	-1.09	-0.84
Salers	46	182	0.20	-0.39	-0.67	5.73	-0.36	-0.10
Simmental	64	365	0.08	-0.02	-0.62	5.29	-0.80	-0.42

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 5.81) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]4.00 = Sl^{00}, 5.00 = Sm^{00}

[b]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 6. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – RIBEYE AREA (in^2)

	Number		Ave. Base EPD		Breed Soln	BY 2011	BY 2011	Factor to
			Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2011	Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	111	664	0.42	0.06	0.00	13.12	0.00	0.00
Hereford	128	877	0.26	-0.05	-0.21	12.87	-0.25	-0.09
Red Angus	40	176	0.15	-0.10	-0.23	12.77	-0.35	-0.08
Shorthorn	43	201	0.07	0.01	0.16	12.98	-0.14	0.21
South Devon	13	49	0.21	0.21	0.32	13.07	-0.05	0.16
Santa Gertrudis	21	101	0.01	-0.02	-0.13	12.66	-0.46	-0.05
Braunvieh	30	184	0.71	0.83	0.98	13.63	0.51	0.22
Charolais	42	208	0.20	0.07	1.03	13.92	0.80	1.02
Chiangus	23	96	0.09	0.00	0.39	13.24	0.12	0.45
Gelbvieh	68	375	0.30	0.20	0.92	13.78	0.66	0.78
Limousin	59	346	0.54	0.30	1.33	14.33	1.21	1.09
Maine Anjou	37	191	0.15	0.12	1.01	13.80	0.68	0.95
Salers	46	183	0.03	0.03	0.76	13.52	0.40	0.79
Simmental	64	366	0.59	0.42	0.89	13.82	0.70	0.53

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 12.76 in^2) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 7. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2011 base and factors to adjust within breed EPD to an Angus equivalent – FAT THICKNESS (in)

			Ave. Base EPD		Breed Soln	BY 2011	BY 2011	Factor to
	Number		Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2011	Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	111	664	0.010	0.001	0.000	0.611	0.000	0.000
Hereford	128	877	0.002	-0.005	-0.056	0.552	-0.058	-0.050
Red Angus	40	176	-0.002	-0.008	-0.037	0.570	-0.041	-0.029
Shorthorn	43	201	-0.010	-0.005	-0.149	0.448	-0.162	-0.142
South Devon	13	49	0.010	0.010	-0.102	0.500	-0.111	-0.111
Santa Gertrudis	21	101	0.002	0.010	-0.106	0.487	-0.124	-0.116
Braunvieh	30	184	-0.067	-0.104	-0.206	0.432	-0.179	-0.102
Charolais	42	208	0.000	0.001	-0.219	0.381	-0.230	-0.220
Chiangus	23	96	0.005	0.029	-0.129	0.449	-0.162	-0.157
Gelbvieh	68	375	-0.042	-0.075	-0.213	0.422	-0.189	-0.136
Maine Anjou	37	191	0.000	0.000	-0.230	0.372	-0.239	-0.229
Salers	46	183	0.000	-0.006	-0.214	0.394	-0.217	-0.207
Simmental	64	366	-0.058	-0.058	-0.199	0.402	-0.209	-0.141

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 0. 601 in) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 8. Mean weighted[a] accuracies for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), maternal weaning weight (MWWT), milk (MILK), marbling (MAR), ribeye area (REA), and fat thickness (FAT) for bulls used at USMARC

Breed	BWT	WWT	YWT	MILK	MAR	REA	FAT
Angus	0.79	0.77	0.71	0.72	0.52	0.51	0.49
Hereford	0.65	0.62	0.61	0.58	0.26	0.39	0.30
Red Angus	0.92	0.91	0.91	0.88	0.65	0.64	0.66
Shorthorn	0.81	0.80	0.74	0.79	0.62	0.60	0.54
South Devon	0.41	0.45	0.37	0.44	0.02	0.05	0.05
Beefmaster	0.87	0.89	0.86	0.73			
Brahman	0.67	0.67	0.61	0.60			
Brangus	0.87	0.81	0.79	0.69			
Santa Gertrudis	0.85	0.82	0.74	0.77	0.33	0.52	0.44
Braunvieh	0.55	0.48	0.38	0.41	0.11	0.15	0.09
Charolais	0.80	0.74	0.65	0.68	0.48	0.51	0.45
Chiangus	0.82	0.79	0.79	0.75	0.25	0.23	0.34
Gelbvieh	0.84	0.83	0.82	0.80	0.55	0.54	0.55
Limousin	0.93	0.89	0.83	0.83	0.75	0.75	
Maine Anjou	0.78	0.77	0.77	0.77	0.31	0.28	0.32
Salers	0.83	0.82	0.76	0.81	0.25	0.29	0.33
Simmental	0.94	0.94	0.94	0.92	0.72	0.72	0.72
Tarentaise	0.94	0.93	0.95	0.94			

[a]Weighted by relationship to phenotyped animals at USMARC for BWT, WWT, YWT, MAR, REA, and FAT and by relationship to daughters with phenotyped progeny MILK.

Table 9. Estimates of variance components (lb^2) for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), and maternal weaning weight (MWWT) and for marbling (MAR; marbling score units^2), ribeye area (REA; in^4), and fat thickness (FAT; in^2) from mixed model analyses

	Direct		
Analysis	BWT	WWT[a]	YWT
Direct			
Animal within breed (19 breeds)	71.69	479.57	3596.10
Maternal genetic within breed (19 breeds)		425.79	
Maternal permanent environment		723.31	
Residual	51.39	1227.99	4411.95

Carcass Direct	MAR	REA	FAT
Animal within breed (13-14 breeds)	0.278	0.671	0.0099
Residual	0.286	0.729	0.0148

[a]Direct maternal covariance for weaning weight was -61.43 lb^2

Table 10. Pooled and within-breed regression coefficients (lb/lb) for weights at birth (BWT), 205 days (WWT), and 365 days (YWT) of F_1 progeny and for calf weights (205 d) of F_1 dams (MILK) on sire expected progeny difference and by sire breed

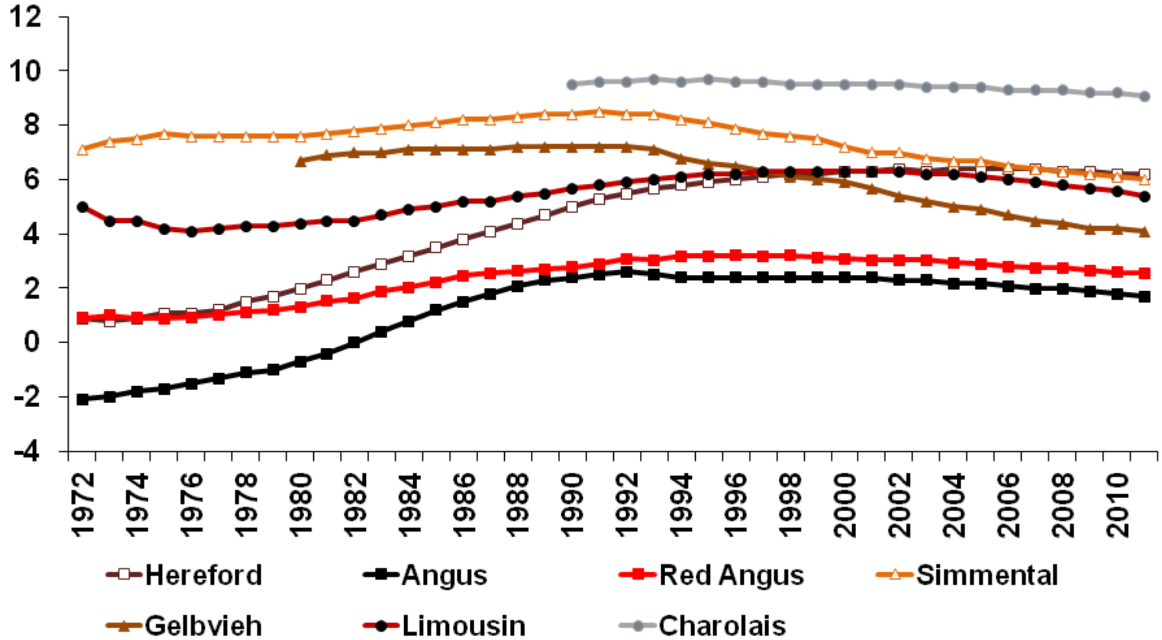
	BWT	WWT	YWT	MILK
Pooled	1.17 ± 0.04	0.84 ± 0.03	1.01 ± 0.04	1.14 ± 0.07
Sire breed				
Angus	1.05 ± 0.10	0.87 ± 0.07	1.18 ± 0.08	1.04 ± 0.15
Hereford	1.17 ± 0.07	0.76 ± 0.05	0.97 ± 0.06	1.03 ± 0.15
Red Angus	1.10 ± 0.15	0.81 ± 0.15	0.61 ± 0.17	1.42 ± 0.28
Shorthorn	0.62 ± 0.22	0.56 ± 0.20	0.64 ± 0.26	1.25 ± 0.73
South Devon	-0.29 ± 0.52	0.69 ± 0.32	0.02 ± 0.48	0.17 ± 1.57
Beefmaster	1.98 ± 0.36	0.86 ± 0.25	0.73 ± 0.40	3.79 ± 0.72
Brahman	2.03 ± 0.21	1.00 ± 0.19	1.28 ± 0.23	0.07 ± 0.45
Brangus	1.57 ± 0.26	0.85 ± 0.23	1.16 ± 0.33	0.31 ± 0.65
Santa Gertrudis	4.08 ± 0.84	1.41 ± 0.31	1.11 ± 0.35	0.63 ± 1.05
Braunvieh	0.70 ± 0.27	0.58 ± 0.25	0.71 ± 0.38	0.44 ± 0.58
Charolais	1.16 ± 0.12	0.93 ± 0.11	0.80 ± 0.13	1.15 ± 0.25
Chiangus	1.68 ± 0.30	0.27 ± 0.26	0.72 ± 0.32	0.22 ± 0.55
Gelbvieh	1.14 ± 0.14	0.82 ± 0.12	1.03 ± 0.13	1.02 ± 0.26
Limousin	0.99 ± 0.12	1.01 ± 0.10	1.13 ± 0.12	1.77 ± 0.26
Maine Anjou	1.47 ± 0.19	0.86 ± 0.20	0.54 ± 0.27	1.91 ± 0.46
Salers	1.30 ± 0.24	0.77 ± 0.27	0.42 ± 0.26	1.69 ± 0.44
Simmental	1.08 ± 0.16	1.51 ± 0.14	1.27 ± 0.13	0.99 ± 0.34
Tarentaise	0.78 ± 0.59	1.03 ± 0.24	1.49 ± 0.84	1.12 ± 0.93

Table 11. Pooled and within-breed regression coefficients marbling (MAR; score/score), ribeye area (REA; in^2/in^2), and fat thickness (FAT; in/in) of F_1 progeny on sire expected progeny difference and by sire breed

	MAR	REA	FAT
Pooled	0.57 ± 0.05	0.86 ± 0.06	1.01 ± 0.09
Sire breed			
Angus	0.97 ± 0.10	0.86 ± 0.14	1.29 ± 0.17
Hereford	0.50 ± 0.14	0.54 ± 0.14	0.98 ± 0.17
Red Angus	0.62 ± 0.19	1.10 ± 0.23	0.74 ± 0.47
Shorthorn	1.54 ± 0.32	1.31 ± 0.59	1.81 ± 0.51
South Devon	-0.28 ± 0.61	2.01 ± 3.21	9.34 ± 2.58
Santa Gertrudis	0.60 ± 0.82	0.95 ± 0.45	0.75 ± 0.50
Braunvieh	0.74 ± 0.52	0.23 ± 0.27	0.35 ± 0.43
Charolais	1.21 ± 0.26	1.22 ± 0.31	1.56 ± 0.49
Chiangus	0.66 ± 0.23	0.71 ± 0.49	0.79 ± 0.47
Gelbvieh	1.37 ± 0.21	1.32 ± 0.17	1.83 ± 0.31
Limousin	1.11 ± 0.39	1.22 ± 0.18	
Maine Anjou	-0.05 ± 0.26	-1.23 ± 0.50	0.95 ± 0.56
Salers	0.05 ± 0.08	1.74 ± 0.65	1.35 ± 0.63
Simmental	0.87 ± 0.20	0.68 ± 0.18	0.58 ± 0.36

Figure 1. Relative genetic trends for birth weight (lb) of the seven most highly used beef breeds (1a) and all breeds that submitted 2013 trends (1b) adjusted for birth year 2011 using the 2013 across-breed EPD adjustment factors.

1a.



1b.

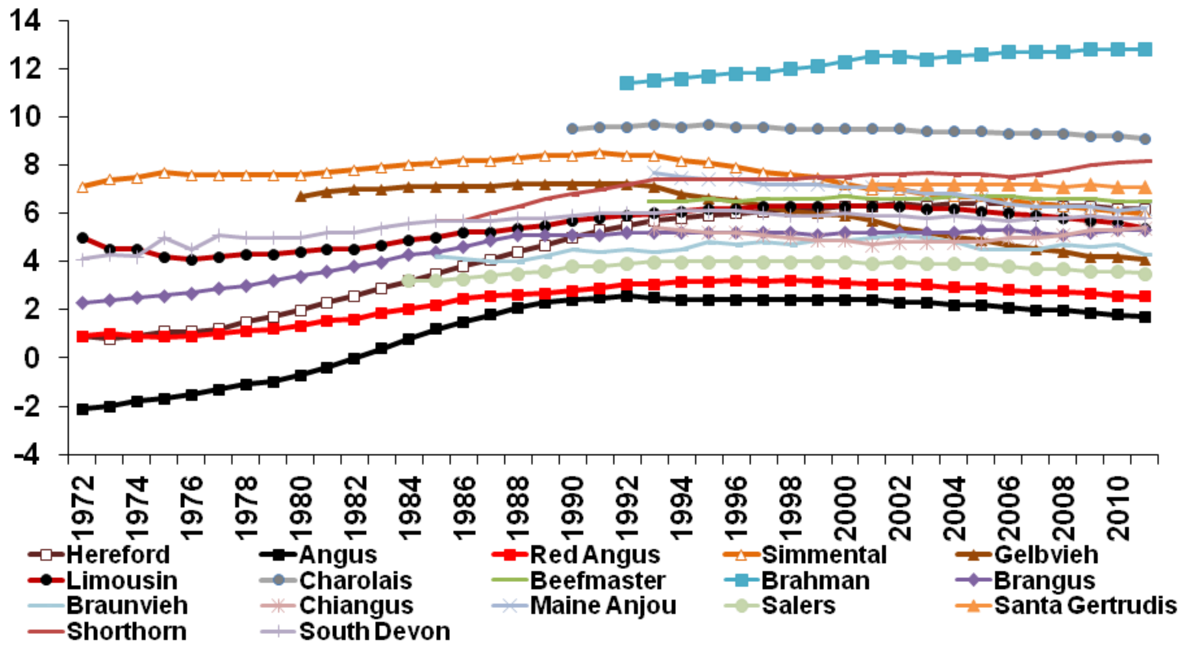
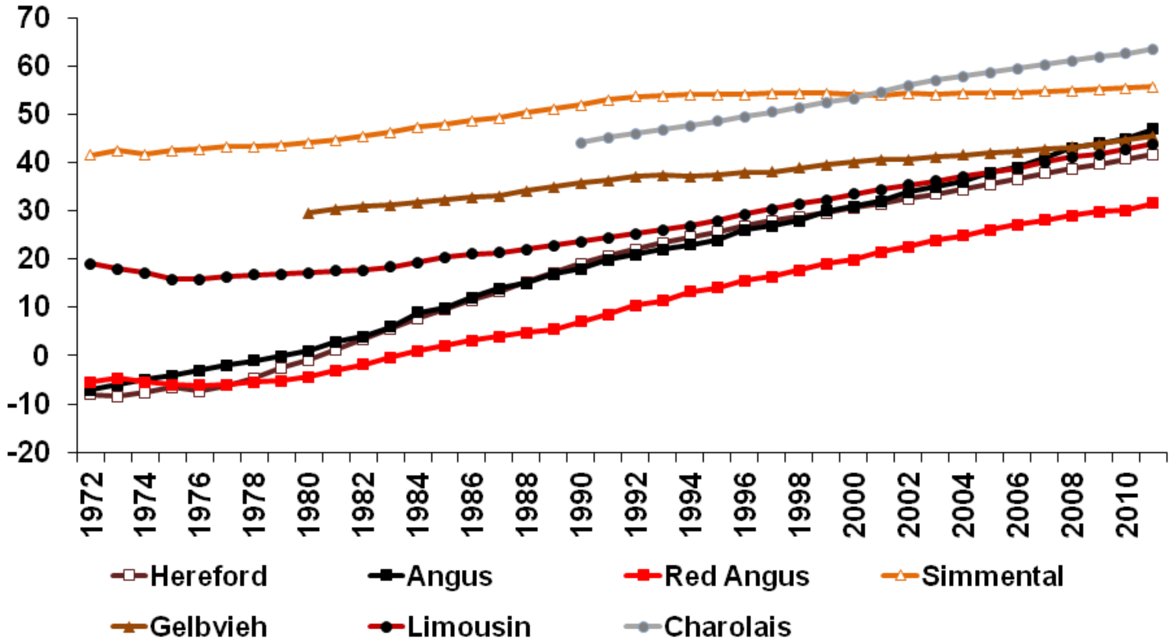


Figure 2. Relative genetic trends for weaning weight (lb) of the seven most highly used beef breeds (2a) and all breeds that submitted 2013 trends (2b) adjusted for birth year 2011 using the 2013 across-breed EPD adjustment factors.

2a.



2b.

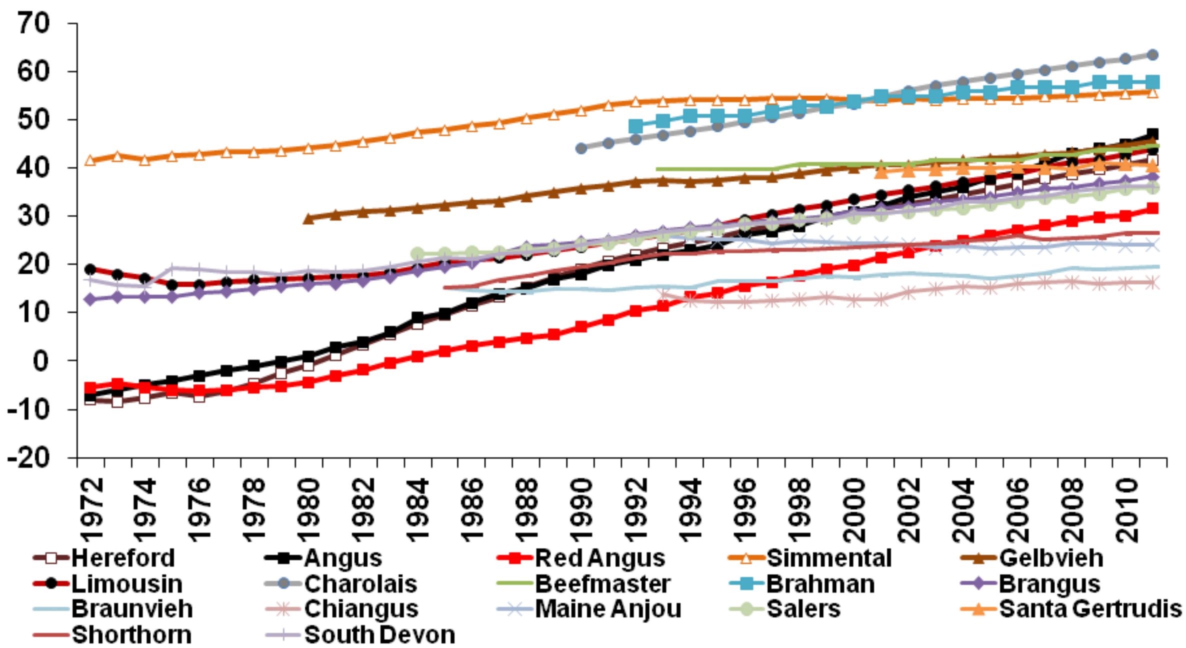
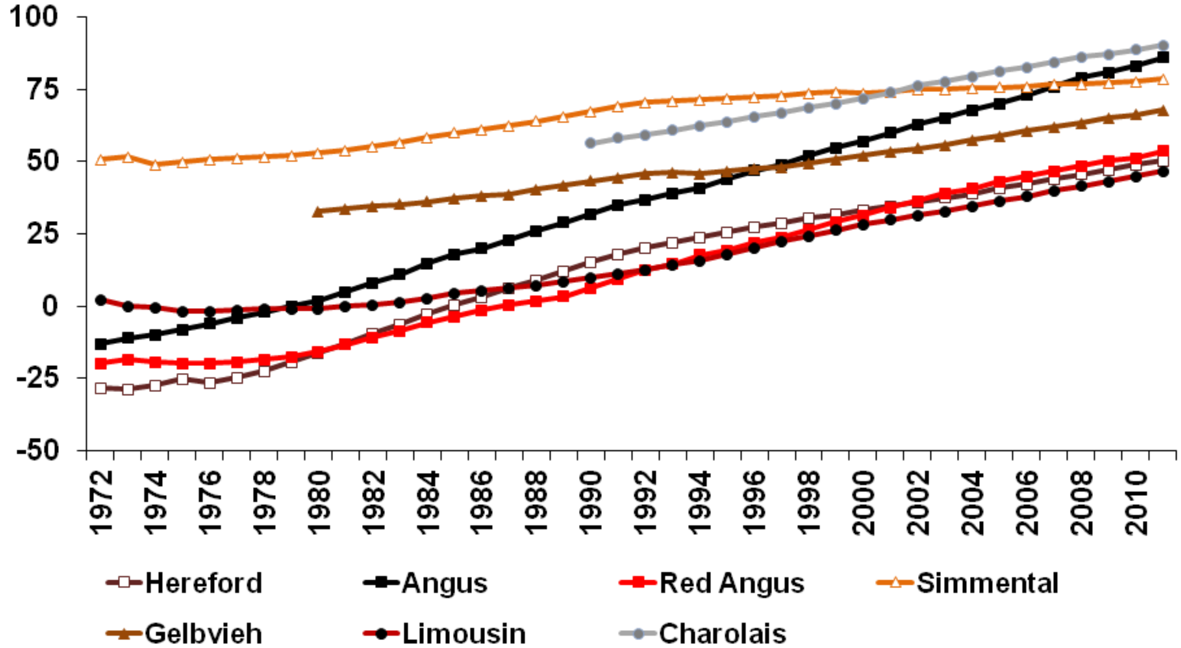


Figure 3. Relative genetic trends for yearling weight (lb) of the seven most highly used beef breeds (3a) and all breeds that submitted 2013 trends (3b) adjusted for birth year 2011 using the 2013 across-breed EPD adjustment factors.

3a.



3b.

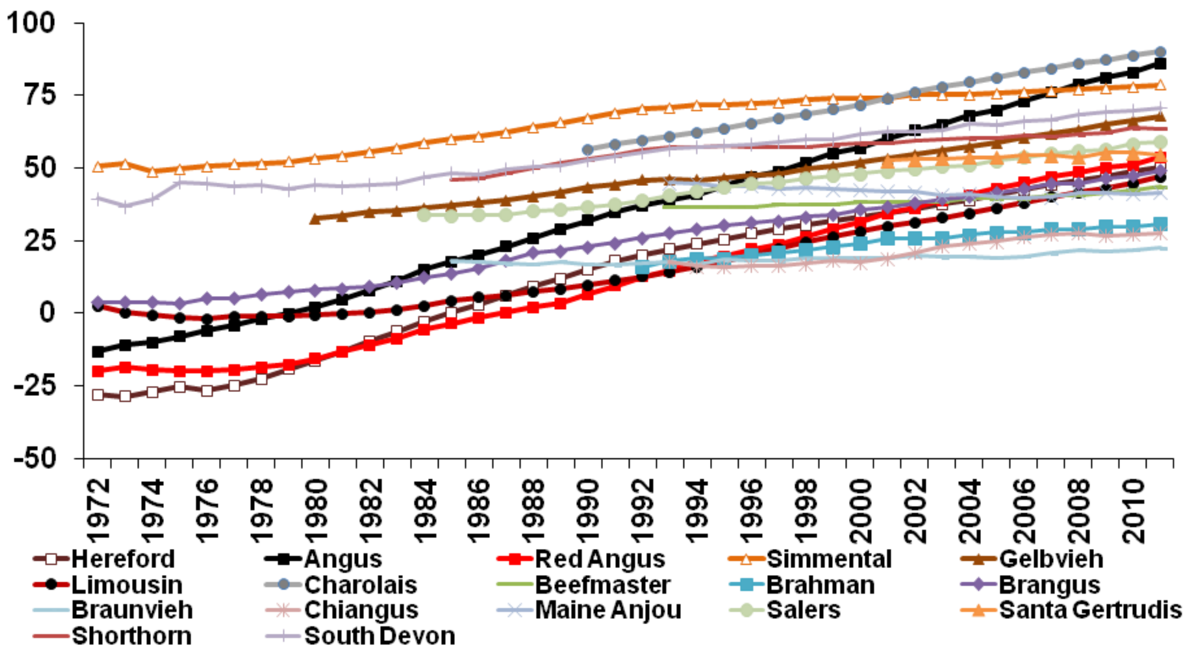
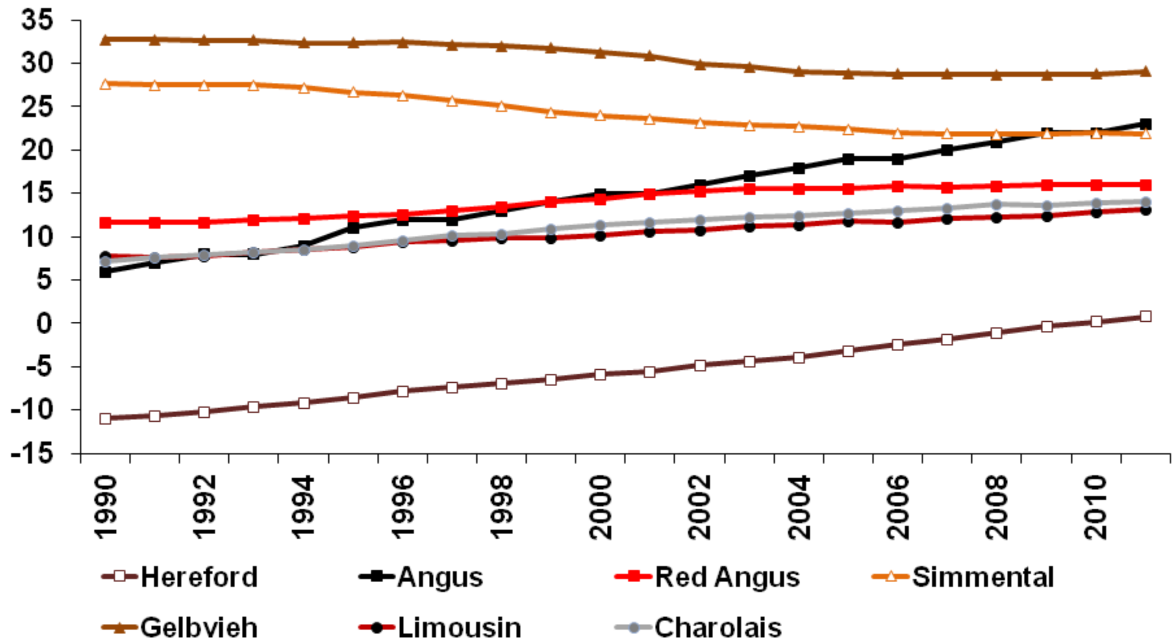
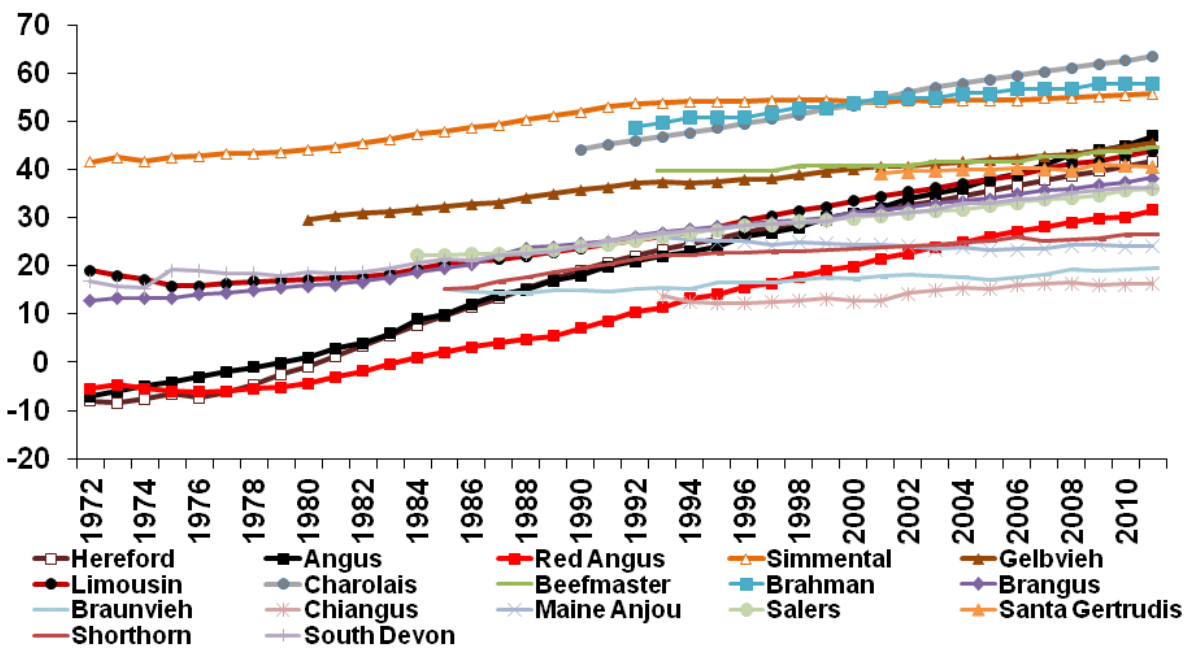


Figure 4. Relative genetic trends for maternal milk (lb) of the seven most highly used beef breeds (4a) and all breeds that submitted 2013 trends (4b) adjusted for birth year 2011 using the 2013 across-breed EPD adjustment factors.

4a.



4b.



Literature Cited

Arnold, J. W., J. K. Bertrand, and L. L. Benyshek. 1992. *Animal model for genetic evaluation of multibreed data.* J. Anim. Sci. 70:3322-3332.

Barkhouse, K. L., L. D. Van Vleck, and L. V. Cundiff. 1994. *Breed comparisons for growth and maternal traits adjusted to a 1992 base.* Proc. Beef Improvement Federation 26th Research Symposium and Annual Meeting, Des Moines, IA, May, 1994. pp 197-209.

Barkhouse, K. L., L. D. Van Vleck, and L. V. Cundiff. 1995. *Mixed model methods to estimate breed comparisons for growth and maternal traits adjusted to a 1993 base.* Proc. Beef Improvement Federation 27th Research Symposium and Annual Meeting, Sheridan, WY. May 31-June 3, 1995. pp 218-239.

Boldman, K. G., L. A. Kriese, L. D. Van Vleck, and S. D. Kachman. 1993. A Manual for Use of MTDFREML (DRAFT). *A set of programs to obtain estimates of variances and covariances.* USDA-ARS, Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE. (120 pp).

Cundiff, L. V. 1993. *Breed comparisons adjusted to a 1991 basis using current EPD's.* Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Asheville, NC. May 26-29, 1993. pp 114-123.

Cundiff, L. V. 1994. *Procedures for across breed EPD's.* Proc. Fourth Genetic Prediction Workshop, Beef Improvement Federation, Kansas City, MO. Jan. 1994.

Koch, R. M., L. V. Cundiff, and K. E. Gregory. 1994. *Cumulative selection and genetic change for weaning or yearling weight or for yearling weight plus muscle score in Hereford cattle.* J. Anim. Sci. 72:864-885.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2007. *Across-breed EPD tables for the year 2007 adjusted to breed differences for birth year of 2005.* Proc. Beef Improvement Federation 39th Annual Research Symposium and Annual Meeting, Fort Collins, CO. June 6-9, 2007. pp 74-92.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2008. *Across-breed EPD tables for the year 2008 adjusted to breed differences for birth year of 2006.* Proc. Beef Improvement Federation 40th Annual Research Symposium and Annual Meeting, Calgary, AB. June 30-July 3, 2008. pp 53-74.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2009. *Across-breed EPD tables for the year 2009 adjusted to breed differences for birth year of 2007.* Proc. Beef Improvement Federation 41th Annual Research Symposium and Annual Meeting, Sacramento, CA. April 30-May 3, 2009. pp 160-183.

Kuehn L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2010. *Across-breed EPD tables for the year 2010 adjusted to breed differences for birth year of 2008.* Proc. Beef Improvement Federation 42nd Annual Research Symposium and Annual Meeting, Columbia, MO. June 28-July 1, 2010. pp. 71-92.

Kuehn L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2011. *Across-breed EPD tables for the year 2011 adjusted to breed differences for birth year of 2009.* Proc. Beef Improvement Federation 43rd Annual Research Symposium and Annual Meeting, Bozeman, MT. June 1-4, 2011. pp. 92-111.

Kuehn L. A., and R. M. Thallman. 2012. *Across-breed EPD tables for the year 2012 adjusted to breed differences for birth year of 2010.* Proc. Beef Improvement Federation 44th Annual Research Symposium and Annual Meeting, Houston, TX. April 18-21, 2012. pp. 152-177.

Notter, D. R., and L. V. Cundiff. 1991. *Across-breed expected progeny differences: Use of within-breed expected progeny differences to adjust breed evaluations for sire sampling and genetic trend.* J. Anim. Sci. 69:4763-4776.

Núñez-Dominguez, R., L. D. Van Vleck, and L. V. Cundiff. 1993. *Breed comparisons for growth traits adjusted for within-breed genetic trend using expected progeny differences.* J. Anim. Sci. 71:1419-1428.

Van Vleck, L. D. 1994. *Prediction error variances for inter-breed EPD's.* Proc. Fourth Genetic Predication Workshop, Beef Improvement Federation, Kansas City, MO. Jan. 1994.

Van Vleck, L. D., and L. V. Cundiff. 1994. *Prediction error variances for inter-breed genetic evaluations.* J. Anim. Sci. 71:1971-1977.

Van Vleck, L. D., and L. V. Cundiff. 1995. *Assignment of risk to across-breed EPDs with tables of variances of estimates of breed differences.* Proc. Beef Improvement Federation 27th Research Symposium and Annual Meeting, Sheridan, WY. May 31-June 3, 1995. pp 240-245.

Van Vleck, L. D., and L. V. Cundiff. 1997. *Differences in breed of sire differences for weights of male and female calves.* Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Dickinson, ND. May 14-17, 1997. pp 131-137.

Van Vleck, L. D., and L. V. Cundiff. 1997. *The across-breed EPD tables adjusted to a 1995 base.* Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Dickinson, ND. May 14-17, 1997. pp 102-117.

Van Vleck, L. D., and L. V. Cundiff. 1998. *Across-breed EPD tables for 1998 adjusted to a 1996 base*. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Calgary, Alberta, Canada. July 2, 1998. pp 196-212.

Van Vleck, L. D., and L. V. Cundiff. 1998. *Influence of breed of dam on across-breed adjustment factors.* Midwestern Section ASAS and Midwest Branch ADSA 1998 Meeting, Des Moines, IA. Abstract # 10. p 31.

Van Vleck, L. D., and L. V. Cundiff. 1999. *Across-breed EPD tables for 1999 adjusted to a 1997 base.* Proc. Beef Improvement Federation 31th Annual Research Symposium and Annual Meeting, Roanoke, VA. June 15-19, 1999. pp 155-171.

Van Vleck, L. D., and L. V. Cundiff. 2000. *Across-breed EPD tables for 2000 adjusted to a 1998 base.* Proc. Beef Improvement Federation 32th Annual Research Symposium and Annual Meeting, Wichita, KS. July 12-15, 2000. pp 98-116.

Van Vleck, L. D., and L. V. Cundiff. 2001. *Across-breed EPD tables for 2001 adjusted to breed differences for birth year 1999.* Proc. Beef Improvement Federation 33th Annual Research Symposium and Annual Meeting, San Antonio, TX. July 11-14, 2001. pp 44-63.

Van Vleck, L. D., and L. V. Cundiff. 2002. *Across-breed EPD tables for 2002 adjusted to breed differences for birth year of 2000.* Proc. Beef Improvement Federation 34th Annual Research Symposium and Annual Meeting, Omaha, NE. July 10-13, 2002. pp 139-159.

Van Vleck, L. D., and L. V. Cundiff. 2003. *Across-breed EPD tables for the year 2003 adjusted to breed differences for birth year of 2001*. Proc. Beef Improvement Federation 35th Annual Research Symposium and Annual Meeting, Lexington, KY. May 28-31, 2003. pp 55-63.

Van Vleck, L. D., and L. V. Cundiff. 2004. *Across-breed EPD tables for the year 2004 adjusted to breed differences for birth year of 2002.* Proc. Beef Improvement Federation 36th Annual Research Symposium and Annual Meeting, Sioux Falls, SD. May 25-28, 2004. pp 46-61.

Van Vleck, L. D., and L. V. Cundiff. 2005. *Across-breed EPD tables for the year 2005 adjusted to breed differences for birth year of 2003.* Proc. Beef Improvement Federation 37th Annual Research Symposium and Annual Meeting, Billings, MT. July 6-9, 2005. pp 126-142.

Van Vleck, L. D., and L. V. Cundiff. 2006. *Across-breed EPD tables for the year 2006 adjusted to breed differences for birth year of 2004.* Proc. Beef Improvement Federation 39th Annual Research Symposium and Annual Meeting, Choctaw, MS. April 18-21, 2006.

Available online at: http://www.beefimprovement.org/proceedings/06proceedings/2006-bif-vanvleck-cundiff.pdf.

Van Vleck, L. D., L. V. Cundiff, T. L. Wheeler, S. D. Shackelford, and M. Koohmaraie. 2007. *Across-breed adjustment factors for expected progeny differences for carcass traits.* J. Anim. Sci. 85:1369-1376.

Westell, R. A., R. L. Quaas, and L. D. Van Vleck. 1988. *Genetic groups in an animal model.* J. Dairy Sci. 71:1310-1318.

MEAN EPDs REPORTED BY DIFFERENT BREEDS

Larry A. Kuehn[1] *and R. Mark Thallman*[1]

[1]*Roman L. Hruska U.S. Meat Animal Research Center, USDA-ARS, Clay Center, NE 68933*

Expected progeny differences (EPDs) have been the primary tool for genetic improvement of beef cattle for over 40 years beginning with evaluations of growth traits. Since that time EPDs have been added for several other production traits such as calving ease, stayability, carcass merit and conformation. Most recently, several breed associations have derived economic indices from their EPDs to increase profit under different management and breeding systems.

It is useful for producers to compare the EPDs of potential breeding animals with their breed average. The current EPDs from the most recent genetic evaluations of 24 breeds are presented in this report. Mean EPDs for growth traits are shown in Table 1 (24 breeds), for other production traits in Table 2 (18 breeds), and for carcass and composition traits in Table 3 (20 breeds). Several breeds also have EPDs and indices that are unique to their breed; these EPDs are presented in Table 4.

Average EPDs should only be used to determine the genetic merit of an animal relative to its breed average. To compare animals of different breeds, across breed adjustment factors should be added to animals' EPDs for their respective breeds (see Across-breed EPD Tables reported by Kuehn and Thallman in these proceedings).

This list is likely incomplete; evaluations for some breeds are not widely reported. If you see a breed missing and would like to report the average EPDs for that breed, please contact Larry (Larry.Kuehn@ars.usda.gov) or Mark (Mark.Thallman@ars.usda.gov).

Table 1. Birth year 2011 average EPDs from 2013 evaluations for growth traits

Breed	Birth	Weaning	Yearling	Maternal	Total
Angus	1.7	47	86	23	
Hereford	3.5	45	74	18	41
Murray Grey	3.5	21	33	4	14
Red Angus	-0.9	55	82	20	47
Red Poll	1.7	15	24	6	
Shorthorn	2.4	15.3	24.8	2.3	10.0
South Devon	2.6	40.9	77.2	22.9	43.4
Beefmaster	0.2	10	14	2	
Braford	1.1	9	14	2	7
Brahman	1.8	15	24.1	6.4	
Brangus	0.8	23.7	43.1	11.3	23.1
Red Brangus	1.6	13.2	20.6	5.2	11.8
Santa Gertrudis	0.5	4.3	6.3	0.7	
Senepol	0.9	9.0	9.9	2.5	6.9
Simbrah	4.0	62.3	85.5	21.8	52.8
Braunvieh	2.4	41.1	64.8	34.0	54.5
Charolais	0.6	24.4	43.1	6.9	19.1
Chianina	3.1	36.8	67.9	10.9	29.3
Gelbvieh	1.4	63.7	93.5	25.5	57.3
Limousin	1.5	46.5	84.2	22.1	
Maine-Anjou	2.0	39.4	78.2	19.7	
Salers	1.7	41.3	79.6	19.5	40.2
Simmental	2.3	62.1	90.3	22.9	53.8
Tarentaise	1.9	16	28.6	0.6	

Table 2. Birth year 2011 average EPDs from 2013 evaluations for other production traits

Breed	Calving Ease Direct (%)	Calving Ease Maternal (%)	Scrotal Circ (cm)	Docility Score	Mature Weight (lb)	Heifer Pregnancy (%)	Stayability (%)
Angus	5	7	0.60	11	37	8.4	
Hereford	0.6	1	0.7		85		
Murray Grey	-0.6	-0.2	0.2		50		
Red Angus	4	4				10	10
Shorthorn	-1.7	-1.7					
South Devon			0.1				
Beefmaster			0.2				
Brangus	5.1	7.1	0.62				
Simbrah	3.9	4.7		7.4			
Braunvieh	6.1	5.6					
Charolais	2.8	3.7	0.61				
Chianina	5.6	-1.2					
Gelbvieh	8.6	5.9[a]					5.5
Limousin	8.8	5.0	0.4	20.3			
Maine Anjou	7.7	3.7					
Salers	0.3	0.3	0.3	8.4			23.3
Simmental	9.0	8.1		9.3			18.9
Tarentaise	-1.2	0.6					

[a]Maternal calving ease listed as Calving Ease Daughters (CED) in Gelbvieh sire summary.

Table 3. Birth year 2011 average EPDs from 2013 evaluations for carcass and composition traits

Breed	Carcass Wt (lb)	Retail Product (%)	Yield Grade	Carcass: Marbling Score	Carcass: Ribeye Area (in^2)	Carcass: Fat Thickness (in)	Rump fat (in)	WBSF (lb)
Angus	25			0.46	0.42	0.01		
Hereford				0.05	0.26	0.002		
Murray Grey	29	0.4		0.0[a]	0.10[a]	0.00[a]	0.00[a]	
Red Angus	17		-0.01	0.38	0.15	0.00		
Shorthorn	4.9			-0.02	0.07	-0.01		
South Devon	27.5	0.8		0.4	0.21	0.01		
Beefmaster				0.00[a]	0.04[a]	0.00[a]	0.01[a]	
Braford	6			0.01	0.05	0.012		
Brahman	6.6	0.01		0.00	0.06	-0.001		-0.01
Brangus	14.8			0.01[b]	0.30[b]	-0.001[b]		
Santa Gertrudis	0.8			0.00	0.01	0.002		
Simbrah	25.9		-0.21	-0.06	0.35	-0.070		-0.02
Braunvieh	34.6			0.50	0.71	-0.067		
Charolais	14.5			0.03	0.20	0.000		
Chianina	6.0	-0.02		0.19	0.09	0.005		
Gelbvieh	27.0		-0.12	0.04	0.30	-0.042		
Limousin	24.5		-0.05	-0.02	0.54			
Maine-Anjou	0.26	0.27		0.21	0.15	0.00		
Salers	21.5	0.0		0.2	0.03	0.00		
Simmental	26.5		-0.25	0.08	0.59	-0.058		-0.29

[a]Derived using ultrasound measures and reported on an ultrasound scale (IMF% instead of marbling score)
[b]Reported on an ultrasound scale (IMF% instead of marbling score) but calculated using ultrasound and carcass data in a multi-trait model

Table 4. Birth year 2011 average EPDs from 2013 evaluations for other traits unique to individual breeds

Angus	Residual Average Daily Gain (lb)	Mature Height (in)	Yearling Height (in)	Cow Energy Value ($)	Weaned Calf Value ($)	Feedlot Value ($)	Grid Value ($)	Beef Value ($)
	0.16	0.4	0.4	-3.74	26.33	27.73	27.88	63.17

Hereford	Baldy Maternal Index	Brahman Influence Index ($)	Certified Hereford Beef Index ($)	Calving Ease Index ($)
	17	15	21	15

Red Angus	Mature Cow Maintenance (Mcal/mo)
	2

Gelbvieh	Feedlot Merit ($)	Carcass Value ($)
	32.32	19.88

Limousin	Mainstream Terminal Index ($)
	44.4

Simmental	All Purpose Index ($)	Terminal Index ($)
	106.0	62.9

Simbrah	All Purpose Index ($)	Terminal Index ($)
	65.62	51.25

Murray Grey	600-d wt (lb)	Gestational length (d)	Days to calving (d)
	48	-0.1	-0.7

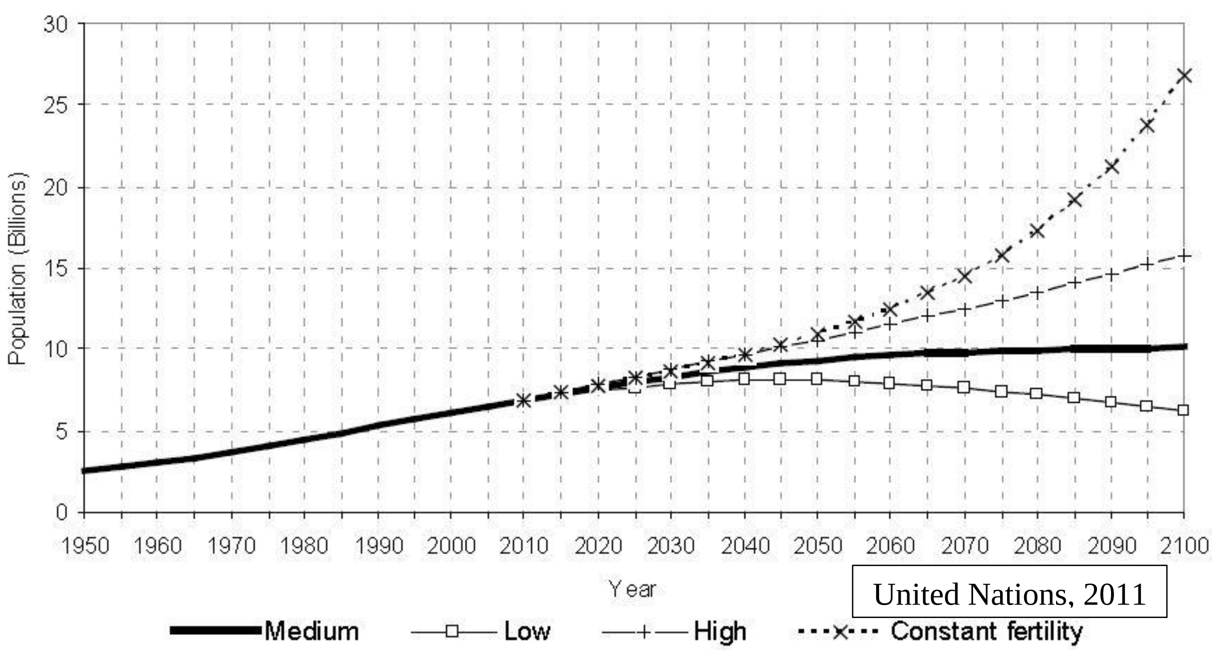
Technology lag: Is there a cost for failing to do it right?

David S. Buchanan[1]

[1]*North Dakota State University*

Technological advances should, logically, result in improved efficiency for any industry. The beef industry certainly follows this simple rule. The need for capitalizing upon this opportunity is obvious. The beef industry will be an important contributor to one of the most important tasks of the next 40 years: feeding an expanding population. Future projections in world population vary but many seem to agree that 9 billion people by the year 2050 is a reasonable projection. Projections beyond 2050 vary widely due to different potential scenarios concerning mean fertility rates for the human population.

Population of the world, 1950-2100, according to different projections and variants



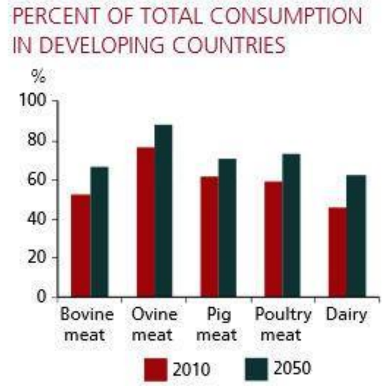
Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2011). World Population Prospects: *The 2010 Revision*. New York: United Nations.

In addition to expansions in world population, there are predicted changes in the types of foods consumed by the growing population. As affluence increases in developing countries there is a projected increase in the proportion of the diet consumed as animal products (FAO, 2011)

PROJECTED TOTAL CONSUMPTION OF MEAT AND DAIRY PRODUCTS

	2010	2020	2030	2050	2050/2010
	(million tonnes)				
WORLD					
All meat	268.7	319.3	380.8	463.8	173%
Bovine meat	67.3	77.3	88.9	106.3	158%
Ovine meat	13.2	15.7	18.5	23.5	178%
Pig meat	102.3	115.3	129.9	140.7	137%
Poultry meat	85.9	111.0	143.5	193.3	225%
Dairy not butter	657.3	755.4	868.1	1 038.4	158%
DEVELOPING COUNTRIES					
All meat	158.3	200.8	256.1	330.4	209%
Bovine meat	35.1	43.6	54.2	70.2	200%
Ovine meat	10.1	12.5	15.6	20.6	204%
Pig meat	62.8	74.3	88.0	99.2	158%
Poultry meat	50.4	70.4	98.3	140.4	279%
Dairy not butter	296.2	379.2	485.3	640.9	216%

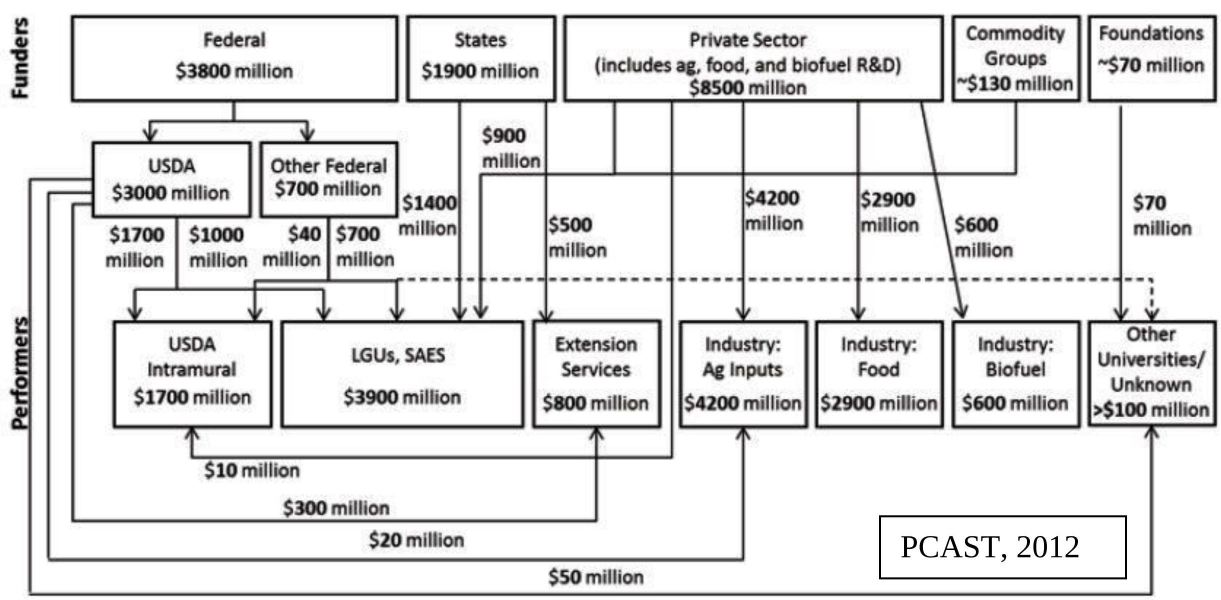
Source: FAO, 2006c. Some calculations by authors.
Note these figures are based on World Population Prospects: The 2002 Revision.



FAO, 2011

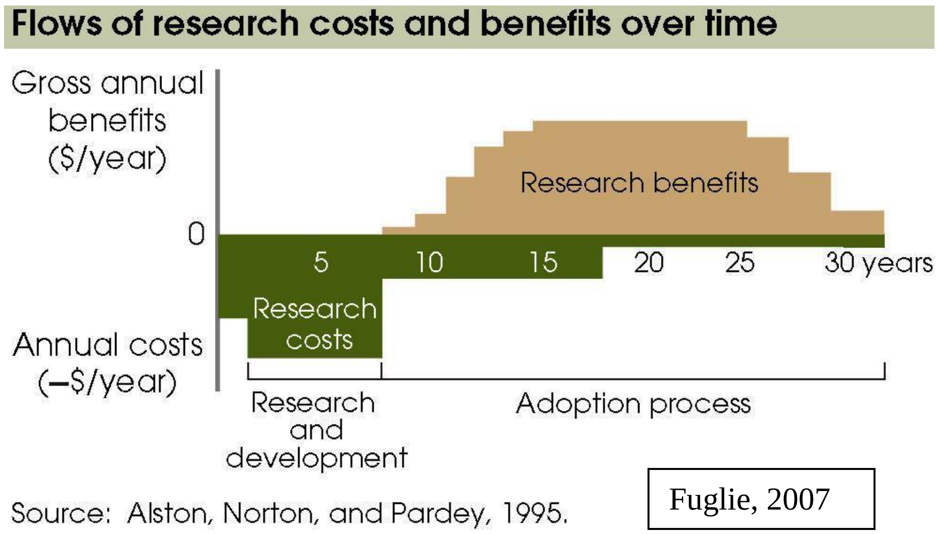
Will the beef industry be in a position to meet these demands for the next 30+ years? First, we must continue to have technological advances. This will require continued investment in research and technology. It is estimated that each dollar invested in agricultural research returns $10 in increased productivity and efficiency (PCAST, 2012). They also showed that

2009 U.S. public and private agricultural research, development, and extension expenditures.

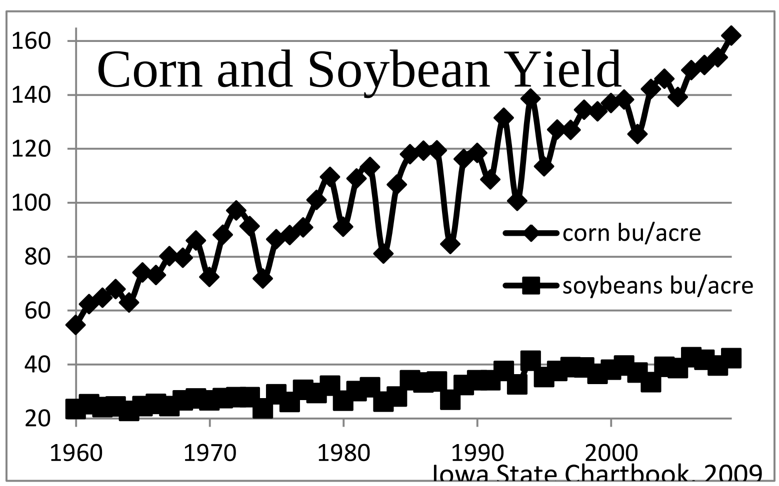


annual investment in agriculture research exceeds $14 billion (PCAST, 2012).

The benefits derived from research do not happen overnight. The research enterprise necessarily includes fundamental research which may not yield benefits for many years while more applied research may have benefit which is immediate. I have had the good fortune to work for universities at which the balance of fundamental and applied research has been good. Some of my colleagues were answering questions about basic biology that set the stage for other colleagues who were doing research that was so immediate that producers were calling to ask them how they thought the research was going to turn out so that they could make management decisions NOW. The time relationship between the cost of research and the resulting benefits are illustrated here.



Agricultural research has certainly paid off. The increases in yields of various crops have been very substantial. A near tripling of corn yield and a near doubling of soybean yield over a period of 50 years has been the result of research that contributed improved varieties and management practices. Many other crops have shown similar improvements. Were it not for these improvements, much more land would be required to feed the world.

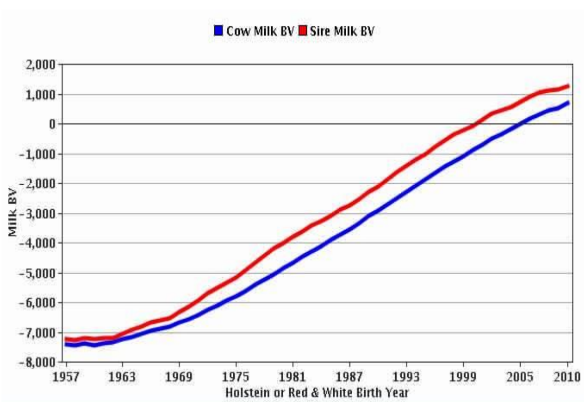


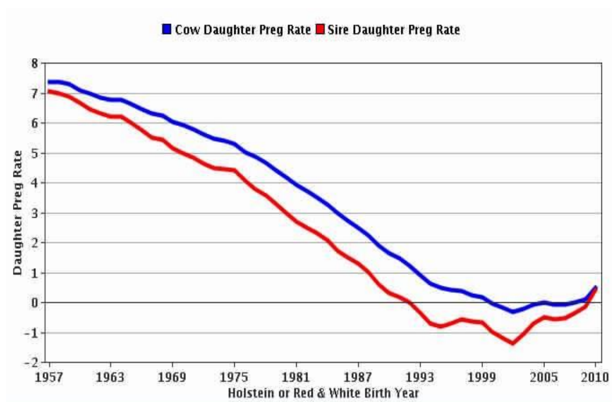
Such changes raise the question: Could it have been more? Development of technology is only helpful if it is used. Research that just sits on the shelf is a waste of resources. The Office of Technology Assessment (eliminated as a Congressional Agency in 1995) examined the potential productivity resulting from different levels of technology adoption in 1992. The study identified several measures of productivity for both plant and animal agriculture from 1990 and predicted productivity in 2000 based upon less, likely or more adoption of technology by 2000. Comparison of the predictions in the table illustrate that both corn and soybean yield actually exceeded the projections for the year 2000. This raises an important question: Is technology being adopted at a rapid enough rate in animal agriculture. Assessment of progress in animal agriculture is a bit more difficult than for plant agriculture because standard measuring sticks, like yield in bushels/acre, are more difficult to identify due to variation in types and locations of production.

Estimates of Crop Yield and Animal Production Efficiency by 2000 (Office of Technology Assessment. 1992. A New Technological Era for American Agriculture

	1990	Less new technology - 2000	Most likely technology - 2000	More new technology - 2000
Corn—bu/acre	116.2	113.8	128.5	141.6
Soybeans—bu/acre	32.4	32.6	33.7	36.4
Wheat—bu/acre	34.8	37.7	42.6	53.8
Beef Lbs meat/lb feed	0.143	0.146	0.154	0.169
Calves/100 cows	90.0	93.75	96.22	102.45
Dairy Lbs milk/lb feed	1.010	1.030	1.050	1.057
Lbs.milk/cow/year	14,200	17,247	19,191	20,498
Pork Lbs meat/lb feed	0.154	0.174	0.181	0.196
Pigs/sow/year	13.9	14.0	15.7	17.8

The number of calves/100 cows has, obviously, not been reached. Improvements in efficiency of production of beef, milk or pork are somewhat difficult to assess, especially for



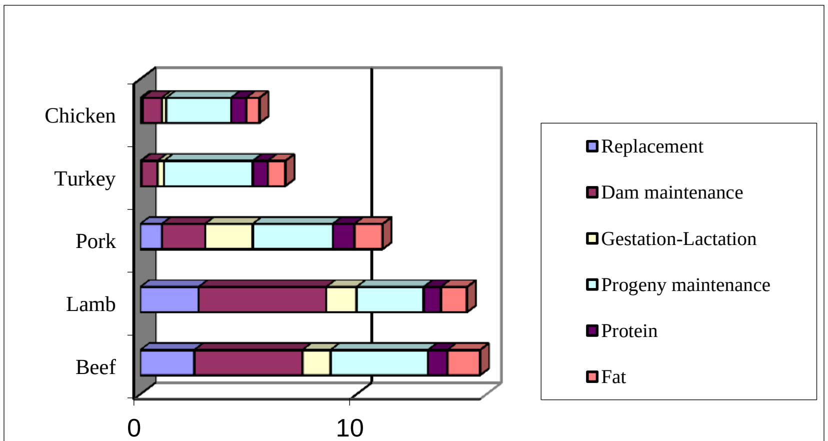


Animal Improvement Programs Laboratory

beef because of the variety of ways that beef is finished. The projections seem somewhat reasonable for milk production per cow per year and the commercial pork industry has easily exceeded these projections for pigs/sow/year (National Hog Farmer, 2011). In fact, the 1990 base point for this measure of productivity was probably too low. The dairy industry has certainly achieved an enviable record in improvement of milk production although it has been at a cost in reproductive performance.

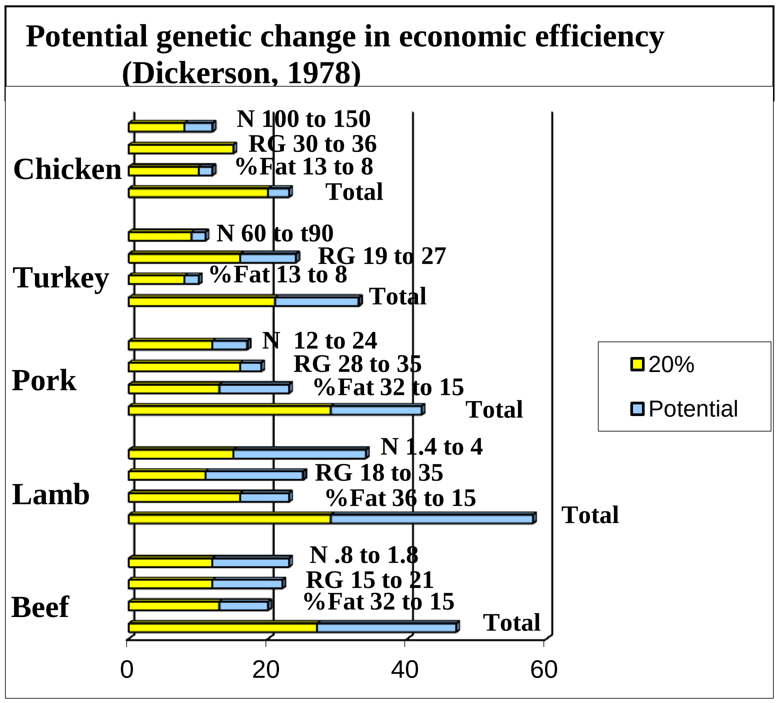
The question before us here is whether the beef industry is making full use of the available technology. When asked "what are beef producers breeding for?" at the 1995 Feed Intake Symposium, Dr. Gordon Dickerson replied "for fun!" This tongue-in-cheek response was Gordon's way of telling beef producers that not all of their genetic decisions have always made sense. Harlan Ritchie put together a nice set of information illustrating changes in cattle type across the 20th Century (https://www.msu.edu/~ritchieh/historical/cattletype.html). The meanderings through the short, dumpy cattle of the 1940s-1950s and the changeover to larger-framed cattle, which reached its apex (literally and figuratively) in the 1980s have illustrated that efficiency of production has not always been the central focus of genetic improvement in the beef industry. The Beef Improvement Federation has been at the forefront of genetic improvement for more than 40 years. There have been, of course, tremendous gains in understanding of management of beef cattle as well but the focus of this discussion will be on genetic improvement.

Dr. Dickerson provided some guidance about bioeconomic objective 35 years ago (Dickerson, 1978). He pointed out one of the difficulties in establishing goals for genetic improvement in beef cattle: the costs are spread out over several different phases of production with about half of the costs being associated with the cow herd while the other half are associated with the animal which is going to be used for meat. This division of costs is quite different from the pork industry and extremely different from the poultry industry. Historically, much of the selection emphasis, through the show ring and other aspects of visual appraisal as well as during the early phases of the use of performance information, have probably placed considerable emphasis on traits associated with output and less attention was placed on the costs of production.

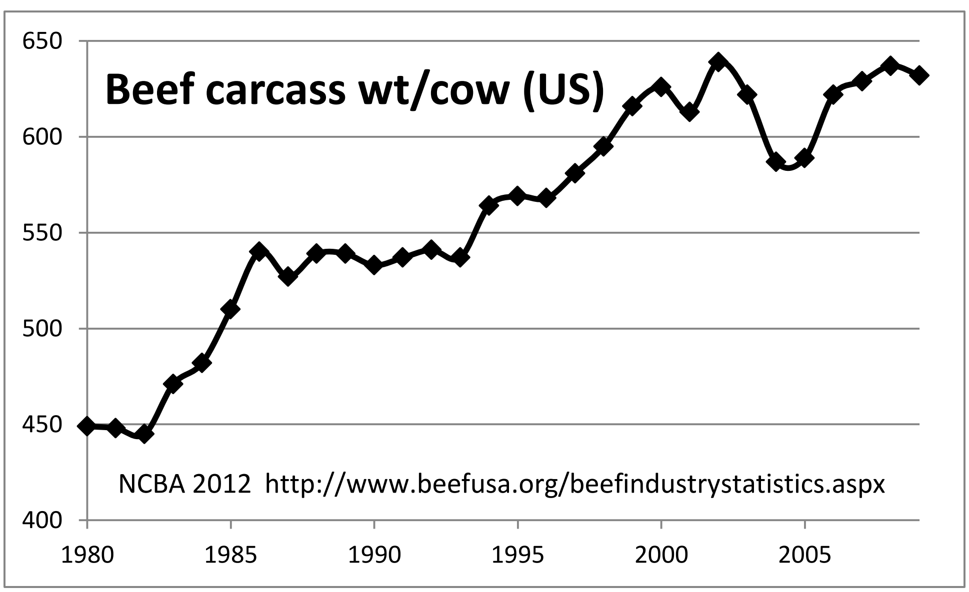


Life cycle cost/kg of edible protein (Dickerson, 1978)

Dr. Dickerson went on to assess the future of the various industries. He projected what would happen to the economic efficiency of the various industries if certain genetic improvements were made. He examined the effects of 20% increases in reproductive rate, and relative growth rate (a measure of efficiency) and a 20% decrease in carcass fat. He further projected amounts of genetic change which he felt were possible with future optimistic advances in technology. For the beef industry, this included an increase in reproductive performance which would include twinning. This is a topic which frequently causes a reaction from beef producers because twin calves are usually viewed as a problem, rather than as an opportunity. When students react negatively to the idea that we might incorporate twinning into beef production, I ask a simple question: "If we could figure out a way for almost all of the cows to have twins, would be build a production system that could take advantage of it?" The answer to that question is, obviously "Yes".



The encouraging thing to note in this graph is that the opportunity for improvement in economic efficiency of beef production in considerable. The disheartening thing to note is that the pork, turkey and chicken industries have, since 1978, met or surpassed the projected improvements proposed by Dr. Dickerson. Genetic improvement in beef production is, to be sure, more time consuming because the lower rate of reproduction and the longer time from conception to production of a carcass which combine to form a



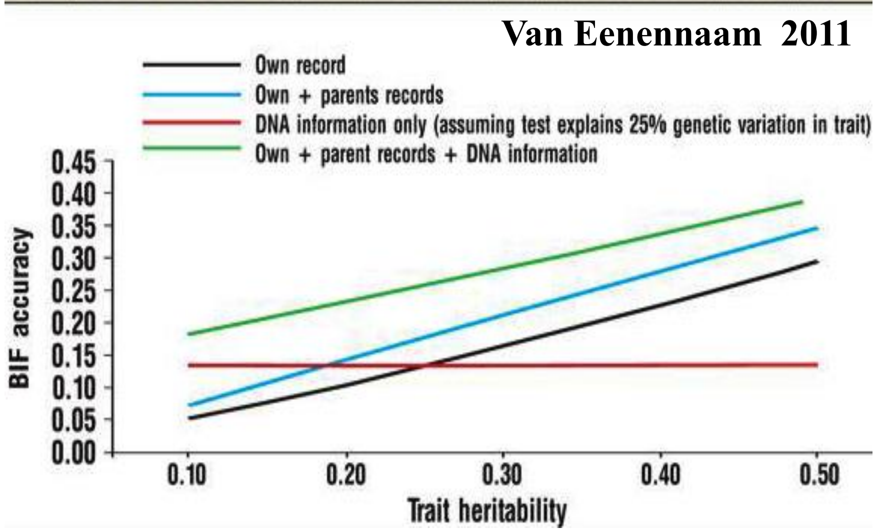
much longer generation interval. However, we must also honestly assess whether we have been doing all that we can do to generate genetic improvement.

Although it is an imperfect means of evaluating progress in the beef industry, the accompanying graph illustrates the pounds of carcass beef per cow in the national beef herd (November 2012). This would reflect change due to both genetics and management since 1980. The genetic component of this change is partially illustrated with the genetic trend values for the traits that are included in the respective genetic evaluation programs of the various breed associations. The changes that have been accomplished during the period in which EPDs have been available have been quite impressive. The degree of change for various traits differs widely among breeds. Some common themes emerge. Size has been emphasized in many breeds, with the exception of some breeds which were already quite large. Several breeds experienced an increase in birth weight, and accompanying increase in calving difficulty for a period of time but there appears to have been a point at which many breeds decided to place some emphasis on improving calving ease and that has been accomplished. Genetic merit for milk production and scrotal circumference has generally increased. Marbling has shown genetic improvement. Interestingly, a breed that has shown above average improvement in marbling is the breed with an already high reputation for marbling: the Angus. Improvements in fatness and muscling have not been uniform across breeds. Although the changes have been impressive and we must keep in mind the complexities associated with the contributions of the various phases of production when evaluating genetic improvement, it is safe to say that we cannot hang our hat on an aspect of genetic change which would be comparable to the tripling of corn yield in the past 50 years. Some of the reasons for the lower rate of genetic improvement are obvious. We are working with a species which reproduces slowly, is part of a very complex system of production in which the animals change ownership multiple times in their life and where the costs of production are highly diversified and are not all incurred by the owner which sells the animal for slaughter. However, we might be wise to heed the warning of Dr. Dickerson. Are we still breeding "for fun"?

It is very encouraging that several breed associations have adopted index or "$ value" EPDs which combine information from various traits. This has several virtues as we move forward. It emphasizes the idea that economic considerations must be included into selection decisions. It also spreads out the selection intensity among several traits which should reduce the likelihood of the emphasis on extremes which have plagued us in the past. It is interesting to note, however, that the genetic trend for the traits associated with $EN (Cow energy) in the Angus breed are in a direction which would suggest that many of the bulls with high $EN values would be older bulls. Indeed, a search of the top end bulls for $EN reveals that only 7 out of the top 26 bulls for $EN were born during the 21st Century. However, the presence of such a tool, including further refinements, and consideration of traits like heifer pregnancy, stayability and calving ease, should enable beef producers to pay additional attention to genetic improvement in the contributors to cost of production in the cow herd.

The beef industry is rapidly moving forward in its evaluation of the use of various molecular biology tools to enhance genetic change. Genomic enhanced EPDs have been introduced. This has tremendous promise for enhancing the accuracy of genetic evaluation (Van Eenennaam, 2011). Rates of genetic improvement should increase when this technology is more fully understood and implemented. We do need to continue to be mindful of Dr. Dickerson's admonitions. Better accuracy associated with genetic prediction is only helpful if we are making decisions which are in line with reasonable production objectives. The industry has demonstrated in the past that it can go too far in pursuit of some genetic improvement goals. More accurate evaluations will only mean that we can go too far more quickly unless proper objectives are established. However, I am optimistic that the changes of the past 30 years have made it more likely that the industry will pursue appropriate goals. The array of traits under consideration is much more broad-based. It includes traits associated with growth, efficiency, maternal ability, reproductive performance and carcass merit. The industry has embraced the concept of the selection index through the various $Value EPDs that have been developed by some breeds. The efforts of the Beef Improvement Federation, and many other organizations, have been a source of education and encouragement for the industry to pursue comprehensive selection objectives.

Figure 1. Effect of DNA information on Beef Improvement Federation (BIF) accuracy of EPDs given different sources of information and trait heritability



New tools for genetic improvement, as well as many management tools, have the potential for raising questions about the societal assessment of various technologies. The beef industry is already under attack for the use of hormonal implants and antibiotics in the feed. It is conceivable that genetic tools will be developed which also generate concerns among consumers. The Aqua-Advantage Salmon (http://www.aquabounty.com/) is a genetically engineered fish with greatly enhanced growth rate. It is under consideration by the FDA for approval to be a part of the food supply. It is also being criticized by many in the anti-GMO movement (http://www.fooddemocracynow.org/). It remains to be seen whether the beef industry will move in a similar technological direction.

We only have to look at our colleagues in the dairy industry to see a technology which is demonstrably safe but is very limited in its use because of consumer concerns. Recombinant DNA derived bovine somatotropin has been available for nearly 20 years but many food companies have adopted practices which have served to diminish its application in the dairy industry (http://news.walmart.com/news-archive/2008/03/24/wal-mart-offers-private-label-milk-produced-without-artificial-growth-hormone).

Failure to use technological advances exerts a cost. The cost is obvious for the producer who lags behind and loses a competitive edge compared with other producers. The cost is, perhaps, less obvious but no less real for an industry which fails to take advantage of technology while competing industries make more rapid improvement in production efficiency. Limitations on use of technology include failure to invest in the necessary research to develop new technology, failure to use the available technology and the prevention of the use of technology due to consumer concerns which may, or may not, have a basis in good science. One might say that the beef industry is “at a crossroads”. However, I have been hearing that the beef industry is “at a crossroads” for all of my adult life. So, in lieu of that, I will just conclude by saying that the beef industry has made good use of technological advances, but it could have been better. I am optimistic that, in the future, it will be better.

Literature Cited

Dickerson, G. E. 1978. *Animal size and efficiency: basic concepts.* Animal Production 27:367-379.

Dickerson. G. E. 1995. *Selecting for optimum feed intake and efficiency.* Feed Intake Symposium. http://beefextension.com/proceedings/feed_intake86/feed_intake86_33.pdf. (accessed 5-15-2013)

Food and Agriculture Organization. 2011. World Livestock 2011: Livestock in food security.

Fuglie, K. O. and P. W. Heisey. 2007. *Economic returns to publish agricultural research.* USDA-ERS. Economic Brief Number 10.

Iowa State University. 2009. Chartbook Iowa State University.http://www2.econ.iastate.edu/outreach/agriculture/periodicals/chartbook/Chartbook2/Tables/Table10.pdf (accessed 5-15-2013).

Animal Improvement Programs Laboratory. http://www.aipl.arsusda.gov/ (accessed 5-15-2013)

National Hog Farmer. 2011. *Understanding the Physiology of 20+ pigs/sow/year.* National Hog Farmer October 2011.

NCBA. 2012. *Beef Industry Statistics – 2012.* http://www.beefusa.org/beefindustrystatistics.aspx (accessed 5-15-2013)

Office of Technology Assessment. 1992. A new technological era for American Agriculture. OTA-F-474.

PCAST. 2012. *Report to the President on agricultural preparedness and the agriculture research enterprise.* President's Council of Advisors on Science and Technology December 2012.

United Nations. 2011. *World Population Prospects: the 2010 Revision.* Economics and Social Affairs. United Nations.

Van Eenennaam, A. 2011. *Combining EPD Info with DNA test results improves genetic prediction accuracy.* Beef February 2011.

MANAGEMENT PRACTICES OF DEVELOPING HEIFERS AFFECTS LIFETIME PRODUCTIVITY

Dr. Jack C Whittier[1]

[1]*Colorado State University*

Introduction

The manner in which replacement heifers are managed during development has an impact on their lifetime productivity. Because beef production occurs across a wide range of environments and under many different production objectives, it is important for this presentation to focus on management practices that are somewhat "environment neutral". Therefore, I will focus primarily on fundamental principles related to heifer management and approaches that have proven beneficial under many different scenarios.

Heifer Management to Produce Early Calving Cows

As a boy, I recall my dad saying "Once an early calver, always an early calver". While Dad may have been exaggerating when he used the word "always", this fundamental principle has stuck with me and I accept it as a truism.

Principles from the 1950s and 60s in Montana (Lesmeister et al., 1973)

An oft quoted study, to document the relationship of relative date of first calving compared to herd mates and subsequent calf production, was published in Journal of Animal Science in 1973 – forty years ago – by Lesmeister, Burfening and Blackwell (Lesmeister et al., 1973). I quote the summary from that article:

> *"A study was made of the effect of relative first calving date in beef heifers on lifetime production using production records from two beef herds[Bozeman and Havre, Montana]. The study involved 2036 spring calves [born] from 481 cows weaned in October or November of each year. An initial calving group was determined for each heifer based on the relative birth date of her first calf. A subsequent calving group was similarly assigned to each additional calf from the same cow. Heifers calving initially in the early, first and second groups tended to calve earlier throughout the remainder of their productive lives than heifers calving initially in later groups. However, repeatability estimates for calving group in the two herds were 0.092 and 0.105 indicating that only moderate improvement might be made by culling cows that calve late during the normal calving season. Calves born in earlier groups grew significantly faster from birth to weaning and weighed more at weaning than calves born in later groups. Lifetime production was significantly affected by initial calving group. Early calving heifers had higher average annual lifetime calf production than late calving heifers. This study indicates the importance of managing and breeding heifers so they will calve early in the season and thus tend to maintain early calving throughout their*

productive lives. Such management should contribute profit in the cow-calf operation." (Lesmeister et al., 1973)

As mentioned, this study is frequently quoted since it describes and documents the benefits of managing heifers to calve in the first 21 days of their first calving season. Let's explore a few of the fundamental management principles that can be gleaned from this study and apply them to current opportunities in heifer development.

Principle #1 (Lesmeister) – Heifers that conceive early as yearlings during their first breeding season appear to be "programmed" for productive lives. The summary paragraph of this article demonstrates the wisdom of the authors in setting the stage for many of the management practices used in the beef industry currently. Today, the term "programmed" is frequently used in connection with "fetal programming", or the impact that the maternal environment plays on the performance of the individual throughout its life. The author's use of the term "programmed" did not encompass today's fetal programming meaning, but it is insightful that even in 1973 it was suggested that preparing heifers for early calving by nutrition and selection was a recommended practice. Here is a portion of the concluding paragraph:

"[T]hese data indicate the importance of managing first-calf heifers for early calving in the optimum season in herds with a limited breeding season and a definite time of weaning. A larger proportion of replacement heifers than needed should be bred, pregnancy tested and culled at the end of the breeding period if they are open. The heifers that conceive and calve the earliest immediately indicate their greater reproductive efficiency and lifetime potential. They should be given some preference in selection. The proper application of selection for rapid growth and early sexual maturity in yearling beef heifers and adequate nutritional regime are essential for "programming" beef cows for early, regular calving throughout their productive lives." (Lesmeister et al., 1973)

Principle #2 (Lesmeister) – Early-born calves performed better than later-born calves. The Lesmeister study was done with spring-calving cows in native range grazing environments near Bozeman and Havre, Montana (MT). The breeding season at Havre began approximately June 15 each year of the study and lasted for 60 days. The length of the breeding season at Bozeman ranged from 10 to 133 days. Weaning occurred each year in October and November across the 19 years at Bozeman and 15 years at Havre that were studied. The reported results for calf performance were:

"The calving group [early, mid or late] for a particular calf had a highly significant (P< .01) effect on its performance from birth to weaning. Calves born earlier in the normal season weighed more at weaning than later calves due to their older age and their faster rate of pre-weaning gain." (Lesmeister et al., 1973)

Calf survival from birth to weaning at Havre was also enhanced if calves were born early in the calving season.

"Calving group significantly (P<.01) affected the percent of calves surviving from birth to weaning in the Havre herd but not in the Bozeman herd. The percent survival declined continually for each 21 days later that calves were born during the calving season at Havre." (Lesmeister et al., 1973)

Higher survival rate and greater weaning weights combined to improve the lifetime productivity of the cows. The authors emphasized this outcome when they stated:

"One of the most important findings of this study was the fact that cows calving early the first time produce more kilograms of calf (P<.01) in their lifetime than cows calving later the first time… Most of the difference in average annual lifetime production was associated with increased production at the first calving." (Lesmeister et al., 1973)

Principle #3 (Lesmeister) – Release of dominance expressed as heterosis in reproductive traits is real. The cow records in this study were collected during the 1950's and 1960's and included purebred Angus and Hereford cows in Bozeman and four different closed lines and one crossline of Herefords at Havre. The Havre crossline Hereford cows (line 5) resulted from mating line 1 cows with line 4 cows to evaluate the release of linebreeding dominance. The results of this crossing were:

"…cow line…significantly (P<.01) affected birth weight, weaning weight and ADG of calves…There was a consistent and statistically significant difference among the cow lines at Havre for all of the production traits analyzed. The crossline cows [line 5] consistently showed better performance than the straight line cows and earlier initial calving groups than the mean of straight line cows. The calves had heavier birth weights, heavier weaning weights, older weaning ages and higher average daily gains than the straight line calves. Inbreeding depression and heterosis were evident." (Lesmeister et al., 1973)

As noted, this study dealt with straightbred cows and cows of the same breed (Hereford) in a cross with selected lines. Numerous additional studies have clearly shown heterosis for reproductive traits when breeds are crossed. For example, Cundiff (Cundiff, 1970) reported the results of projects conducted by W-1, NC-1 and S-10 animal breeding regional committees. The reported conclusions from this report (Cundiff, 1970) identify the advantages of heterosis on reproductive traits as follows:

"…the major benefit will be accrued through the cumulative effects of heterosis on fertility, maternal ability and growth rate. It appears conservative to conclude that production per cow exposed for breeding can be increased 20 to 25 % by systematic crossing of British breeds. About half of this advantage is dependent upon the use of crossbred cows to take advantage of heterosis for maternal ability and reproduction."(Cundiff, 1970)

The advantage in herd survival rate to 12 years of age and longevity for crossbred cows compared to straightbred cows was reported by Núñez-Dominguez et al. (1991) from the population of Angus, Hereford and Shorthorn first-cross cows in the animal breeding regional projects described above by Cundiff (1970). Núñez-Dominguez et al. (1991) concluded:

> *"Survival of cows is an important component of lifetime productivity measured as the total calf weight weaned per initial replacement female. Longevity is an equivalent measure of cumulative survival at some final age. In either trait, performance of crossbreds was higher than that of straightbred cows. Thus, crossbreds needed fewer replacements than straightbreds and had a lower culling rate at any age." (Núñez-Dominguez et al., 1991)*

Effect of Calving Distribution on Progeny Performance

The objectives of the Lesmeister paper published in 1973 from cows in the 50s and 60s discussed above were investigated recently in a paper by Rick Funston and co-workers (Funston, et at., 2012) in cows in Nebraska. The Funston paper reported on records from 1997 to 2010 for steer and heifer progeny from composite cows (Red Angus x Simmental) at the Gudmundsen Sandhills Laboratory, Whitman, Nebraska (NE). These two studies report on different environments (MT vs. NE), different breed-types (straightbred AN and HH vs. crossbred), and across a 40 to 50 year difference in time. Funston and co-workers also collected more detailed information, including feedlot and carcass characteristics of steer progeny and reproductive traits of heifer progeny, than Lesmeister and co-workers. This is expected with advances in sophistication of research approaches over the past 40 years since 1973. However, the outcomes of the importance of cows calving early in the calving season are very similar.

Principles from the 1990s and 2000s in Nebraska (Funston, et at., 2012)

In the introduction of the Funston paper (Funston, et at., 2012) the authors review additional advantages seen in other research reports as related to retention of cows in the herd and the influence of preweaning growth on puberty.

> *"Calving date can also influence the number of cows calving the next year. Cows that calved late 1 yr tended to calve late or not calve the next year (Burris and Priode, 1958; Kill et al., 2012). In a review by Patterson et al. (1992), data are cited from the 1950s to early 1980s, indicating preweaning growth exerts a greater influence on puberty than postweaning growth." (Funston, et al., 2012)*

Principle #4 (Funston) – Heifers born early in relation to herdmates, increases the likelihood that they will conceive early in their first breeding season. Funston and co-workers followed the heifer progeny through development and their first breeding and calving seasons.

> *"Percentage of heifers cycling at the beginning of the breeding season decreased ($P < 0.01$) with advancing calving date (70, 58, and 39%, respectively) and 45 d pregnancy rates were*

lowest (P = 0.02) for heifers born in the third calving period (90, 86, and 78%, respectively)." (Funston, et al., 2012)

Dunn and Kaltenbach (1980) point out that females conceiving early in the breeding season result in increased postpartum recovery period the following year, thus increasing the probability of early conception again.

Principle #5 (Funston) – Early-born heifers tend to have early calves themselves. It is interesting, though not surprising, that heifers born as first calf progeny tended ($P \leq 0.10$) to have the greatest weaning weight if they were born to a heifer that was born in the first calving period. Thus, there was a generational advantage for early calvers.

"…more (P < 0.01) calves were born in the first 21 d of the calving season if the heifer herself was born in the first calving period." (Funston, et al., 2012)

Principle #6 (Funston) – Steer progeny from early calving cows produce higher value carcasses than late calving cows. The Funston study reported that steer progeny also displayed an advantage if they were born during the early portion of the calving season when compared with later born steer progeny.

"Carcasses of earlier born steers were more valuable on a [body weight] basis and received a greater premium on a carcass basis than later born steers." (Funston, et al., 2012)

A summary of the results reported in the Nebraska study is explained in the implications section of the Funston article as follows:

"Heifer calves born during the first 21 d of the spring calving season had greater weaning, prebreeding, and precalving [body weight]; greater percent cycling before breeding; and greater pregnancy rates compared with heifers born in the third calving period. First calf progeny from heifers born in the first 21 d of the calving period also had an earlier birth date and greater weaning [body weight]. Calving period of heifer progeny significantly impacts development and first calf characteristics. Steer calves born earlier in the calving season have greater weaning [body weight], [hot carcass weight], and marbling scores. Increasing early calving frequency may increase progeny value at weaning and enhance carcass value of the steers. Managing groups of heifer and steer progeny by calving date may allow for more efficient use of resources and optimize reproductive performance of heifer calves and feedlot performance of steer calves." *(Funston, et al., 2012)*

Lifetime productivity has been shown to be greater in heifers managed so they calve early their first calving. This results from both older and faster growing calves that are born early relative to later-born herdmates. Advantages of early-born calves are perpetuated by greater pregnancy rates at first mating in early-born heifers and greater carcass value in early-born steer calves.

Differences in Lifetime Productivity of Heifers Conceived by AI or Natural Service

A study done by Colorado State University and recently published (French et al., 2013) evaluated 6,693 records from 1,173 females at the CSU John E. Rouse Beef Improvement Center **(BIC)** located in Saratoga, WY. The objectives of the study were: 1) determine the effect of conception to AI or natural service **(NS)** as yearlings on lifetime productivity, and 2) compare lifetime productivity among females that were the offspring of an AI or NS sire.

In herds that use AI, such as BIC, it is a standard practice to conduct AI at the beginning of the breeding season, and follow later with clean-up bulls for natural mating. Therefore, the opportunity for NS sires to produce early born calves is compromised under these circumstances. It is also quite common for heifers to be synchronized for estrus in some manner when AI is part of the ranch management practice. This practice will also skew the data for AI toward the early part of the calving season compared to non-synchronized breeding with either AI or NS. Since both of these practices were used at BIC in the data reported by French et al. (2013) we must recognize that the results likely contain a bias toward AI.

As further explanation of the CSU study, each year yearling heifers were inseminated 3 to 4 weeks before the cows. This is also a common industry management practice. As a result of this practice the production records from the dams at BIC were classified into 4 different categories: 1) heifers that conceived to AI **(H-AI)**, 2) heifers that conceived to NS **(H-NS)**, 3) cows that conceived to AI **(C-AI)** and 4) cows that conceived to NS **(C-NS).** This delineation was made to isolate the effect of the parity of the dam of a female on its lifetime productivity. In addition, due to the genetic objectives at BIC related to investigation of high-elevation (brisket) disease, the same sires used for AI were used for NS with the heifers; different AI and NS sires were used with the cows.

Lifetime revenue from females in the CSU study was estimated using the sum of the weaned calf value for all calves produced by these females. Calf value was computed based on local auction market prices over the period from 1991 to 2010. These estimates reflected varied prices for various weight and sex classes. Using this approach, it was possible to compute lifetime revenue for each female category of females (H-AI, H-NS, C-AI, and C-NS) as classified above.

The overall purpose of the present paper is to discuss the effect of management practices of developing heifers on lifetime productivity. There are some additional principles that can be drawn from the CSU study (French et al., 2013) to add to the work of Lesmeister and Funston already discussed.

Principle #7 (French) – Yearling heifers that respond to estrus synchronization and conceive early to AI produce greater lifetime revenue than heifers that conceive to natural service. When Lesmeister et al. (1973) published their study on cow records from the 1950s and 1960s, estrus synchronization was not done, other than experimentally. Therefore, as Lesmeister and co-workers point out in their publication, “All cows could not be expected to be in estrus the first day of the breeding season due to the length of the estrous cycle." With advances in estrous cycle management over the intervening 50 years, it is common, especially in heifers, for a high percentage of synchronized females to be in estrus on the first day of the breeding season. The majority of females that are not in estrus in synchronized herds are not cycling – either due to being non-pubertal or anestrus cows. In cows, anestrus likely results from short postpartum intervals at the beginning of the breeding season in later calving cows.

> *"Females that conceived to AI as a yearling were older and heavier (P = 0.02) at the time of AI than were females that conceived to a clean-up bull via NS. Females that conceived to AI as a yearling also had greater (P = 0.04) average weaning weight for calves produced during their lifetime and weaned more (P < 0.0001) weight and more (P < 0.0001) total calves throughout their lifetime than did females that conceived to NS as a yearling [Table 1]." (French et al., 2013)*

Table 1. Measures of heifer's own performance and summarized performance of its calves among females that conceived at AI or natural service (NS) as yearlings.

	Performance of heifer				Performance of progeny		
Conception Classification	n	Age of heifer at 1st AI (d)	PPI[1] (d)	Lifetime revenue[2] ($, actual price basis)	n	Lifetime weight weaned (lb)	Lifetime calves weaned
Conceived to AI	871	429[a]	92	$2,483	4,530	2,363[a]	5.2[a]
Conceived to NS	302	418[b]	87	$1,561	909	1,398[b]	3.0[b]
Difference		11	5	$922		965	2.2

[a,b] Means within a column without a common superscript differ ($P < 0.05$).
[1] PPI = postpartum interval; defined as the number of days between the calving date of the female and the subsequent date of AI. This number is the average PPI across all years that the female was in the herd.
[2] Lifetime revenue produced per female was calculated using prices from Torrington Livestock Market LLC (Torrington, WY) from 1991 to 2010. See original manuscript for further explanation of how this was calculated.

The use of AI in beef herds allows use of proven sires with documented genetic merit. Lamberson et al. (1993) stated that AI offers the advantage of making available many sires with outstanding genetic merit, a situation that would not be economical for most commercial producers for use in NS. As noted above, heifers at BIC were mated to the same sires AI and NS, therefore, some of the potential advantages of AI compared to NS are not fully reflected in the article by French et al. (2013). As further explanation why this was done at BIC, the authors state:

> *"One of the goals of the BIC was to produce seedstock Angus bulls specifically adapted to high-altitude environments. Because of this, ranch management inseminated heifers to bulls produced by the ranch and then used these same bulls via NS on their females. This facilitated genetic improvement of the herd while also using sires that could perform in*

the environment. This decision to AI heifers to the same bulls used for NS is noteworthy because it reduced some of the benefit of using elite genetics through AI but also reduced the risk of introducing genetics that were not adapted to the high-altitude environment. The average weaning weight of calves from females conceiving to AI may have been greater if outside sires with improved genetics for growth had been used (Ellis, 2005) but also would have increased the risk of mortality in offspring associated with nonadapted genetics." (French et al., 2013)

However, the advantage of females conceiving to AI was demonstrated indirectly due to earlier conception in both females that conceived to AI and those sired by AI when compared to NS (Table 2.) This table reports the female's response, based on the dam classification, based on age of dam and whether progeny resulted from AI or NS.

Table 2. Measures of female's own performance and performance of calves by dam classification.

	Performance of female				Performance of progeny		
Dam Classification[1]	n	Age of heifer at 1st AI (d)	PPI[2] (d)	Lifetime revenue[3] ($, actual price basis)	n	Lifetime weight weaned (lb)	Lifetime calves weaned
H-AI	195	450[a]	88	$2,223	926	2,147	4.6
H-NS	40	421[b]	88	$1,949	175	1,918	4.2
C-AI	618	427[b]	87	$2,253	2,928	2,129	4.7
C-NS	320	403[c]	84	$2,313	1,454	2,180	4.7

[a,b,c,d] Means within a column without a common superscript differ ($P < 0.05$).
[1] H-AI = female born to a primiparous heifer and the offspring of an AI mating; H-NS = female born to a primiparous heifer and the offspring of a natural service (NS) mating; C-AI = female born to a multiparous cow and the offspring of an AI mating; C-NS = female born to a multiparous cow and the offspring of an NS mating.
[2] PPI = postpartum interval; defined as the number of days between the calving date of the female and the subsequent date of AI. This number is the average PPI across all years that the female was in the herd.
[3] Lifetime revenue produced per female was calculated using prices from Torrington Livestock Market LLC (Torrington, WY) from 1991 to 2010. See original manuscript for further explanation of how this was calculated.

French et al. (2013) summarized the results of their study in the implications section of their paper as follows:

"Replacement females that conceive earlier in the breeding season, accomplished via the use of estrus synchronization and AI, have increased longevity. Furthermore, estrus synchronization with AI can be an effective management tool to produce replacements that are older at breeding, become pregnant early in the breeding season, and have the potential to consist of superior genetics." (French et al., 2013)

Summary

The primary focus of this paper has been on the benefits of managing heifers to conceive early in their first breeding season. This practice produces cows that have greater lifetime productivity due to more growing days of their progeny before a set weaning date, which results in greater weight weaned. It also provides for longer postpartum intervals to prepare for the subsequent breeding season, therefore increasing the probability of conception early in the breeding season to facilitate early calving the next calving season. Combined, these factors result in greater lifetime productivity of heifers that calve early relative to herdmates.

The use of estrus synchronization and accompanying AI are tools available to increase lifetime productivity and facilitate earlier calving.

Over the past several years, the traditional practice of developing replacement heifers to a target weight of 65% of expected mature weight has been questioned. Funston and Deutscher (2004) and Funston et al. (2011) reported that prebreeding rate of gain has minimal effect on heifer pregnancy rate. This has led to changes in management by some producers in an attempt to reduce input costs for heifer development while not compromising reproductive performance.

Approaches such as developing heifers at a rate of gain and target weight at first breeding lower than traditionally used (55 vs. 65% of mature weight) appear to be a viable practice for heifers with improved genetic merit for growth and reproduction available in today's beef industry. In addition, exposing a higher number of heifers during a short breeding season and retaining pregnant heifers into the herd will serve to improve the lifetime productivity of heifers.

The principles outlined in this paper will allow producers to identify heifers that match the production environment and contribute to having early calving cows in the herd.

References:

Burris, M. J., and B. M. Priode. 1958. *Effect of calving date on subsequent calving performance.* J. Anim. Sci. 17:527–533.

Cundiff, L. V. 1970. *Experimental results on crossbreeding cattle for beef production.* J. Anim. Sci. 30:694–705.

Dunn, T. G., and C. C. Kaltenbach. 1980. *Nutrition and the postpartum interval of the ewe, sow and cow.* J. Anim. Sci. 51(Suppl. 2):29. (Abstr.)

Funston, R.N., J.A. Musgrave, T.L. Meyer and D.M. Larson. 2012. *Effect of calving distribution on beef cattle progeny performance.* J. Anim. Sci. 90:5118-5121.

Funston, R. N., and G. H. Deutscher. 2004. *Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance.* J. Anim. Sci. 82:3094–3099.

Funston, R. N., J. A. Musgrave, T. L. Meyer, and D. M. Larson. 2011. *Effect of calving period on ADG, reproduction, and first calf characteristics of heifer progeny.* Proc. West. Sect. Am. Soc. Anim. Sci. 62:231–233.

Ellis, W. 2005. Beef artificial insemination economics. J. Anim. Sci. 83(Suppl. 1):332. (Abstr.).

Kill, L. K., E. M. Mousel, R. A. Cushman, and G. A. Perry. 2012. *Effect of heifer calving date on longevity and lifetime productivity.* J. Anim. Sci. 95 (Suppl. 1):131.

Lamberson, B., J. Massey and J.C. Whittier. 1993. *Crossbreeding Systems for Small Herds of Beef Cattle*. University of Missouri Department of Animal Sciences Extension Factsheet G2040. http://extension.missouri.edu/p/G2040. Accessed May 18, 2013.

Lesmeister, J.L., P.J. Burfening and R.L. Blackwell. 1973. *Date of first calving in beef cows and subsequent calf production.* J. Anim. Sci. 36:1-6.

Núñez-Dominguez, R., L.V. Cundiff, G.E Dickerson, K.E. Gregory and R.M. Koch. 1991. *Heterosis for survival and dentition in Hereford, Angus, Shorthorn, and crossbred cows*. J Anim Sci 69:1885-1898.

Patterson, D. J., R. C. Perry, G. H. Kiracofe, R. A. Bellows, R. B. Staigmiller, and L. R. Corah. 1992. *Management considerations in heifer development and puberty.* J. Anim. Sci. 70:4018–4035.

FRANK H. BAKER

Born: May 2, 1923, Stroud, Oklahoma

Died: February 15, 1993, Little Rock, Arkansas

Frank H. Baker

Photograph of portrait in Saddle and Sirloin Club

Gallery – Everett Raymond Kinstler, Artist

Dr. Frank Baker is widely recognized as the “Founding Father” of the Beef Improvement Federation (BIF). Frank played a key leadership role in helping establish BIF in 1968, while he was Animal Science Department Chairman at the University of Nebraska, Lincoln, 1966-74. The Frank Baker Memorial Scholarship Award Essay competition for graduate students provides an opportunity to recognize outstanding student research and competitive writing in honor of Dr. Baker.

Frank H. Baker was born May 2, 1923, at Stroud, Oklahoma, and was reared on a farm in northeastern Oklahoma. He received his B.S. degree, with distinction, in Animal Husbandry from Oklahoma State University (OSU) in 1947, after 2½ years of military service with the US Army as a paratrooper in Europe, for which he was awarded the Purple Heart. After serving three years as county extension agent and veterans agriculture instructor in Oklahoma, Frank returned to OSU to complete his M.S. and Ph.D. degrees in Animal Nutrition.

Frank’s professional positions included teaching and research positions at Kansas State University, 1953-55; the University of Kentucky, 1955-58; Extension Livestock Specialist at OSU, 1958-62; and Extension Animal Science Programs Coordinator, USDA, Washington, D.C., 1962-66. Frank left Nebraska in 1974 to become Dean of Agriculture at Oklahoma State University, a position he held until 1979, when he began service as International Agricultural Programs Officer and Professor of Animal Science at OSU. Frank joined Winrock International, Morrilton, Arkansas, in 1981, as Senior Program Officer and Director of the International Stockmen’s School, where he remained until his retirement.

Frank served on advisory committees for Angus, Hereford, and Polled Hereford beef breed associations, the National Cattlemen’s Association, Performance Registry International, and the Livestock Conservation, Inc. His service and leadership to the American Society of Animal Science (ASAS) included many committees, election as vice-president and as president, 1973-74. Frank was elected an ASAS Honorary Fellow in 1977, he was a Fellow of the American Association for the Advancement of Science, and served the Council for Agricultural Science and Technology (CAST) as president in 1979. Frank Baker received many awards in his career, crowned by having his portrait hung in the Saddle and Sirloin Club Gallery at the International Livestock Exposition, Louisville, Kentucky, on November 16, 1986. His ability as a statesman and diplomat for the livestock industry was to use his vision to call forth the collective best from all those around him. Frank was a “mover and shaker” who was skillful in turning “Ideas into Action” in the beef cattle performance movement. His unique leadership abilities earned him great respect among breeders and scientists alike. Frank died February 15, 1993, in Little Rock, Arkansas.

GENETICS OF UDDER QUALITY IN BEEF CATTLE

Heather Bradford

Kansas State University

Introduction

Beef production is a billion dollar industry in the United States (USDA, 2012). With increasing cost of production, producers are faced with the challenge of reducing costs to remain profitable and efficient. Seedstock producers are responsible for the genetics that are used in the commercial segment for beef production. Thus, seedstock producers have many economically important traits to consider in their selection program. One potential trait for producers to consider is udder quality because better udder quality reduces labor costs and increases cow longevity (Wythe, 1970; Frisch, 1982).

Review of Literature

Importance of Udder Quality

Newborn calves need to nurse unassisted, particularly in range conditions where assisting those calves may not be feasible. Dam udder type is one factor that affects the calf's ability to nurse. Calves had difficulty nursing when the dams have poor udder attachment or teat sizes of either extreme (Wythe, 1970; Edwards, 1982; Ventorp and Michanek, 1992). Poor udder quality resulted in delayed consumption of colostrum, which was important for immunity. Therefore, calf mortality rates were higher when dams had large teats and pendulous udder suspension (Frisch, 1982). Thus, improving udder quality can be beneficial to producers through reducing the amount of labor associated with assisting calves to nurse and increasing the number of calves weaned per cow, an important measure of efficiency.

Mastitis involves an inflammation of the mammary gland resulting from bacteria. Infection rates in beef cows ranged from less than 10% to upwards of 66% (Haggard et al., 1983; Watts et al., 1986; Simpson et al., 1995; Paape et al., 2000; Dueñas et al., 2001; Lents et al., 2002). Cows with poor udder attachment were at a greater risk of developing mastitis because the udder came into contact with more fecal matter and bacteria (DeGroot et al., 2002; Rupp and Boichard, 2003). Infected cows then weaned lighter calves, reducing the pounds of sale weight at weaning (Watts et al., 1986; Newman et al., 1991; Paape et al., 2000). Mastitis can cause blind, unproductive quarters. Cows with at least one blind quarter weaned light weight calves due to the reduction in milk production (Dueñas et al., 2001; Lents et al., 2002). Improving udder attachment decreased the prevalence of mastitis and helped prevent the subsequent reduction in calf weight.

Because many beef producers sell feeders calves, calf weaning weight is one of the most important traits affecting revenue. Dam udder type has impacted calf growth and performance (Goonewardene et al., 2003). Cows with extremely large or small teats weaned light weight calves (Wythe, 1970; Frisch, 1982; Goonewardene et al., 2003). The difference in calf weight could be attributed to a difference in milk production because milk yield accounted for approximately 60% of the variation in calf weaning weight (Jeffery and Berg, 1971; Rutledge et al., 1971). Based on these studies, cows with intermediate teat sizes were most desirable for producing more pounds of calf at weaning.

Udder quality is one of many factors considered by producers when culling cows from the herd. Poor udder quality, defined by large teats, pendulous udder suspension, or mastitis, ranked as one of the top reasons for culling aged cows (Greer et al., 1980; Frisch, 1982). No significant difference in culling for udder problems was found across breeds in Canadian data (Arthur et al., 1992). Udder quality continuously declined with age; therefore, more aged cows were culled for this reason. By improving udder quality, cows remained in the herd longer resulting in the need for fewer replacement heifers. Replacement heifer development is a significant cost to producers; so, increasing cow longevity should result in more efficient and economical beef production.

Measuring Udder Quality

The American Hereford Association (AHA) initially recommended producers record an overall udder score, which combines suspension and teat size into a single score (Denton, 2007). This scoring system is displayed in Figure 1.1 (MacNeil and Mott, 2006). Then, the Beef Improvement Federation (BIF) created udder scoring guidelines in July 2008, which have been adopted by many of the beef breed associations including the AHA (Ward, 2012). In August 2008, the AHA stopped collecting overall scores and switched to recording suspension and teat size scores (Ward, 2012). The BIF guidelines recommend scoring udder suspension and teat size as separate traits (BIF, 2010). These guidelines are shown in Figure 1.2 (BIF, 2010). All 3 types of scores are subjective and are recorded on a one to nine scale, scores of nine are considered ideal. These traits should be scored within 24 hours after calving and should be recorded by the same person within a herd (BIF, 2010). Scoring by a single person helps ensure that scores are consistent within a contemporary group so accurate comparisons can be made among individuals for genetic evaluation purposes.

Dairy breed associations record data on more udder type traits than the beef industry. Holstein Association USA, Inc. (2012) has a scoring system for fore udder attachment, front teat placement, rear udder height, teat length, rear udder width, udder tilt, udder cleft, rear teat placement, and udder depth. These scores are recorded on a 1 to 50 scale with either scores of 25 or 50 being most desirable, depending on the trait (Holstein Association USA, Inc., 2012). These scores are often associated with a quantifiable measurement of the udder. For example, a teat length of 2.25 inches is equivalent to a score of 25 (Holstein Association USA, Inc., 2012). Trained evaluators travel to farms to score cows making these scores less subjective than those recorded in the beef industry. The other dairy associations also have programs to collect similar udder type traits and use the data in genetic evaluations.

Genetic and Phenotypic Parameters

Heritability

Heritability is the proportion of phenotypic variation that is explained by additive genetics. A phenotype results from the combination of additive genetics, gene combination value, environment, and the interaction between genetics and environment. The equation for calculating heritability is where σ_a^2 is the additive genetic variance and σ_p^2 is the phenotypic variance. This measure is important because the higher the heritability, the greater the response to selection because additive genetics, which are passed from parent to offspring, have a relatively large role in determining a phenotype.

Most research on udder type traits has been in the dairy industry because these traits are of greater importance. Heritabilities for teat size in dairy cattle range from 0.29 to 0.33 (Rupp and Boichard, 1999; DeGroot et al., 2002; Royal et al., 2002). Similarly, heritabilities in Simmental and Gelbvieh cattle were 0.38 and 0.21, respectively (Kirschten et al., 2001; Sapp et al., 2003). The dairy industry measures different types of udder suspension including fore and rear udder attachment. Udder attachment heritabilities for dairy cows ranged from 0.18 to 0.37 (Rupp and Boichard, 1999; DeGroot et al., 2002; Royal et al., 2002). The heritabilities of attachment in Simmental and Gelbvieh cows were 0.23 and 0.22, which were in the range estimated in the dairy industry (Kirschten et al., 2001; Sapp et al., 2003). In addition, the heritability of a total udder score, considering both suspension and teat size, was 0.23 in Line 1 Herefords (MacNeil and Mott, 2006). The heritability of udder quality in beef cows was very similar to that seen in the dairy industry. Thus, udder quality is moderately heritable, and genetic progress can be made through genetic selection.

Repeatability

Repeatability measures the strength of the relationship between repeated records in a population. The equation for calculating repeatability is where σ_a^2 is additive genetic variance, σ_c^2 is permanent environmental variance, and σ_p^2 is phenotypic variance. The first record for a highly repeatable trait is a good indicator of future performance, but the first record for a lowly repeatable trait is a poor indicator of future performance. MacNeil and Mott (2006) found a repeatability of 0.34 for udder scores, making udder quality a moderately repeatable trait. Estimates of repeatability in dairy cows ranged from 0.36 to 0.51 (Gengler et al., 1997). Fore udder attachment was one of the least repeatable traits, and teat length was one of the most repeatable traits (Gengler et al., 1997). The potential difference between industries was likely due to how the traits were scored. Trained classifiers recorded type traits on dairy cows, while individual beef producers recorded scores on beef cows. Beef producers were less likely consistent when scoring their cows. In addition, beef and dairy cows have been selected for different traits; udder quality could decline more rapidly in beef cows than dairy cows. Nonetheless, udder quality can be used in making culling decisions, especially because udder quality decreases with age. When a cow's udder begins becoming a problem for the calf to nurse, producers should consider culling that female to prevent the additional labor required when assisting future calves to nurse and the subsequent decrease in calf performance.

Genetic Correlations

Between Udder Type Traits

Correlated traits are important to consider, because selection for one trait can result in potentially undesirable changes in other traits. Phenotypic correlations between udder type traits in Simmental cattle were positive (r = 0.31 to 0.49; Kirschten et al., 2001). Genetic correlations among udder attachment, udder depth, and teat size were very strong and positive (r = 0.52 to 0.60; Kirschten et al., 2001). Data used in this analysis were collected by trained evaluators similar to recording type traits in the dairy industry (Kirschten et al., 2001). However, Sapp et al. (2004) found an extremely high correlation between teat size and udder suspension in beef cows (r = 0.95). Thus, beef producers could be misusing the 2-part scoring system by submitting the same score for both traits. These data were recorded using a 0 to 50 scoring system making it very unlikely that the majority of cows would have the exact same score for both traits. In addition, the evaluators in the dairy industry have considerably more experience and expertise in measuring these subjective traits. Overall, there was a positive correlation among udder traits; so, selection for one trait should result in improvement in the others as well.

Several measures of teat quality are recorded in dairy cows. An important difference between beef and dairy cows is longer teats are more desirable in dairy cows for milking purposes. Teat length was highly correlated to teat form, placement, and position (r = 0.54 to

0.82; Vukasinovic et al., 1997). Cows with longer teats had better form, placement, and position, because these data were scored so larger numbers were always more desirable. However, Gengler et al. (1997) found a negative correlation between teat length and front teat placement (r = -0.10). In this case, cows with longer teats had genetics for slightly wider teat placement. Teat placement was moderately to strongly correlated to measures of udder attachment, width, and depth (r = 0.16 to 0.58; Vanraden et al., 1990; Gengler et al., 1997; Vukasinovic et al., 1997). Generally cows with genetics for closer teat placement had genetics for tighter attachment, wider udders, and shallower udders. Teat length was generally positively correlated to measures of udder attachment (r = 0.01 to 0.40), but this relationship was not consistent for fore udder attachment (r = -0.22 to 0.31; Vanraden et al., 1990; Gengler et al., 1997; Vukasinovic et al., 1997).

The dairy industry quantifies a variety of traits relating to udder attachment. Measures of udder attachment including fore udder, rear udder, rear udder height, and rear udder width generally had strong positive genetic correlations between traits (r = 0.17 to 0.91; Vanraden et al., 1990; Gengler et al., 1997; Vukasinovic et al., 1997). Specifically, rear udder width and height had extremely strong correlations along with the correlation between udder depth and fore udder attachment (r = 0.83 to 0.92; Vanraden et al., 1990; Gengler et al., 1997; Berry et al., 2004). Cows that had very high udders also had very wide udders. If a cow had genetics for tight fore udder attachment, she likely had genetics for tight rear udder attachment and shallow udder depth as well. Thurl width and rear udder width had a strong positive correlation meaning wider based cows also had wider udders (r = 0.56 and 0.40; Gengler et al., 1997; Vukasinovic et al., 1997). Fortunately, these genetic correlations were all in a desirable direction for both beef and dairy cows.

Udder Type and Longevity

Replacement heifer development is an important cost to producers, and fewer heifers are needed when cows remain in the herd longer. Udder quality had a low to moderate positive genetic correlation with dairy cow longevity (r = 0.17 to 0.44; Vukasinovic et al., 1997; Tsuruta et al., 2004; Strapák et al., 2005). Most udder type traits had a weak positive correlation with stayability in Czech Fleckvieh cows (r = 0.06 to 0.18; Bouška, 2006). Teat placement had a slight negative correlation with stayability, but teat placement is not evaluated in most beef cows (r = -0.06; Bouška, 2006). Cows with better udder quality have longer productive lives and are more profitable for producers because they produce more calves in their lifetime. With the trend toward publishing stayability EPD in beef cattle, stayability could be one of the more highly correlated traits to udder quality.

The relationship between milk production and longevity is important for dairy producers. There was a significant positive correlation between estimated breeding values for longevity and milk yield (r = 0.41; Strapák et al., 2005). In first parity females, there were a positive relationships for mean milk yield with percent survival and calving interval, and these relationships persisted in second parity females (r = 0.28 and 0.58; Haile-Mariam et al., 2003). Visscher and Goddard (1995) found an even stronger relationship between survival to the second lactation and first lactation milk yield in different dairy breeds (r = 0.62 and 0.90). Hence, cows with greater genetic potential for milk production also had greater genetic potential for longevity.

Udder Type, and Milk Production

Udder quality is generally negatively correlated to production traits. Cows with larger udders and larger teats produce more milk than cows with better udder quality (r = -0.22 to -0.09; Tsuruta et al., 2004; MacNeil and Mott, 2006). Dairy cows with weaker fore udder attachment and deeper udders had greater genetic potential for milk yield (r = -0.45 and -0.65; DeGroot et al., 2002); however, tight fore and rear udder attachment, tight udder support, and shorter teats were all associated with greater milk yield (r = -0.14 to 0.48; Berry et al., 2004). The maternal component of preweaning gain and udder quality were strongly negatively correlated (r = -0.47 to -0.66; Sapp et al., 2004). Thus, beef cows with better udder quality produced less milk resulting in less calf growth, which is undesirable for beef producers. An intermediate udder type likely exists that best combines sufficient calf growth with the benefits of cow longevity, calf nursing ability, and calf survival from improved udder quality. In addition, producers should find those elite individuals that have the genetic potential for both good udder quality and greater maternal calf growth.

Fore udder attachment, udder depth, and teat size were all negatively correlated to milk fat (r = -0.51 to -0.38; DeGroot et al., 2002). Because longer teats are more desirable in dairy cows, cows with shorter teats had greater genetic potential for milk fat, which would be a desirable relationship in beef cattle. Likewise, udder depth was negatively correlated to milk protein (r = -0.44; DeGroot et al., 2002). In addition, protein and fat percentage in the milk was negatively correlated to milk yield (r = -0.67 to -0.52), and protein and fat percentage were positively correlated to each other (r = 0.66 and 0.78; Van Der Werf and De Boer, 1989; Schultz et al., 1990). Cows that produced large quantities of milk also produced less fat and protein as a percentage of total output.

Milking speed in dairy cows is important because cows that are milked faster require less time, and labor is a significant cost involved in milk production. Milking speed had positive genetic correlations with udder depth, texture, and fore udder attachment (r = 0.11 to 0.18; Boet-

-tcher et al., 1998). Wiggans et al. (2007) also found miking speed to be positively correlated to udder depth and fore udder attachment along with rear udder width (r = 0.18 to 0.22). Yet, milking speed was negatively correlated to rear udder height, rear udder width, teat length, and front teat length (r = -0.35 to -0.12; Boettcher et al., 1998; Wiggans et al., 2007). A more recent study found all measures of udder attachment, teat length, and teat placement to be positively correlated to milking speed (r = 0.09 to 0.50; Berry et al., 2004). While the relationships between milking speed and some measures of attachment and teat length were desirable, other udder traits had undesirable relationships with milking speed. Due to the conflicting nature of these studies, there was no clear connection between milking speed and udder type.

Udder Type, Mastitis, and Milk Production

Indicators of mastitis are frequently recorded in the dairy industry and have been correlated to udder type. Somatic cell count (SCC) and somatic cell score (SCS) are common indicators of mastitis. Milk SCC increased when the cow had a mastitis infection because of the increased quantity of white blood cells traveling from the blood to the milk to fight the infection (Rupp and Boichard, 2003). Given SCC, SCS can be calculated by the equation
(Rupp and Boichard, 2003). There were negative genetic correlations between udder attachment and depth with SCC and mastitis (r = -0.70 to -0.19; DeGroot et al., 2002; Rupp and Boichard, 2003). Dairy cows with deeper and weakly attached fore udders were more prone to mastitis infection, possibly due to the proximity of the udder to the ground. Teat length and SCS were negatively correlated indicating that cows with genetics for longer teats had greater genetic resistance to mastitis (r = -0.24; DeGroot et al., 2002); however, teat length had a positive relationship with SCC in another study (r = 0.31; Berry et al., 2004). Udder type traits can be important in preventing mastitis in dairy cows.

Milk production and mastitis are positively correlated in dairy cattle. The genetic correlation between clinical mastitis and milk production in dairy cattle was positive (r = 0.24 to 0.55; Simianer et al., 1991; Rupp and Boichard, 2003). The correlation between SCS and milk yield was not different from zero (r = 0.13 and -0.21; Schultz et al., 1990; DeGroot et al., 2002). Yet, Simpson et al. (1995) found Simmental cows with greater milk production had lower SCC at 189 days postpartum than cows with lesser milk production (P = 0.03). The lower SCC in some heavy milking cows could be caused by the dilution of somatic cells in larger quantities of milk. Generally, cows with greater genetic potential for milk production had lesser genetic resistance to mastitis than cows with lesser genetic potential for milk production.

Protein and fat content of milk are other important factors besides milk yield. Protein and fat percentage had a slight negative correlation with mastitis incidence (r = -0.15 and -0.12; Simi-

-aner et al., 1991; Rupp and Boichard, 2003). The correlation between SCS and milk yield was not different from zero (r = 0.13 and -0.21; Schultz et al., 1990; DeGroot et al., 2002). Yet, Simpson et al. (1995) found Simmental cows with greater milk production had lower SCC at 189 days postpartum than cows with lesser milk production (P = 0.03). The lower SCC in some heavy milking cows could be caused by the dilution of somatic cells in larger quantities of milk. Generally, cows with greater genetic potential for milk production had lesser genetic resistance to mastitis than cows with lesser genetic potential for milk production.

Protein and fat content of milk are other important factors besides milk yield. Protein and fat percentage had a slight negative correlation with mastitis incidence (r = -0.15 and -0.12; Simianer et al., 1991). Yet, protein yield and clinical mastitis had a moderate positive correlation in another study (r = 0.33; Hansen et al., 2002). The correlation between protein and SCS has been reported as being no different from zero and positive (r = 0.11 and 0.29; Schultz et al., 1990; DeGroot et al., 2002). Selecting cows with high milk protein and fat could potentially help improve mastitis resistance.

Genetic Evaluation

Genetic evaluations are important to purebred livestock industries for producers to identify the superior animals for specific traits. Thus, these evaluations need to be as accurate as possible so that the elite individuals are identified correctly and genetic progress is maximized. The general form of the model used for genetic predictions is Y = Xb + Zu + e, where Y is a vector of observations, X is a matrix relating fixed effects in vector b to observations in Y, Z is a matrix relating random effects in vector u to observations in Y, and e are random errors (Golden et al., 2009).

Evaluations for type traits using a sire model began in 1978 with Jerseys and other breeds followed shortly thereafter (Wiggans, 1991). Later, multiple trait sire models were used for genetic prediction (Wiggans, 1991). Holsteins included the correlations between traits in their analyses while the other breeds assumed no correlations between traits (Wiggans, 1991). With the move to a multiple trait animal model in 1998, correlations between predicted transmitting abilities (PTA) for udder type traits calculated with a sire model and calculated with an animal model in Ayrshire, Brown Swiss, Guernsey, Jersey, and Milking Shorthorn cattle were strong (r = 0.62 to 0.91; Gengler et al., 1999). Differences in the PTA could result from the additional relatives that were included in the analysis as well as different adjustments, models, and genetic parameters (Gengler et al., 1999).

Presently, no beef breed association publishes an EPD for udder quality while the dairy industry publishes numerous PTA for udder traits. Early records of teat and udder quality were impacted by sire of dam, age of dam, and month of calf birth (Wythe, 1970). Teat scores from the American Gelbvieh Association were modeled with random effects for animal and residual and fixed effects for herd-year class, calving month, age at calving, and a regression coefficient of the percent Gelbvieh (Sapp et al., 2003). Breeds without open herd books and percentage individuals would not need to incorporate the percentage of that respective breed into the model. Line 1 Hereford udder score data were modeled with the sum of a constant, class effect, linear regression on the inbreeding of the cow, direct genetic effect, permanent environmental effect from repeated observations, and temporary environmental effect with each phenotype (MacNeil and Mott, 2006). Future work might not include the variable for inbreeding since Line 1 Herefords are more inbred by definition. Thus, some components of the model may need to differ by breed; yet, both genetic and environmental factors still need to be considered in predicting udder quality.

Conclusion and Implications to Genetic Improvement of Beef Cattle

Udder quality is an important trait for beef producers because udder structure affects nursing ability and longevity. Previous research indicates that measures of udder quality are moderately heritable and generally highly correlated. The dairy industry has incorporated udder type traits into their national genetic evaluation, and producers have used the results of this evaluation to improve udders in their herds. Thus, beef breed associations could include udder quality in their genetic evaluations and provide producers with a selection tool for improving udders. Improving udder quality would increase cow longevity resulting in the need for fewer replacement females and reducing heifer development costs. Also, producers would assist fewer calves to nurse at birth reducing labor costs. Calf mortality rates would decrease with improved udder quality resulting in a greater percent calf crop weaned and more total pounds for sale at weaning. Thus, genetic selection for udder quality by beef producers could potentially improve profitability.

Figure 1.1 American Hereford Association udder scoring guidelines prior to August 2008 (MacNeil and Mott, 2006)

Score	Description
9	An ideal mammary system. Udder is held high up near the rear and is level in front. Teats are small.
8	Very good udder with level attachment in front and high attachment in the rear with desirable teats.
7	A sound and functional udder fairly level with small, good teats.
6	A very functional udder and teats. This is a problem free udder and teats, but will not have the balance of an udder scored 7, 8, or 9.
5	A functional udder and teats and labor free. Udder and teat scores of 5 or better should be "Labor Free."
4	An udder that could become a problem because of attachments and/or shape and size of teats.
3	A problem udder and teats. The udder will show tendencies of breaking down and teats are too large and balloon shaped.
2	A definite problem udder and teats. The udder is poorly attached in the front and back with weak suspension and teats are large and balloon shaped.
1	A very pendulous udder and balloon teats. These udders will cause frequent labor problems.

Udder score = 8

Udder score = 5

Udder score = 2

Figure 1.2 Beef Improvement Federation udder scoring guidelines (BIF, 2010)

	Udder Suspension		Teat Size	
Score	Description		Description	
9	Very tight		Very small	
7	Tight		Small	
5	Intermediate /moderate		Intermediate/ moderate	
3	Pendulous		Large	
1	Very pendulous, broken floor		Very large, balloon-shaped	

Bibliography

Arthur, P. F., M. Makarechian, R. T. Berg, and R. Weingardt. 1992. Reasons for disposal of cows in a purebred Hereford and two multibreed synthetic groups under range conditions. Can. J. Anim. Sci. 72(4): 751-758.

Beef Improvement Federation. 2010. Guidelines for uniform beef improvement programs. 9th ed. BIF, Raleigh, NC.

Berry, D. P., F. Buckley, P. Dillon, R. D. Evans, and R. F. Veerkamp. 2004.Genetic relationships among linear type traits, milk yield, body weight, fertility and somatic cell count in primiparous dairy cows. Irish J. of Agri. and Food Res. 43: 161-176.

Boettcher, P. J., J. C. M. Dekkers, and B. W. Kolstad. 1998. Development of an udder health index for sire selection based on somatic cell score, udder conformation, and milking speed. J. Dairy Sci. 81(4): 1157-1168.

Bouška J., M. Vacek, M. Štípková, and A. Němec. 2006. The relationship between linear type traits and stayability of Czech Fleckvieh cows. Czech J. Anim. Sci. 7: 299-304.

Denton, A. S. 2007. Scoring momma. Hereford World. 97(8): 6.

DeGroot, B. J., J. F. Keown, L. D. VanVleck, and E. L. Marotz. 2002. Genetic parameters and responses of linear type, yield traits, and somatic cell scores to divergent selection for predicted transmitting ability for type in Holsteins. J. Dairy Sci. 85(6): 1578.

Dueñas, M. I., M. J. Paape, R. P. Wettemann, and L. W. Douglass. 2001. Incidence of mastitis in beef cows after intramuscular administration of oxytetracycline. J. Anim. Sci. 79(8): 1996.

Edwards, S. A. 1982. Factors affecting the time to first suckling in dairy calves. Anim. Prod. 34 (03): 339-346.

Frisch, J. E. 1982. The use of teat-size measurements or calf weaning weight as an aid to selection against teat defects in cattle. Anim. Prod. 32: 127-133.

Gengler, N., G. R. Wiggans, J. R. Wright, H. D. Norman, and C. W. Wolfe. 1997. Estimation of (co)variance components for Jersey type traits using a repeatability model. J. Dairy Sci. 80: 1801-1806.

Golden, B. L., D. J. Garrick, and L. L. Benyshek. 2009. Milestones in beef cattle genetic evaluation. J. Anim. Sci. 87: E3-E10.

Goonewardene, L. A., Z. Wang, M. A. Price, R. C. Yang, R. T. Berg, and M. Makarechian. 2003. Effect of udder type and calving assistance on weaning traits of beef and dairy x beef calves. Livest. Prod. Sci. 81(1): 47-56.

Greer, R. L., R. W. Whitman, and R. R. Woodward. 1980. Estimation of probability of beef cows being culled and calculation of expected herd life. J. Anim. Sci. 51(1): 10.

Haggard, D. L., R. J. Farnsworth, and J. A. Springer. 1983. Subclinical mastitis of beef cows. J. Am. Vet. Med. Assoc. 182(6): 604-606.

Haile-Mariam, M., P. J. Bowman, M. E. Goddard. 2003. Genetic and environmental relationship among calving interval, survival, persistency of milk yield and somatic cell count in dairy cattle. Livest. Prod. Sci. 80: 189-200.

Hansen, M., M. S. Lund, M. K. Sørensen, and L. G. Christensen. 2002. Genetic parameters of dairy character, protein yield, clinical mastitis, and other diseases in the Danish Holstein cattle. J. Dairy Sci. 85: 445-452.

Holstein Association USA, Inc. 2012. Linear descriptive traits. http://www.holsteinusa.com/pdf/print_material/linear_traits.pdf. Accessed Feb 8, 2013.

Jeffery, H. B., and R. T. Berg. 1971. Evaluation of milk variables as measures of milk effect on preweaning performance of beef cattle. Can. J. Anim. Sci. 51(1): 21-30.

Kirschten, D. P., D. D. Kress, M. W. Tess, and K. L. Davis. 2001. Estimating genetic parameters of a linear type scoring method in beef cattle. Proceedings, Western Section, American Society of Animal Science.

Lents, C. A., R. P. Wettemann, M. J. Paape, J. A. Vizcarra, M. L. Looper, D. S. Buchanan et al. 2002. Efficacy of intramuscular treatment of beef cows with oxytetracycline to reduce mastitis and to increase calf growth. J. Anim. Sci. 80(6): 1405.

MacNeil, M. D., and T. B. Mott. 2006. Genetic analysis of gain from birth to weaning, milk production, and udder conformation in Line 1 Hereford cattle. J. Anim. Sci. 84(7): 1639.

Newman, M. A., L. L. Wilson, E. H. Cash, R. J. Eberhart, and T. R. Drake. 1991. Mastitis in beef cows and its effects on calf weight gain. J. Anim. Sci. 69(11): 4259.

Paape, M. J., M. I. Dueñas, R. P. Wettemann, and L. W. Douglass. 2000. Effects of intramammary infection and parity on calf weaning weight and milk quality in beef cows. J. Anim. Sci. 78 (10): 2508.

Royal, M. D., J. E. Pryce, J. A. Woolliams, and A. P. F. Flint. 2002. The genetic relationship between commencement of luteal activity and calving interval, body condition score, production, and linear type traits in Holstein-Friesian dairy cattle. J. Dairy Sci. 85(11): 3071-3080.

Rupp, R., and D. Boichard. 1999. Genetic parameters for clinical mastitis, somatic cell score, production, udder type traits, and milking ease in first lactation Holsteins. J. Dairy Sci. 82(10):

Rupp, R., and D. Boichard. 2003. Genetics of resistance to mastitis in dairy cattle. Vet. Res. 34 (5): 671-688.

Rutledge, J. J., O. W. Robison, W. T. Ahlschwede, and J. E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33(3): 563.

Sapp, R. L., R. Rekaya, and J. K. Bertrand. 2003. Simulation study of teat score in first-parity Gelbvieh cows: Parameter estimation. J. Anim. Sci. 81(12): 2959.

Sapp, R. L., R. Rekaya, and J. K. Bertrand. 2004. Teat scores in first-parity Gelbvieh cows: Relationship with suspensory score and calf growth traits. J. Anim. Sci. 82(8): 2277.

Schultz, M. M., L. B. Hansen, G. R. Steurnagel, J. K. Reneau, and A. L. Kuck. 1990. Genetic parameters for somatic cells, protein, and fat in milk of Holsteins. J. Dairy Sci. 73: 494-502.

Simianer, H., H. Solbu, and L. R. Schaeffer. 1991. Estimated genetic correlations between disease and yield traits in dairy cattle. J. Dairy Sci. 74: 4358-4365.

Simpson, R. B., D. P. Wesen, K. L. Anderson, J. D. Armstrong, and R. W. Harvey. 1995. Subclinical mastitis and milk production in primiparous Simmental cows. J. Anim. Sci. 73(6): 1552.

Strapák, P., J. Candrák, and J. Aumann. 2005. Relationship between longevity and selected production, reproduction and type traits. Czech J. Anim. Sci. 50(1): 1-6.

Tsuruta, S., I. Misztal, and T. S. Lawlor. 2004. Genetic correlations among production, body size, udder, and productive life traits over time in Holsteins. J. Dairy Sci. 87(5): 1457-1468.

USDA. 2012. Meat animals production, disposition, and income 2011 summary. http:// usda01.library.cornell.edu/usda/current/MeatAnimPr/MeatAnimPr-04-26-2012.pdf. (Accessed 25 March 2013).

Van Der Werf, J. H. J., and W. De Boer. 1989. Estimation of genetic parameters in a crossbred population of black and white dairy cattle. J. Dairy Sci. 72: 2615-2623.

Vanraden, P. M., E. L. Jensen, T. J. Lawlor, and D. A. Funk. 1990. Prediction of transmitting abilities for Holstein type traits. J. Dairy Sci. 73(1): 191-197.

Ventorp, M., and P. Michanek. 1992. The importance of udder and teat conformation for teat seeking by the newborn calf. J. Dairy Sci. 75(1): 262-268.

Visscher, P. M., and M. E. Goddard. 1995. Genetic parameters for milk yield, survival, workability, and type traits for Australian dairy cattle. J. Dairy Sci. 78: 205-220.

Vukasinovic, N., J. Moll, and N. Künzi. 1997. Factor analysis for evaluating relationships between herd life and type traits in Swiss Brown cattle. Livest. Prod. Sci. 49: 227-234.

Ward, J. Udder scoring. http://hereford.org/static/files/udderscoringfactsheet.pdf. Accessed June 7, 2012.

Watts, J. L., J. W. Pankey, W. M. Oliver, S. L. Nickerson, and A. W. Lazarus. 1986. Prevalence and effects of intramammary infection in beef cows. J. Anim. Sci. 62(1): 16-20.

Wiggans, G. R. 1991. National genetic improvement programs for dairy cattle in the United States. J. Anim. Sci. 69: 3853-3860.

Wythe, L. D. 1970. Genetic and environmental effects on characters related to productive ability of the American Brahman. PhD Diss. Texas A&M Univ., College Station.

Understanding the genetic mechanisms that underlie variation in immune response and disease susceptibility

Erika Downey

Texas A&M University

Introduction

The beef industry is currently facing many challenges, from feed efficiency, to drought and costly feedstuff inputs, to the nutritional value of beef protein and nutritional benefits of beef to consumers, to disease and animal welfare. Animal health and disease has quickly moved to the front-line of issues that are currently facing the beef industry. Animal health and disease is an issue that affects production, quality, and the public perception of the beef and livestock industries. Disease is costly to the industry. Disease such as bovine respiratory disease (BRD) has been shown to cost the industry approximately $750 million dollars annually (HOLLAND *et al.* 2010). Disease outbreaks can devastate an industry and cost millions of dollar as was experienced with the bovine spongiform encephalopathy (BSE). The 2004 outbreak of BSE has been estimated to of cost the US 3.2 to 4.7 billion dollars in losses, though loss of export markets and recalls on retail products (PENDELL *et al.* 2007). Improving the understanding of the mechanisms that control disease susceptibility, can offer the potential of genetic selection to remove animals that are immunologically challenged and that have high susceptibility to diseases.

Disease prevention and treatment can be costly and in the case of some vaccines and treatments for some diseases, ineffective. The public consumer has developed many misconceptions about the use of antibiotics and hormones in food livestock production, which are beginning to play a role in management decisions of producers. In addition to misconceptions that have been created among consumers with regards to antibiotic and hormone use in cattle, legislature has tried to impose regulations to remove the use of sub-therapeutic antibiotic in livestock. Currently, disease prevention though vaccine use is one of the most commonly used methods for disease prevention. However, a large amount of variation in immune response and disease susceptibility has been observed among animals. The variation in the immune response and disease susceptibility phenotypes has been observed in all breeds and ages of cattle, contributing to the challenges associated with studying disease and immune response.

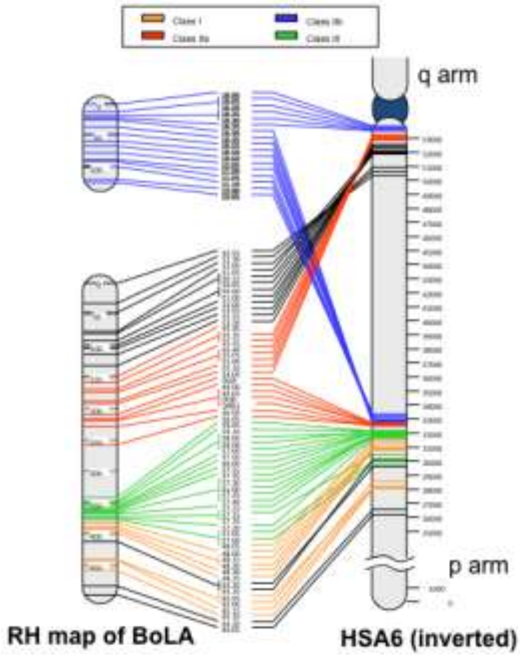
While, prevention methods such as vaccination serve to protect the animals from infectious pathogens, not all animals appear to respond equally to the same vaccine nor are protected to the same degree (DUFF and GALYEAN 2007; SALAK-JOHNSON 2007). Improvement for feed efficiency, growth and performance, and other traits have began to use genetic selection to make improvement in quantitative traits. However, during this time of selection, little to no selection pressure has been implemented for animal health or disease resistance and susceptibility. This may be partially due to the complexity of phenotypes, complications and expense of collecting quality data, and limitations to understanding the genetic mechanisms that underlie immune response and disease resistance.

Variation in immune response and disease susceptibility has often been attributed to the highly polymorphic MHC and associated with serotypes, gene markers, and more recently single nucleotide polymorphism (SNP) defined haplotypes. However, evidence suggests that more variation exists in immune response than can be attributed to SNP-defined haplotypes. In addition to SNP variation, genomic structural variation, such as: insertion, deletions, inversions and copy number variant (CNV) regions, which may contribute to the variability in immune phenotypes that are observed. Approximately 2,600 copy number variant (CNV) regions have been identified in the cattle genome (BICKHART *et al.* 2012; HOU *et al.* 2012; LIU *et al.* 2011; LIU *et al.* 2010; SE-ROUSSI *et al.* 2010; STOTHARD *et al.* 2011). Evidence suggests there is an enrichment of CNVs in genes associated with immune function and metabolism pathways (BICKHART *et al.* 2012; FADISTA *et al.* 2010; HOU *et al.* 2012; STOTHARD *et al.* 2011; TENNESSEN *et al.* 2012). Enrichment of CNVs in genes involved in immune functions might account for the previously unexplained variation in immune response and disease susceptibility phenotypes. Improved understanding of the genetic structure of immune related genome regions might offer advancement in selection for animals with improved or optimal immune responses and improve the understanding of genetic mechanisms that underlie immune responses.

Literature review

Major Histocompatibility Complex Structure

The bovine major histocompatibility complex (MHC) is a gene dense region located on bovine chromosome 23, composed primarily of genes associated with immune response or disease susceptibility (MIYASAKA *et al.* 2011; TAKESHIMA and AIDA 2006). The bovine MHC, referred to as the bovine leukocyte antigen (BoLA), is divided into three regions, classes I, II, and III, which display conserved syntenic regions with the MHCs of other mammalian species (KELLEY *et al.* 2005), as illustrated in Figure 1. The organization of BoLA differs from that of other mammals at the class II region. The BoLA class II region has apparently been disrupted by a large inversion to place a portion of the class II region, called IIb, near the centromere, separated from the main MHC region by approximately 20 Mb of non-MHC DNA (CHILDERS *et al.* 2006). BoLA class IIa region, composed of functionally expressed DQ and DR genes, is tightly linked to the class I region, creating a diverse cohort of MHC haplotypes (DAVIES *et al.* 1997). The classical BoLA class I and IIa are highly polymorphic and have been associated with various immune responses. The largest portion of variation in BoLA class I has been attributed to deletions and duplications, resulting in a number of different gene configurations (ELLIS *et al.* 1999). Altered gene configurations may result in varied immune responses that have not previously been detected by SNPs. Polymorphic BoLA genes and variation in BoLA haplotypes contribute to diversity in immune responses.



(BRINKMEYER-LANGFORD *et al.* 2009)

Figure 1. Map of the bovine major histocompatability complex.

BoLA genes encode five peptide-binding proteins: DQ, DR, DN, DO, and DY (BAKER *et al.* 2006; KELLEY *et al.* 2005). Class I and IIa genes have been the focus to understand the immune function of the MHC. MHC class IIa region, composed of functionally expressed DQ and DR genes, is tightly linked to the class I region creating a diverse cohort of MHC haplotypes (DAVIES *et al.* 1997). MHC class II alleles are redundant and highly polymorphic, enhancing the repertoire of epitopes that an individual can recognize (NORIMINE and BROWN 2005). Class II DQα and β and DRβ are the most polymorphic genes in the bovine MHC, similar to other species (ANDERSSON *et al.* 1986). There are five different DQα and β genes and three DRβ genes that have been identified. Most haplotypes express two DQα and β genes and one DRβ functionally expressed gene, the number of DQ genes is shown to vary with haplotype (ANDERSSON *et al.* 1988; GELHAUS *et al.* 1999; TAKESHIMA and AIDA 2006). To date, 106 DRB3, 46 DQA, and 52 DQB alleles have been reported (BAXTER *et al.* 2009; NORIMINE and BROWN 2005). Bovine MHC class I is composed of 10 genes and pseudogenes, four of these genes are transcribed but expression is highly variable among individuals (BABIUK *et al.* 2007). Twenty-eight distinct class I sequences have been identified (TAKESHIMA and AIDA 2006). Allelic polymorphisms are associated with the antigen-binding region which is used to define the specificity of the acquired immune response and for haplotype identification (BALLINGALL *et al.* 1998). Polymorphic MHC genes and variation in the MHC haplotypes contributes to the diverse range of immune responses.

Haplotype Structure

The haplotype structure across the MHC is rather conserved in most mammals, however cattle and other ruminants are unique in the expression of multiple DQA and DQB loci which may be contributing to the variation in the immune phenotypes that are observed(SCOTT *et al.* 1987). While at least four DQB loci have been identified, and there is strong evidence for a fifth DQB loci, only two DQA and DQB loci have been identified in a single haplotype (GELHAUS *et al.* 1999). In haplotypes with single and duplicated versions of DQ loci, all loci appear to be functional (GELHAUS *et al.* 1999). The presence of a heterozygous DQ duplication may lead to the increase diversity of immune phenotypes, and may explain some of the variation that has not been previously identified by SNP-haplotypes in the event new loci have been identified and if duplications of the gene are not detected with classic SNP panels. To support this idea, Gelhaus et al. suggests that in the presence of DQA5 and DQB5 together in the same haplotype, DQA5 and DQB5 products are able to form a divergent DQ molecule suggesting a divergent immunological function (GELHAUS *et al.* 1999). Additionally, in the presence of a duplication of DQ, there is the potential to increase the variety of class II molecules at the cell surface to ensure inter- and intrahaplotype pairing of the alpha and beta chains (GLASS *et al.* 2000). Duplications of genes within given haplotypes might offer an advantage to the variation of the immune response that able to be mounted in cattle.

Approximately 80 BoLA haplotypes have been identified by SNPs across a diverse cohort of cattle breeds, largely influenced by taurine breeds. Haplotype differences have primarily been described by SNP differences rather than other structural variation differences. Creating identical genotypes with varying specificities, sequence to sequence variation or possible copy number influences on gene expression (USINGER *et al.* 1981). More than one copy of a gene can be expressed in some haplotypes but is unaccounted for in the current method of haplotype identification. Unaccounted for variation in copy number and expression might influence diversity in immune responses that are associated with a single haplotype (ELLIS *et al.* 1999). Absolute gene number has not been captured in the current haplotype identification system. Polymorphisms, some that are undetected yet, drive the variation that underlies the BoLA haplotypes.

Polymorphisms

The MHC contains some of the most polymorphic genes in mammalian genomes. High levels of polymorphisms expressed in the antigen presenting genes of the MHC contribute to the diverse immune responses developed to host pathogens and individual variation of expressed immune response (BABIUK *et al.* 2007). Polymorphisms in BoLA class I and II genes influence immune response through peptide binding, antigen presentation, T-cell repertoire, humoral response, cytotoxic response, cytokine networks, vaccine response, and disease susceptibility (MIYASAKA *et al.* 2011; TAKESHIMA and AIDA 2006). SNPs in the HLA class II genes have been shown to determine the specificity of the immune response and play a role in conferring disease susceptibility (NAGAOKA *et al.* 1999). Similarly, SNPs and insertion/deletion polymorphisms have been identified and have been associated with individual variation in cattle (SCHRIDER and HAHN 2010). Allele specific polymorphisms have been shown to be different between breeds and might influence the duration of the immune response along with diversity of immune phenotypes (BAXTER *et al.* 2009; MIYASAKA *et al.* 2011).

Genome Structural Variation

The genome structure is constantly undergoing changes and rearrangements (STANKIEWICZ and LUPSKI 2010; ZHANG *et al.* 2009a), however the phenotypic contributions for many structural changes are unknown. Genomic structural variation includes: insertions, duplications, deletions, inversions and translocations of DNA (FADISTA *et al.* 2010; STANKIEWICZ and LUPSKI 2010). SNPs have been thought to be the major source of individual genetic variation, but undefined phenotypic diversity may be due to larger regions of variation such as CNVs (FADISTA *et al.* 2010; REDON *et al.* 2006). CNVs contain more total sequence than SNPs and are large enough to encompass whole genes. Therefore, CNVs have a potential for more significant effects on evolution, fitness, and genetic diversity (FADISTA *et al.* 2010; HOU *et al.* 2012; REDON *et al.* 2006; SCHRIDER and HAHN 2010; ZHANG *et al.* 2009b). Characterization of genetic variation in livestock species is an important step towards linking genes or genomic regions with phenotypes (STOTHARD *et al.* 2011). Detection of CNVs in the immune specified region of the genome might explain variation in immune response.

Copy Number Variation

Identified CNVs have included translatable genes, functional elements, and noncoding RNAs; many of which have not been associated with phenotypes (REDON *et al.* 2006). The GC content associated with CNV regions has been shown to be slightly higher than the GC content of the whole genome, suggesting CNVs arise more frequently in gene rich regions (FADISTA *et al.* 2010). Redon et al. (2006) defined a CNV as 1 Kb or larger, however other studies have identified CNVs of smaller sizes (CONRAD *et al.* 2010; DOAN *et al.* 2012; ZHANG *et al.* 2009a). The CNV detection resolution depends on the design of the array. This presents a challenge not only to detect CNVs but also to characterize expression and associate CNV changes with phenotypes.

Now that arrays with higher resolution have been designed, smaller CNVs have been reported to be as frequent as large (>1 Kb) CNVs (FADISTA *et al.* 2010). Due to the design of SNP arrays, the smaller CNVs would not have likely been detected and therefore may not be accounted for in haplotype characterization.

CNVs account for a significant source of variation in mammals (FADISTA *et al.* 2010). CNVs have been shown to be associated with quantitative phenotypes and to be known causative agents of genetic disorders (FADISTA *et al.* 2010). However, little is known about CNV variation in relation to bovine immune phenotypic diversity. The proportion of predicted CNVs per individual human varies between 2.3 and 4.2% (TENNESSEN *et al.* 2012), suggesting individual variation may be associated with differences in immune response expression (HOU *et al.* 2012; SCHRIDER and HAHN 2010; TENNESSEN *et al.* 2012). Pairwise comparisons of taurine and indicine cattle suggested that CNV differences between subspecies are greater than across breeds within a subspecies (BICKHART *et al.* 2012). Stothard *et al.* (2001) has shown that genomic regions enriched with CNVs are breed dependent, which may show selection pressure. Breed dependent CNVs may be relevant to unexplained haplotype variation that exists between breeds, and disease may be influencing selection pressure for CNVs enriched in immune function genes. CNV detection and variation may help interpret diverse expressed immune responses that have previously been associated with identical haplotypes.

Association with Disease

The MHC has been associated with immune response and disease susceptibility in many species (KELLEY *et al.* 2005). Disease association studies have shown large variability in allele association with immune response. In cattle, alleles of class II are associated with animal-to-animal variation in disease susceptibility to hoof-and-mouth disease, dematophilosis, mastitis, bovine leukemia virus, and tick resistance (FADISTA *et al.* 2010; LEWIN and BERNOCO 1986; MIYASAKA *et al.* 2011; SHARIF *et al.* 1998; UNTALAN *et al.* 2007; XU *et al.* 1993). An indirect relationship between health and production traits was shown based on which DRβ3 allele was present for mastitis resistance/susceptibility (OPRZADEK *et al.* 2012). Within some defined diseases, affected members share a common haplotype at a higher frequency than would be expected with independent segregations, thus suggesting that there is a haplotype association with disease susceptibility (TODD *et al.* 1988). BoLA haplotypes and CNVs have been associated with disease phenotypes, however the associations are not well characterized and need further investigation. BoLA heterozygotes have an advantage of enhanced resistance and increased diversity of antigens presented and recognized (TAKESHIMA *et al.* 2008). Multiple studies have demonstrated a strong link between copy number differences at a specific location and differ

-ences in phenotypic traits (SCHRIDER and HAHN 2010).

Conclusion

Immune response and disease resistance and susceptibility are not yet well characterized nor are the genetic mechanisms that control immune response and disease susceptibility well understood. More variation in immune phenotypes has been observed than can be accounted for in the current SNP-defined haplotypes and association studies. A limited about of research that is available on CNV and other structural arrangements shows strong evidence that structural rearrangements could contribute to the degree of variation in immune phenotypes. To increase the strength of the association tests, and to increase the likelihood of using genetic selection for health improvements, immune response and disease phenotypes need to be better characterized. This is one of the most restricting limiting factors to the use of genetic selection for improved health.

Genetic selection has now been used as a selection tool for many breeds and for quantitative traits. The literature has evidence for the possibility of using genetic selection for animal health improvement. The use of genetic selection to improve immune response and minimized disease susceptibility could serve as an alternative to minimize antibiotic use and improve the immune response to vaccines as disease prevention methods. The use genetic selection to improve animal health may minimize the financial costs that have previously been associated with disease and treatment, while boosting the benefits from disease prevention with improved immune response from vaccine treatments.

The MHC is a single region of the genome that is known to have immune related function, and has been the focus of this review. This multigene family constitutes the larges known region of the genome with immune function. There are studies that have showed associations between MHC genes and immune phenotypes that suggest that it might offer a region of selection to improve immune response and to decrease disease susceptibility. However, animal health improvement though genetic selection is not limited to the MHC, but offers a starting point for genetic selection and illustrates the complexity of immune mechanisms.

Literature Cited

ANDERSSON, L., J. BOHME, P. A. PETERSON and L. RASK, 1986 Genomic hybridization of bovine class II major histocompatibility genes: 2. Polymorphism of DR genes and linkage disequilibrium in the DQ-DR region. Anim Genet **17:** 295-304.

ANDERSSON, L., A. LUNDÉN, S. SIGURDARDOTTIR, C. J. DAVIES and L. RASK, 1988 Linkage relationships in the bovine MHC region. High recombination frequency between class II subregions. Immunogenetics **27:** 273-280.

BABIUK, S., B. HORSEMAN, C. ZHANG, M. BICKIS, A. KUSALIK *et al.*, 2007 BoLA class I allele diversity and polymorphism in a herd of cattle. Immunogenetics **59:** 167-176.

BAKER, C., M. VANT, M. DALEBOUT, G. LENTO, S. O'BRIEN *et al.*, 2006 Diversity and duplication of <i>DQB and <i>DRB -like genes of the MHC in baleen whales (suborder: Mysticeti<b>)</b&gt. Immunogenetics **58:** 283-296.

BALLINGALL, K. T., B. S. MARASA, A. LUYAI and D. J. MCKEEVER, 1998 Identification of diverse BoLA DQA3 genes consistent with non-allelic sequences. Animal Genetics **29:** 123 -129.

BAXTER, R., S. C. CRAIGMILE, C. HALEY, A. J. DOUGLAS, J. L. WILLIAMS *et al.*, 2009 BoLA-DR peptide binding pockets are fundamental for foot-and-mouth disease virus vaccine design in cattle. Vaccine **28:** 28-37.

BICKHART, D. M., Y. HOU, S. G. SCHROEDER, C. ALKAN, M. F. CARDONE *et al.*, 2012 Copy number variation of individual cattle genomes using next-generation sequencing. Genome Research **22:** 778-790.

BRINKMEYER-LANGFORD, C., C. CHILDERS, K. FRITZ, A. GUSTAFSON-SEABURY, M. COTHRAN *et al.*, 2009 A high resolution RH map of the bovine major histocompatibility complex. BMC Genomics **10:** 182.

CHILDERS, C. P., H. L. NEWKIRK, D. A. HONEYCUTT, N. RAMLACHAN, D. M. MUZNEY *et al.*, 2006 Comparative analysis of the bovine MHC class IIb sequence1 identifies inversion breakpoints and three unexpected genes. Animal Genetics **37:** 121-129.

CONRAD, D. F., D. PINTO, R. REDON, L. FEUK, O. GOKCUMEN *et al.*, 2010 Origins and functional impact of copy number variation in the human genome. Nature **464:** 704-712.

DAVIES, C. J., L. ANDERSSON, S. MIKKO, S. A. ELLIS, E. J. HENSEN *et al.*, 1997 Nomenclature for factors of the BoLA system, 1996: report of the ISAG BoLA Nomenclature Committee. Animal Genetics **28:** 159-168.

DOAN, R., N. COHEN, J. HARRINGTON, K. VEAZY, R. JURAS *et al.*, 2012 Identification of copy number variants in horses. Genome Research **22:** 899-907.

DUFF, G. C., and M. L. GALYEAN, 2007 Recent advances in management of highly stressed, newly received feedlot cattle. Journal of Animal Science **85:** 823-840.

ELLIS, S. A., E. C. HOLMES, K. A. STAINES, K. B. SMITH, M. J. STEAR *et al.*, 1999 Variation in the number of expressed MHC genes in different cattle class I haplotypes. Immunogenetics **50:** 319-328.

FADISTA, J., B. THOMSEN, L. HOLM and C. BENDIXEN, 2010 Copy number variation in the bovine genome. BMC Genomics **11:** 284.

GELHAUS, A., B. FÖRSTER, C. WIPPERN and R. D. HORSTMANN, 1999 Evidence for an additional cattle <i>DQA locus, <i>BoLA-DQA5</i&gt. Immunogenetics **49:** 321-327.

GLASS, E. J., R. A. OLIVER and G. C. RUSSELL, 2000 Duplicated DQ Haplotypes Increase the Complexity of Restriction Element Usage in Cattle. The Journal of Immunology **165:** 134 -138.

HOLLAND, B. P., L. O. BURCIAGA-ROBLES, D. L. VANOVERBEKE, J. N. SHOOK, D. L. STEP *et al.*, 2010 Effect of bovine respiratory disease during preconditioning on subsequent feedlot performance, carcass characteristics, and beef attributes. Journal of Animal Science **88:** 2486-2499.

HOU, Y., D. BICKHART, H. CHUNG, J. HUTCHISON, H. NORMAN *et al.*, 2012 Analysis of copy number variations in Holstein cows identify potential mechanisms contributing to differences in residual feed intake. Functional & Integrative Genomics**:** 1-7.

KELLEY, J., L. WALTER and J. TROWSDALE, 2005 Comparative genomics of major histocompatibility complexes. Immunogenetics **56:** 683-695.

LEWIN, H. A., and D. BERNOCO, 1986 Evidence for BoLA-linked resistance and susceptibility to subclinical progression of bovine leukaemia virus infection. Animal Genetics **17:** 197-207.

LIU, G., T. BROWN, D. HEBERT, M. CARDONE, Y. HOU *et al.*, 2011 Initial analysis of copy number variations in cattle selected for resistance or susceptibility to intestinal nematodes. Mammalian Genome **22:** 111-121.

LIU, G., Y. HOU, B. ZHU, M. CARDONE, L. JIANG *et al.*, 2010 Analysis of copy number variations among diverse cattle breeds. Genome Res.

MIYASAKA, T., S.-N. TAKESHIMA, Y. MATSUMOTO, N. KOBAYASHI, T. MATSUHASHI *et al.*, 2011 The diversity of bovine MHC class II DRB3 and DQA1 alleles in different herds of Japanese Black and Holstein cattle in Japan. Gene 472: 42-49.

NAGAOKA, Y., H. KABEYA, M. ONUMA, N. KASAI, K. OKADA *et al.*, 1999 Ovine MHC Class II DRB1 Alleles Associated with Resistance or Susceptibility to Development of Bovine Leukemia Virus-induced Ovine Lymphoma. Cancer Research 59: 975-981.

NORIMINE, J., and W. BROWN, 2005 Intrahaplotype and interhaplotype pairing of bovine leukocyte antigen DQA and DQB molecules generate functional DQ molecules important for priming CD4⁺ T-lymphocyte responses. Immunogenetics 57: 750-762.

OPRZADEK, J., P. URTNOWSKI, G. SENDER, A. PAWLIK and M. LUKASZEWICZ, 2012 Frequency of BoLA-DRB3 alleles in Polish Holstein-Friesian cattle. Animal Science Papers and Reports 30: 91-101.

PENDELL, D. L., T. C. SCHROEDER, J. LEATHERMAN and G. S. ALWARD, 2007 Summary of a regional economic impact of a hypothetical foot-and-mouth disease outbreak in southwestern Kansas, pp. in *Livestock and Wildlife Disease Report*, edited by D. O. A. A. R. ECONOMICS. Colorado State University, Fort Collins, CO.

REDON, R., S. ISHIKAWA, K. FITCH, L. FEUK, G. PERRY *et al.*, 2006 Global variation in copy number in the human genome. Nature 444: 444 - 454.

SALAK-JOHNSON, J. L. A. M., J.J., 2007 Making sense of apparently conflicting data: Stress and immunity in swine and cattle. Journal of Animal Science 85(E. Suppl.): E81-E88.

SCHRIDER, D. R., and M. W. HAHN, 2010 Gene copy-number polymorphism in nature. Proceedings of the Royal Society B-Biological Sciences 277: 3213-3221.

SCOTT, P. C., C.-L. CHOI and M. R. BRANDON, 1987 Genetic organization of the ovine MHC class II region. Immunogenetics 25: 116-122.

SEROUSSI, E., G. GLICK, A. SHIRAK, E. YAKOBSON, J. WELLER *et al.*, 2010 Analysis of copy loss and gain variations in Holstein cattle autosomes using BeadChip SNPs. BMC Genomics 11: 673.

SHARIF, S., B. A. MALLARD, B. N. WILKIE, J. M. SARGEANT, H. M. SCOTT *et al.*, 1998 Associations of the bovine major histocompatibility complex DRB3 (BoLA-DRB3) alleles with occurrence of disease and milk somatic cell score in Canadian dairy cattle. Animal Genetics **29:** 185-193.

STANKIEWICZ, P., and J. R. LUPSKI, 2010 Structural Variation in the Human Genome and its Role in Disease. Annual Review of Medicine **61:** 437-455.

STOTHARD, P., J.-W. CHOI, U. BASU, J. SUMNER-THOMSON, Y. MENG *et al.*, 2011 Whole genome resequencing of black Angus and Holstein cattle for SNP and CNV discovery. BMC Genomics **12:** 559.

TAKESHIMA, S., Y. MATSUMOTO, J. CHEN, T. YOSHIDA, H. MUKOYAMA *et al.*, 2008 Evidence for cattle major histocompatibility complex (BoLA) class II DQA1 gene heterozygote advantage against clinical mastitis caused by Streptococci and Escherichia species. Tissue Antigens **72:** 525-531.

TAKESHIMA, S.-N., and Y. AIDA, 2006 Structure, function and disease susceptibility of the bovine major histocompatibility complex. Animal Science Journal **77:** 138-150.

TENNESSEN, J., A. BIGHAM, T. O'CONNOR, F. WENQING, E. KENNY *et al.*, 2012 Evolution and Functional Impact of Rare Coding Variation from Deep Sequencing of Human Exomes. Science **337:** 64-69.

TODD, J., H. ACHA-ORBEA, J. BELL, N. CHAO, Z. FRONEK *et al.*, 1988 A molecular basis for MHC class II--associated autoimmunity. Science **240:** 1003-1009.

UNTALAN, P. M., J. H. PRUETT and C. D. STEELMAN, 2007 Association of the bovine leukocyte antigen major histocompatibility complex class II DRB3*4401 allele with host resistance to the Lone Star tick, Amblyomma americanum. Veterinary Parasitology **145:** 190-195.

USINGER, W. R., M. CURIE-COHEN, K. BENFORADO, D. PRINGNITZ, R. ROWE *et al.*, 1981 The bovine major histocompatibility complex <i>(BoLA): Close linkage of the genes controlling serologically defined antigens and mixed lymphocyte reactivity. Immunogenetics **14:** 423-428.

XU, A., M. J. VAN EIJK, C. PARK and H. A. LEWIN, 1993 Polymorphism in BoLA-DRB3 exon 2 correlates with resistance to persistent lymphocytosis caused by bovine leukemia virus. The Journal of Immunology **151:** 6977-6985.

ZHANG, F., C. M. B. CARVALHO and J. R. LUPSKI, 2009a Complex human chromosomal and genomic rearrangements. Trends in Genetics **25:** 298-307.

ZHANG, F., W. GU, M. E. HURLES and J. R. LUPSKI, 2009b Copy Number Variation in Human Health, Disease, and Evolution. Annual Review of Genomics and Human Genetics **10:** 451-481.

Past Award Winners

Frank Baker Memorial Scholarship Award Winners

Name	University	Year
Kelly W. Bruns	Michigan State University	1994
William Herring	University of Georgia	1994
D. H. “Denny” Crews, Jr.	Louisiana State University	1995
Dan Moser	University of Georgia	1995
D. H. “Denny” Crews, Jr.	Louisiana State University	1996
Lowell S. Gould	University of Nebraska	1996
Rebecca K. Splan	University of Nebraska	1997
Robert Williams	University of Georgia	1997
Patrick Doyle	Colorado State University	1998
Shannon M. Schafer	Cornell University	1998
Janice M. Rumph	University of Nebraska	1999
Bruce C. Shanks	Montana State University	1999
Paul L. Charteris	Colorado State University	2000
Katherine A. Donoghue	University of Georgia	2000
Khathutshelo A. Nephawe	University of Nebraska	2001
Janice M. Rumph	University of Nebraska	2001
Katherina A. Donoghue	University of Georgia	2002
Khathutshelo A. Nephawe	University of Nebraska	2002
Fernando F. Cardoso	Michigan State University	2003
Charles Andrew McPeake	Michigan State University	2003
Reynold Bergen	University of Guelph	2004
Angel Rios-Utrera	University of Nebraska	2004
Matthew A. Cleveland	Colorado State University	2005
David P. Kirschten	Cornell University	2005
Amy Kelley	Montana State University	2006
Jamie L. Williams	Colorado State University	2006
Gabriela C. Márquez Betz	Colorado State University	2007

Past Award Winners

Frank Baker Memorial Scholarship Award Winners

Name	University	Year
Yuri Regis Montanholi	University of Guelph	2007
Devori W. Beckman	Iowa State University	2008
Kasey L. DeAtley	New Mexico State University	2008
Scott Speidel	Colorado State University	2009
Lance Leachman	Virginia Polytechnic Institute	2009
Kent A. Gray	North Carolina State University	2010
Megan Rolf	University of Missouri	2011
Brian Brigham	Colorado State University	2011
Kristina Weber	University of California-Davis	2012
Jeremy Howard	University of Nebraska-Lincoln	2012

2013 Winners

Heather Bradford

Erika Downey

Roy A. Wallace

The Roy A. Wallace BIF Memorial Fund was established to honor the life and career of Roy A. Wallace. Mr. Wallace worked for Select Sires for 40 years, serving as vice-president of beef programs and devoted his life to beef-cattle improvement. He became involved with BIF in its infancy and was the only person to attend each of the first 40 BIF conventions. He loved what BIF stood for – an organization that brings together purebred and commercial cattle breeders, academia and breed associations, all committed to improving beef cattle. Wallace was honored with both the BIF Pioneer Award and BIF Continuing Service Award and co-authored the BIF 25-year history, *Ideas into Action*. This scholarship was established to encourage young men and women interested in beef cattle improvement to pursue those interests as Mr. Wallace did, with dedication and passion.

Proceeds from the Roy A. Wallace Beef Improvement Federation Memorial Fund will be used to award scholarships to graduate and undergraduate students currently enrolled as fulltime students in pursuit of a degree related to the beef cattle industry. Criteria for selection will include demonstrated commitment and service to the beef cattle industry. Preference will be given to students who have demonstrated a passion for the areas of beef breeding, genetics, and reproduction. Additional considerations will include academic performance, personal character, and service to the beef cattle industry.

Two scholarships will be offered in the amount of $1250 each. One will be awarded to a student currently enrolled as an undergraduate and one will be awarded to a student currently enrolled in a Master of Science or Doctoral program. (From BIF Website/ www.beefimprovement.org.).

Past Award Winners

Roy A. Wallace Memorial Scholarship Award Winners (Undergraduate)

Name	University	Year
Sally Ruth Yon………………………	South Carolina……………..………………....	2010
Cassandra Kniebel……………….……..	Kansas State University…………….……...…	2011
Natalie Laubner………..…………..……	Kansas State University…………………….…	2012

2013 Winners

Tyler Schultz

Kansas State University

Roy A. Wallace Memorial Scholarship Award Winners (Graduate)

Name	University	Year
Paige Johnson……………….…………	Texas Tech University……...………………....	2010
Jessica Bussard…………………….……..	University of Kentucky..………………...…	2011
Ky Pohler……………...…………..……	University of Missouri…..……………………	2012

2013 Winners

Loni Woolley

Texas Tech University

Past Award Winners

Pioneer Award Recipients

Jay L. Lush	Iowa	1973
Reuben Albaugh	California	1974
Charles E. Bell, Jr.	USDA	1974
John H. Knox	New Mexico	1974
Paul Pattengale	Colorado	1974
Fred Wilson	Montana	1974
Ray Woodward	ABS	1974
Glenn Butts	PRT	1975
Keith Gregory	MARC	1975
Braford Knapp, Jr	USDA	1975
Forrest Bassford	Western Livestock Journal	1976
Doyle Chambers	Louisiana	1976
Mrs. Waldo Emerson	Wyoming	1977
Forbes	Virginia	1977
C. Curtis Mast	Oregon	1977
Ralph Bogart	South Dakota	1977
Henry Holsman	Florida	1977
Marvin Koger	Florida	1977
John Lasley	Georgia	1977
W. L. McCormick	Montana	1977
Paul Orcutt	Performance Registry Int'l	1977
J.P. Smith	Colorado	1978
H.H. Stonaker	Wye Plantation	1978
James B. Lingle	Virginia	1978
R. Henry Mathiessen	Virginia	1979
Bob Priode	MARC	1979
Robert Koch	Arizona	1979
Mr. & Mrs. Carl Roubicek	Arizona	1979
Joseph J. Urick	USDA	1980
Richard T. Clark	USDA	1980
Bryon L. Southwell	Georgia	1980
F.R. "Ferry" Carpenter	Colorado	1981
Otha Grimes	Oklahoma	1981
Milton England	Texas	1981
L.A. Moddox	Texas	1981
Charles Pratt	Oklahoma	1981
Clyde Reed	Oklahoma	1981
Gordon Dickerson	Nebraska	1982
Mr. & Mrs. Percy Powers	Texas	1982
Jim Elings	California	1983
W. Dean Frischknecht	Oregon	1983
Ben Kettle	Colorado	1983
Jim Sanders	Nevada	1983
Carroll O. Schoonover	Wyoming	1983
Bill Graham	Georgia	1984
Max Hammond	Florida	1984
Thomas J. Marlowe	Virginia	1984
Mick Crandell	South Dakota	1985
Mel Kirkiede	North Dakota	1985
Charles R. Henderson	New York	1986
Everett J. Warwick	USDA	1986
Glenn Burrows	New Mexico	1987
Carlton Corbin	Oklahoma	1987
Murray Corbin	Oklahoma	1987
Max Deets	Kansas	1987
Christian A. Dinkle	South Dakota	1988
George F. & Mattie Ellis	New Mexico	1988
A.F. "Frankie" Flint	New Mexico	1988
Roy Beeby	Oklahoma	1989
Will Butts	Tennessee	1989
John W. Massey	Missouri	1989

Past Award Winners

Pioneer Award Recipients

Donn & Sylvia Mitchell	Canada	1990
Hoon Song	Canada	1990
Jim Wilton	Canada	1990
Bill Long	Texas	1991
Bill Turner	Texas	1991
Frank Baker	Arkansas	1992
Ron Baker	Oregon	1992
Bill Borror	California	1992
Walter Rowden	Arkansas	1992
James D. Bennett	Virginia	1993
M.K. “Curly” Cook	Georgia	1993
O’Dell G. Daniel	Georgia	1993
Hayes Gregory	North Carolina	1993
Dixon Hubbard	USDA	1993
James W. “Pete” Patterson	North Dakota	1993
Richard Williams	Iowa	1993
Tom Chrystal	Iowa	1994
Robert C. DeBaca	Iowa	1994
Roy A. Wallace	Ohio	1994
James S. Brinks	Colorado	1995
Robert E. Taylor	Colorado	1995
A.L. “Ike” Eller	Virginia	1996
Glynn Debter	Alabama	1996
Larry V. Cundiff	Nebraska	1997
Henry Gardiner	Kansas	1997
Jim Leachman	Montana	1997
John Crouch	Missouri	1998
Bob Dickinson	Kansas	1998
Douglas MacKenzie Fraser	Alberta	1998
Joseph Graham	Virginia	1999
John Pollak	New York	1999
Richard Quaas	New York	1999
J. David Nichols	Iowa	2000
Harlan Ritchie	Michigan	2000
Robert R. Schalles	Kansas	2000
Larry Benyshek	Georgia	2001
Minnie Lou Bradley	Texas	2001
Tom Cartwright	Texas	2001
H.H. “Hop” Dickenson	Kansas	2002
Martin & Mary Jorgensen	South Dakota	2002
L. Dale Van Vleck	Nebraska	2002
George Chiga	Oklahoma	2003
Burke Healey	Oklahoma	2003
Keith Zoellner	Kansas	2003
Frank Felton	Missouri	2004
Tom Jenkins	Nebraska	2004
Joe Minyard	South Dakota	2004
Jack and Gini Chase	Wyoming	2005
Jack Cooper	Montana	2005
Dale Davis	Montana	2005
Les Holden	Montana	2005
Don Kress	Montana	2005
John Brethour	Kansas	2006
Harlan & Dorotheann Rogers	Mississippi	2006
Dave Pingrey	Mississippi	2006
Rob Brown	Texas	2007
David & Emma Danciger	Colorado	2007
Jim Gosey	Nebraska	2007
Donald Vaniman	Montana	2008
Louis Latimer	Canada	2008
Harry Haney	Canada	2008

Past Award Winners

Pioneer Award Recipients

Bob Church	Canada	2008
Bruce Golden	California	2009
Bruce Orvis	California	2009
Roy McPhee	California	2009
Richard McChung	Virginia	2010
John & Bettie Rotert	Missouri	2010
Daryl Strohbehn	Iowa	2010
Glen Klippenstein	Missouri	2010
Mike Tess	Montana	2011
Mike MacNeil	Montana	2011
Jerry Lipsey	Montana	2011
Sally Buxkemper	Texas	2012
Donald Franke	Texas	2012
Leo McDonnell	Montana	2012

Past Award Winners

Continuing Service Award Recipients

Clarence Burch	Oklahoma	1972	Ken W. Ellis	California	1986
F.R. Carpenter	Colorado	1973	Earl Peterson	Montana	1986
Rpbert DeBaca	Iowa	1973	Bill Borror	California	1987
E.J. Warwick	Washington, DC	1973	Jim Gibb	Missouri	1987
Frank H. Baker	Oklahoma	1974	Daryl Strohbehn	Iowa	1987
D.D. Bennett	Oregon	1974	Bruce Howard	Canada	1988
Richard Willham	Iowa	1974	Roger McCraw	North Carolina	1989
Larry V. Cundiff	Nebraska	1975	Robert Dickinson	Kansas	1990
Dixon D. Hubbard	Washington,DC	1975	John Crouch	Missouri	1991
J. David Nichols	Iowa	1975	Jack Chase	Wyoming	1992
A.L. Eller, Jr.	Virginia	1976	Leonard Wulf	Minnesota	1992
Ray Meyer	South Dakota	1976	Robert McGuire	Alabama	1993
Lloyd Schmitt	Montana	1977	Charles McPeake	Georgia	1993
Don Vaniman	Montana	1977	Henry W. Webster	South Carolina	1993
James S. Brinks	Colorado	1978	Bruce E. Cunningham	Montana	1994
Martin Jorgensen	South Dakota	1978	Loren Jackson	Texas	1994
Paul D. Miller	Wisconsin	1978	Marvin D. Nichols	Iowa	1994
C.K. Allen	Missouri	1979	Steve Radakovich	Iowa	1994
William Durfev	NAAB	1979	Doyle Wilson	Iowa	1994
Glenn Butts	PRI	1980	Paul Bennett	Virginia	1995
Jim Gosey	Nebraska	1980	Pat Goggins	Montana	1995
Mark Keffeler	South Dakota	1981	Brian Pogue	Canada	1996
J.D. Mankin	Idaho	1982	Doug L. Hixon	Wyoming	1996
Art Linton	Montans	1983	Harlan D. Ritchie	Michigan	1996
James Bennett	Virginia	1984	Glenn Brinkman	Texas	1997
M.K. Cook	Georgia	1984	Russell Danielson	North Dakota	1997
Craig Ludwig	Missouri	1984	Gene Rouse	Iowa	1997
Jim Glenn	IBIA	1985	Keith Bertrand	Georgia	1998
Dick Spader	Missouri	1985	Richard Gilbert	Texas	1998
Roy Wallace	Ohio	1985	Burke Healey	Oklahoma	1998
Larry Benyshek	Georgia	1986	Bruce Golden	Colorado	1999

Past Award Winners

Continuing Service Award Recipients

John Hough	Georgia	1999
Gary Johnson	Kansas	1999
Norman Vincil	Virginia	2000
Ron Bolze	Kansas	2000
Jed Dillard	Florida	2001
William Altenburg	Colorado	2001
Kent Andersen	Colorado	2001
Don Boggs	South Dakota	2001
S.R. Evans	Mississippi	2002
Galen Fink	Kansas	2002
Bill Hohenboken	Virginia	2002
Sherry Doubet	Colorado	2003
Ronnie Green	Virginia	2003
Connee Quinn	Nebraska	2003
Ronnie Silcox	Georgia	2003
Chris Christensen	South Dakota	2004
Robert “Bob” Hough	Texas	2004
Steven M. Kappes	Nebraska	2004
Richard McClung	Virginia	2004
Jerry Lipsey	Montana	2005
Micheal MacNeil	Montana	2005
Terry O’Neill	Montana	2005
Robert Williams	Missouiri	2005
Jimm Holliman	Alabama	2006
Lisa-Kriese-Anderson	Alabama	2006
Dave Notter	Ohio	2006
Craig Huffhines	Missouri	2007
Sally Northcutt	Missouri	2007
Dale Kelly	Canada	2008
Doug Fee	Canada	2008
Duncan Porteous	Canada	2008
Mark Thallman	Nebraska	2009
Renee Lloyd	Iowa	2009
Dave Daley	California	2009
Darrh Bullock	Kentucky	2009
Bill Bowman	Missouri	2010
Twig Marston	Nebraska	2010
Mike Tess	Montana	2010
David Patterson	Missouri	2010
Tommy Brown	Alabama	2011
Mark Enns	Colorado	2011
Joe Paschal	Texas	2011
Bob Weaber	Missouri	2011
Marty Ropp	Montana	2011
Tom Field	Nebraska	2012
Brian McCulloh	Wisconsin	2012
Larry Olson	South Carolina	2012
Stephen Hammock	Texas	2012

Past Award Winners

Ambassador Award Recipients

Name	Publication	State	Year
Warren Kester	BEEF Magazine	Minnesota	1986
Chester Peterson	Simmental Shield	Kansas	1987
Fred Knop	Drovers Journal	Kansas	1988
Forrest Bassford	Western Livestock Journal	Colorado	1989
Robert C. DeBaca	The Ideal Beef Memo	Iowa	1990
Dick Crow	Western Livestock Journal	Colorado	1991
J.T. “Johnny” Jenkins	Livestock Breeder Journal	Georgia	1993
Hayes Walker III	America’s Beef Cattleman	Kansas	1994
Nita Effertz	Beef Today	Idaho	1995
Ed Bible	Hereford World	Missouri	1996
Bill Miller	Beef Today	Kansas	1997
Keith Evans	American Angus Association	Missouri	1998
Shauna Rose Hermel	Angus Journal & BEEF Magazine	Missouri	1999
Wes Ishmael	C lear Point Communications	Texas	2000
Greg Hendersen	Drovers	Kansas	2001
Joe Roybal	BEEF Magazine	Minnesota	2002
Troy Marshall	Seedstock Digest	Missouri	2003
Kindra Gordon	Freelance Writer	South Dakota	2004
Steve Suther	Certified Angus Beef LLC	Kansas	2005
Belinda Ary	Cattle Today	Alabama	2006
Angie Denton	Hereford World	Missouri	2007
Gren Winslow	Canadian Cattleman Magazine	Canada	2008
Larry Thomas	Canadian Cattleman Magazine	Canada	2008
Kelli Toldeo	Cornerpost Publications	California	2009
Larry Atzenweiler	Missouri Beef Cattlemen	Missouri	2010
Andy Atzenweiler	Missouri Beef Cattlemen	Missouri	2010
Jay Carlson	BEEF Magazine	Kansas	2011
Burt Rutherford	BEEF Magazine	Texas	2012

2013 BIF Award Winners

Graduate Student Travel Scholarship Recipients

Justin Buchanan

Oklahoma State University

Erika Downey

Texas A&M University

Melinda Ellison

University of Wyoming

Breno Fragomeni

University of Georgia

Erika Lundy

Iowa State University

Lauren Schiermiester

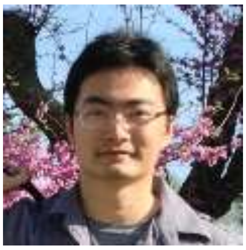
University of Nebraska-Lincoln

Jose Antonio Torres-Vazquez

University of Nebraska-Lincoln

Bryan Welly

University of California-Davis



Jian Zeng

Iowa State University

Xi Zeng

Colorado State University

USDA United States Department of Agriculture National Institute of Food and Agriculture

These travel scholarships are made possible through the National Institute of Food and Agriculture, U.S. Department of Agriculture.

Berk-Mar Farm

Owners: Berkley "Lin" Jones, Brenda Jones, and Kathleen Jones

Managers: Berkley "Lin" Jones and Brenda Jones

New Canton, Virginia

Berk-Mar Farm, located in Buckingham County in the central part of Virginia, was established in 1968. Lin and Brenda Jones began managing the farm in 1980. It is an Angus x Gelbvieh cross beef cattle operation, currently running approximately 200 head of brood cows. The farm totals 555 acres- 300 acres of pasture with 255 acres of hayland. Berk-Mar's breeding program consists of first service by artificial insemination and natural service clean-up; resulting in a 90 day calving season beginning in October.

Berk-Mar Farm has been a member of the Buckingham Cattlemen's Association (BCA) since 1990. Lin and Brenda both serve on the Board of Directors, and Brenda fills the office of Treasurer. Berk-Mar Farm believes strongly in best management practices and value-added marketing which is accomplished through the Virginia Quality Assured Feeder Cattle Program and Virginia Premium Assured Heifer Programs. Berk-Mar participates in the BCA's fall feeder calf sale and their annual Bred Heifer and Young Cow sale.

Their herd health program has resulted in consistent, healthy animals in the feedlots and provides the buyers with a uniform and quality beef product. Pasture and hayland management includes 50 acres of fescue stockpiled for late fall/winter feeding; 17 acres of alfalfa, in addition to the orchard-grass/fescue hay mixtures. The Jones' have been recognized with the Clean Water Farm Award from Peter Francisco Soil and Water Conservation District in 2000, the High Cow Conception Rate Award from ABS Global in 2011, and are active 4-H supporters and volunteers.

The Virginia Beef Cattle Improvement Association is proud to nominate Berk-Mar Farm.

Darnall Ranch, Inc.

Owner: Gary Darnall

Managers: Gary Darnall and Lane Darnall

Harrisburg, Nebraska

Darnall Ranch Inc. is a family owned cow/calf operation, feedlot and farm located in the Panhandle of Nebraska, 30 miles southeast of Scottsbluff, Nebraska. The ranch was originally homesteaded in 1889 by Scott Darnall and incorporated in 1973. The operation has been in the family for 124 years. Mattie Darnall is 3rd generation, Gary and Emilie Darnall are 4th generation, Lane and Robin Darnall along with Bob and Lisa (Darnall) Brenner are 5th generation, with 6th and 7th generations living and working on the ranch.

Darnall Ranch began over 40 years ago from 150 Hereford cows, 1,400 acres of farm ground and by selling their calves at weaning. Today the cow herd consists of 1,700 commercial Angus females utilizing SimAngus bulls which produce 300-400 replacement heifers annually. Bulls are developed using EPD's, genomics and the Grow Safe system. The balance of Darnall Ranch offspring are fed out in the 22,500 head Certified Angus Beef commercial feedlot with records of conversion, rate of gain, grade and yield, along with a profitability analysis each year. Twenty-five thousand acres of grassland, 2,400 acres of irrigated and 4,700 acres of dry land farm ground are used to grow the feedstuffs to help support the cow/calf, yearling, and feedlot operations.

The cow herd calves in February and March with the first calf heifers calving two weeks before the cowherd; and 75% of the calves being born in the first 30 days. Darnall Ranch strives to use the land and cattle as an efficient and economical multi-generational agri-business.

Darnell Ranch is proudly nominated by the Nebraska Cattlemen.

Irsik Ranch
Owner: Irsik Farms
Manager: Jim Reimer
Cimarron, Kansas

Irsik Ranch is headquartered 10 miles north of Kalvesta, KS, or 45 miles northwest of Dodge City, in the northeast corner of Finney County. The ranch was founded in 1981 by the Irsik Brothers, with Steve Irsik as one of the owners and Jim Reimer as ranch manager. Brandon Seifried joined the ranch in 2008 as Irsik Ranch herdsman. Cliff Benner is the manager of the Nebraska ranch.

The operation consists of commercial cows, a backgrounding/grow yard and a dryland farm, producing wheat, alfalfa, cane feed and sorghum silage. A Nebraska Sandhills ranch was purchased in 2012 to hedge against the drought in Kansas. The purchase of the Nebraska ranch began as a way to save the genetics developed through years of an intensive AI program, but also should prove to be an opportunity to grow the operation. Native wet meadow hay and alfalfa are harvested on the Nebraska ranch.

Normal carrying capacity between the two ranches is 2,000 cows, plus replacement heifers. High-performing black Angus cows provide the base for the entire operation. In 2007, 1,000 of those cows were artificially inseminated to industry-leading Hereford bulls. The hybrid vigor realized by crossing top Angus and Hereford genetics produces an animal that not only survives, but also thrives in the harsh range conditions in which they are expected to live. The Irsik Ranch continues to cross Hereford bulls on their Angus cows, while black whiteface cows are bred to Angus bulls.

With Steve Irsik's founding leadership, trust in its managers and a detailed accounting of all aspects of the operation, Irsik Ranch is in a position to be profitable, while improving its natural resources well into the next generation.

The Kansas Livestock Association is proud to nominate Irsik Ranch.

Mayer Ranch
Owners/Managers: Joe and MaryAnn Mayer
Guymon, Oklahoma

Joe Mayer's great grandfather moved to Texline, TX from Savannah, MO to assume management duties of the Buffalo Springs Division for the famed XIT Ranch. Trailing cattle to Dodge City, KS, they passed through this "No Man's Land," which is now the Oklahoma panhandle. They eventually settled there in 1883, establishing their own ranch known as the "Anchor D."

Joe and MaryAnn were married in July of 1971, and after receiving his degree from Oklahoma Panhandle State University, assumed co-management, along with his father, of the family's operation. For 100 years, the operation had consisted of Hereford cows, but eventually became a commercial Angus operation, beginning that transition in the mid- to late 1970's.

Today's ranch consists of 1,400 head of commercial, spring-calving Angus cows that run on 26,000 acres of native range. They recently purchased another ranch at Unionville, MO, that consists of 1,640 acres. They retain their own replacement heifers, and feed their steers and cull heifers at a commercial feedlot in Kansas. Believing that quality is paramount, the cattle are bred for carcass traits and are sold on a grid that pays premiums for carcasses that grade USDA Prime and Certified Angus Beef.

The couple has three children, two of which are involved in the operation. Son, Paul, lives near Hardesty, OK, and is directly involved with the ranch. Daughter, Margie, lives on the ranch and keeps the record books. Oldest daughter, Katie, lives in Evergreen, Colorado, and is an attorney with degrees from Harvard.

Mayer Ranch is proudly nominated by the American Angus Association.

Roberts Farms

Owners: Glen and Tom Roberts

Corning, Iowa

Nestled near the rolling hills of southwestern Iowa, the Roberts operation includes Glen, son Tom and grandson, Ryan who manage the 700 head operation. Glen and Tom were pork producers for several years before they switched to a cow/calf operation in 1988. At that time they purchased their first Limousin bulls and have purchased 4 - 5 bulls every year. They have developed a trusted relationship with their seedstock supplier Leih Limousin, who helps them to add new genetics annually to increase weaning weight and improve fertility in their retained heifers.

The Roberts herd is made up of 500 spring calvers and 200 fall calvers. They have a strict 45-day breeding window using a 15-1 cow to bull ratio. They purchase a few bred heifers per year in addition to retaining approximately 60 home raised heifers. Cows are pregnancy checked and open cows are sent to the market. Steers and commercial replacement heifers are marketed after an extensive vaccination and backgrounding period to ensure the utmost quality and health for their customers.

The North American Limousin Foundation is proud to nominate Roberts Farms.

Rosen's XL Farm

Owners: Gordon and Ann Rosen

Manager: Miguel Ruiz

Tuscaloosa, Alabama

Gordon Rosen graduated from high school in Fort Sumner, New Mexico. While in Fort Sumner, a father of a friend of Mr. Rosen's was the manager of the XL ranch. While on the XL Ranch in the 1930s, a love of ranching and cattle handling was instilled in Gordon. He adopted the XL brand for his own cattle operation in Tuscaloosa, which he still uses today. Gordon Rosen began raising cattle in a modest way in 1968 and acquired more cattle after expanding his acreage by acquiring larger farms. He joined the Alabama Beef Cattle Improvement Association (AL BCIA) in the late 1990's. The AL BCIA program provided the basics for record keeping and the knowledge to improve the performance and productivity of his cowherd. Rosen's XL Farm consists of 90 Simmental and Angus cross cows grazing 340 acres of pasture consisting of Bermudagrass, Bahiagrass and Tall Fescue and seasonal grazing with planted Marshall ryegrass, crimson clover and annual crabgrass. Throughout the year, limit, rotational and strip grazing and also stockpiling are all utilized to maximize forage resources.

A fall calving season, to capture market advantage for feeder cattle, begins in late September and goes through early December. In the fall of 2012, 82 percent of the cows calved in the first thirty days. Artificial insemination (AI) has allowed this higher percentage of the calf crop to be born early in the calving season. AI provided the 2011 calf crop to be 8.7 days older than the 2010 calf crop and produce 23.5 pounds of additional weight per calf with an average daily gain of 2.7 pounds from birth to 205 day weight collection. This herd's success was achieved through careful selection of both culling and replacements, extensive use of AI, utilization of a forage based program and, of course, meticulous record keeping. Rosen's XL Farm has also been honored with earning numerous AL BCIA Gold Star Cow Awards.

The Alabama Beef Cattle Improvement Association is proud to nominate Rosen's XL Farm.

Wood Ranch

Owner: Dell Wood

Manager: Rusty Daniel

Coleman, Oklahoma

Rusty Daniel has managed all cattle operations at the Wood Ranch since 2005. The ranch consists of several properties totaling 3,550 acres around Wapanucka, Oklahoma. There are approximately 475 Angus and Angus-crossbred cows and 20 terminal Charolais bulls. Cows calve in a 75-day period starting the end of January through the first of April. In a typical year, hay is fed for 2-3 months and is purchased off the ranch. Feed supplementation is provided as needed based on body condition score, and mineral is provided free choice. Supplementation costs are less than $100 per cow in a normal year. During the growing season, cows are rotationally grazed to best utilize the forage resources. The forage base is predominately bermudagrass over-seeded with ryegrass and scattered fescue. Cows are vaccinated according to a herd health plan that was developed with the assistance of the Noble Foundation and our veterinarian. Calves are vaccinated according to the requirements of the Integrity Beef Alliance.

All calves are retained after weaning and backgrounded to the point that cost of gain equals the value of gain, typically around 750-850 pounds. Least-cost rations are developed by a Noble Foundation Livestock Consultant and bulk feed is purchased to decrease costs. Calves are marketed directly to the feedlot and performance and carcass data are returned to the ranch.

Kempfer Cattle Company is proudly nominated by The Samuel Roberts Noble Foundation and the American-International Charolais Association.

Past Award Winners

Commercial Producer of the Year Award

Name	State	Year
Chan Cooper	Montana	1972
Pat Wilson	Florida	1973
Lloyd Nygard	North Dakota	1974
Gene Gates	Kansas	1975
Ron Baker	Oregon	1976
Mary and Stephen Garst	Iowa	1977
Mose Tucker	Alabama	1978
Bert Hawkins	Oregon	1979
Jess Kilgore	Montana	1980
Henry Gardiner	Kansas	1981
Sam Hands	Kansas	1982
Al Smith	Virginia	1983
Bob and Sharon Beck	Oregon	1984
Glenn Harvey	Oregon	1985
Charles Fariss	Virginia	1986
Rodney G. Oliphant	Kansas	1987
Gary Johnson	Kansas	1988
Jerry Adamson	Nebraska	1989
Mike and Diana Hopper	Oregon	1990
Dave and Sandy Umbarger	Oregon	1991
Kopp Family	Oregon	1992
Jon Ferguson	Kansas	1993
Fran and Beth Dobitz	South Dakota	1994
Joe and Susan Thielen	Kansas	1995
Virgil and Mary Jo Huseman	Kansas	1996
Merlin and Bonnie Anderson	Kansas	1997
Randy and Judy Mills	Kansas	1998
Mike and Priscilla Kasten	Missouri	1998
Giles Family	Kansas	1999
Mossy Creek Farm	Virginia	1999
Bill and Claudia Tucker	Virginia	2000
Maxey Farms	Virginia	2001
Griffith Seedstock	Kansas	2002
Tailgate Ranch	Kansas	2003
Olsen Ranches, Inc.	Nebraska	2004
Prather Ranch	California	2005
Pitchfork Ranch	Illinois	2006
Broseco Ranch	Colorado	2007
Kniebel Farms and Cattle Company	Kansas	2008
JHL Ranch	Nebraska	2009
Downey Ranch	Kansas	2010
Quinn Cow Company	Nebraska	2011
Maddux Cattle Company	Nebraska	2012

2013 Nominees

Berk-Mar Farm

Darnall Ranch, Inc.

Irsik Ranch

Mayer Ranch

Roberts Farms

Rosen's XL Farm

Wood Ranch

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year
Chan Cooper	Montana	1972
Alfred B. Cobb, Jr.	Montana	1972
Lyle Eivens	Iowa	1972
Broadbent Brothers	Kentucky	1972
Jess Kilgote	Montana	1972
Clifford Ouse	Minnesota	1973
Pat Wilson	Florida	1973
John Glaus	South Dakota	1973
Sig Peterson	North Dakota	1973
Max Kiner	Washington	1973
Donald Schott	Montana	1973
Stephen Garst	Iowa	1973
J.K. Sexton	California	1973
Elmer Maddox	Oklahoma	1973
Marshall McGregor	Missouri	1974
Dave Matti	Montana	1974
Lloyd DeBruycker	Montana	1974
Gene Rambo	California	1974
Jim Wolf	Nebraska	1974
Henry Gardiner	Kansas	1974
Johnson Brothers	South Dakota	1974
John Blankers	Minnesota	1975
Paul Burdett	Montana	1975
Oscar Burroughs	California	1975
John R. Dahl	North Dakota	1975
Eugene Duckworth	Missouri	1975
Gene Gates	Kansas	1975
V.A. Hills	Kansas	1975
Robert D. Keefer	Montana	1975
Kenneth E. Leistritz	Nebraska	1975
Ron Baker	Oregon	1976
Dick Boyle	Idaho	1976
James Hackworth	Missouri	1976
John Higendorf	Minnesota	1976
Kahau Ranch	Hawaii	1976
Milton Mallery	California	1976
Robert Rawson	Iowa	1976
William A. Stegner	North Dakota	1976
U.S. Ranger Exp. Stat	Montana	1977
Maynard Crees	Kansas	1977
Ray Franz	Montana	1977
Forrest H/ Ireland	South Dakota	1977
John A. Jameson	Illinois	1977
Leo Knoblauch	Minnesota	1977
Jack Pierce	Idaho	1977
Mary & Stephen Garst	Iowa	1977
Todd Osteross	North Dakota	1978
Charles M. Jarecki	Montana	1978
Jimmy G. McDonnl	North Carolina	1978
Victor Arnaud	Missouri	1978
Ron McGregor	Iowa	1978
Malcom McGregor	Iowa	1978
Otto Uhrig	Nebraska	1978
Arnold Wyffels	Minnesota	1978
Bert Hawkins	Oregon	1978
Mose Tucker	Alabama	1978
Dean Haddock	Kansas	1978
Myron Hoeckle	North Dakota	1979
Harold Arnold	South Dakota	1979
Wesley Arnold	South Dakota	1979

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year	Name	State	Year
Ralph Neill……………….	Iowa…………..	1979	Rick Turner……………...	Missouri………	1981
Morris Kuschel…………..	Minnesota…….	1979	Oren % Jerry Raburn…….	Oregon………..	1981
Bert Hawkins…………….	Oregon………..	1979	Orin Lamport…………….	South Dakota…	1981
Dick Coon………………..	Washington…..	1979	Leonard Wulf…………….	Minnesota…….	1981
Jerry Northcutt…………...	Missouri………	1979	Wm. H. Romersberter……	Illinois………..	1982
Steve McDonnell………...	Montana………	1979	Milton Krueger…………..	Missouri………	1982
Doug Vandermyde……….	Illinois………..	1979	Carl Odegard……………..	Montana………	1982
Calvin Thompson………...	South Dakota…	1979	Marvin & Donald Stoker...	Iowa…………..	1982
Denton Thompson……….	South Dakota…	1979	Sam Hands……………….	Kansas………..	1982
Norman Thompson……...	South Dakota…	1979	Larry Campbel…………...	Kentucky……..	1982
Jess Kilgore……………...	Montana………	1980	Earl Schmidt……………..	Minnesota…….	1982
Robert & Lloyd Simon…..	Illinois………..	1980	Raymond Josephson……..	North Dakota…	1982
Lee Eaton………………..	Montana………	1980	Clarence Reutter…………	South Dakota…	1982
Leo & Eddie Grubl……...	South Dakota…	1980	Leonard Bergen…………..	Canada………..	1982
Roger Winn, Jr. ………...	Virginia………	1980	Kent Brunner……………..	Kansas………..	1983
Gordon McLean………..	North Dakota…	1980	Tom Chrystal…………….	Iowa ………….	1983
Ed Disterhaupt………….	Minnesota…….	1980	John Freltag………………	Wisconsin…….	1983
Thad Snow……………....	Canada………..	1980	Eddie Hamilton…………..	Kentucky……..	1983
Oren Jerry Raburn……...	Oregon………..	1980	Bill Jones…………………	Montana………	1983
Bill Lee………………….	Kansas………..	1980	Harry & Rick Kline……...	Illinois………..	1983
Paul Moyer……………….	Missouri………	1980	Charlie Kopp……………..	Oregon………..	1983
G.W. Campbell…………..	Illinois………..	1981	Duwayne Olson…………..	South Dakota....	1983
J.J. Feldmann…………….	Iowa…………..	1981	Ralph Pederson…………..	South Dakota....	1983
Henry Gardiner…………..	Kansas………..	1981	Ernest & Helen Schaller…	Missouri……...	1983
Dan L. Weppler…………..	Montana………	1981	Al Smith………………….	Virginia………	1983
Harvey P. Wehri…………	North Dakota…	1981	John Spencer……………..	California……..	1983
Dannie O’Connell……….	South Dakota…	1981	Bud Wishard……………..	Minnesota…….	1983
Wesley Arnold…………...	South Dakota...	1981	Bob & Sharon Beck……...	Oregon………..	1984
Harold Arnold……………	South Dakota...	1981	Leonard Fawcett…………	South Dakota…	1984
Jim Russell……………….	Missouri………	1981	Fred & Lee Kummerfeld…	Wyoming……..	1984

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year
Norman Coyner & Sons….	Virginia………	1984
Franklyn Esser…………..	Missouri……...	1984
Edgar Lewis……………..	Montana………	1984
Boyd Mahrt………………	California……..	1984
Neil Moffat………………	Canada………..	1984
William H. Moss, Jr……..	Georgia……….	1984
Dennis P. Sovie…………..	Minnesota…….	1984
Robert P. Stewart………..	Kansas………..	1984
Charlie Stokes……………	North Carolina..	1984
Milton Wendland………...	Alabama……...	1984
Bob & Sheri Schmidt…….	Minnesota…….	1985
Delmer & Joyce Nelson….	Illinois………..	1985
Harley Brockel…………..	South Dakota…	1985
Kent Brunner……………..	Kansas………..	1985
Glenn Havery…………….	Oregon………..	1985
John Maino………………	California……..	1985
Ernie Reeves……………..	Virginia………	1985
John R. Rouse……………	Wyoming……..	1985
George & Thelma Boucher	Canada………..	1985
Kenneth Bentz……………	Oregon………..	1986
Gary Johnson…………….	Kansas………..	1986
Ralph G. Lovelady……….	Alabama……...	1986
Ramon H. Oliver…………	Kentucky……..	1986
Kay Richarson……………	Florida………..	1986
Mr. & Mrs. Clyde Watts…	North Carolina..	1986
David & Bev Lischka……	Canada………..	1986
Dennis & Nancy Daly……	Wyoming……..	1986
Carl & Fran Dobitz………	South Dakota…	1986
Charles Fariss…………….	Virginia………	1986
David Forster…………….	California……..	1986
Danny Geersen…………..	South Dakota…	1986
Oscar Bradford…………..	Alabama……...	1987
R.J. Mawer……………….	Canada………..	1987
Rodney G. Oliphant……...	Kansas………..	1987
David Reed………………	Oregon………..	1987
Jerry Adamson…………...	Nebraska…...…	1987
Gene Adams……………...	Georgia……….	1987
Hugh & Pauline Maize…..	South Dakota…	1987
P.T. McIntire & Sons…….	Virginia………	1987
Frank Disterhaupt………..	Minnesota…….	1987
Mac, Don & Joe Griffith…	Georgia……….	1988
Jerry Adamson…………...	Nebraska……..	1988
Ken, Wayne & Bruce…….	Gardiner Canada	1988
C.L. Cook………………...	Missouri………	1988
C.J. & D.A. McGee………	Illinois………..	1988
William E. White………...	Kentucky……..	1988
Frederick M. Mallory…….	California……..	1988
Stevenson Family………...	Oregon………..	1988
Gary Johnson…………….	Kansas………..	1988
John McDaniel…………...	Alabama……...	1988
William Stegner………….	North Dakota…	1988
Lee Eaton………………...	Montana………	1988
Larry D. Cundall…………	Wyoming……..	1988
Dick & Phyllis Henze……	Minnesota…….	1988
Jerry Adamson…………...	Nebraska……..	1989
J.W. Aylor………………..	Virginia………	1989
Jerry Bailey………………	North Dakota...	1989
James G. Guyton…………	Wyoming……..	1989
Kent Koostra……………..	Minnesota…….	1989
Ralph G. Lovelady……….	Nebraska……...	1989

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year
Thomas McAvory, Jr.	Virginia	1989
Bill Salton	North Dakota	1989
Lauren & Mel Schuman	Wyoming	1989
Jim Tesher	Kentucky	1989
Joe Thielen	Alabama	1989
Eugene & Ylene Williams	Georgia	1989
Phillip, Patty & Greg Bartz	Missouri	1990
John C. Chrisman	Wyoming	1990
Les Herbst	Kentucky	1990
Jon C. Ferguson	Kansas	1990
Mike & Dianna Hooper	Oregon	1990
James & Joan McKinlay	Canada	1990
Gilbert Meyer	South Dakota	1990
DuWayne Olson	South Dakota	1990
Raymond R. Peugh	Illinois	1990
Lewis T. Pratt	Virginia	1990
Ken & Wendy Sweetland	Canada	1990
Swen R. Swenson Cattle	Texas	1990
Robert A. Nixon & Sons	Virginia	1991
Murray A. Greaves	Canada	1991
James Hauff	North Dakota	1991
J.R. Anderson	Wisconsin	1991
Ed & Rich Blair	South Dakota	1991
Reuben & Connee Quinn	South Dakota	1991
Dave & Sandy Umbarger	Oregon	1991
James A. Theeck	Texas	1991
Ken Stielow	Kansas	1991
John E. Hanson, Jr.	California	1991
Charles & Clyde Henderson	Missouri	1991
Russ Green	Wyoming	1991
Bollman Farms	Illinois	1991
Craig Utesch	Iowa	1991
Mark Barenthsen	North Dakota	1991
Rary Boyd	Alabama	1992
Charles Daniel	Missouri	1992
Jed Dillard	Florida	1992
John & Ingrid Fairhead	Nebraska	1992
Dale J. Fischer	Iowa	1992
E. Allen Grimes Family	North Dakota	1992
Kopp Family	Oregon	1992
Harold Marshall	Pennsylvania	1992
Barbara Marshall	Pennsylvania	1992
Jeff Marshall	Pennsylvania	1992
Clinton E. Martin & Sons	Virginia	1992
Loyd & Pat Mitchell	Canada	1992
William Van Tassel	Canada	1992
James A. Theeck	Texas	1992
Aquilla M. Ward	West Virginia	1992
Albert Wiggins	Kansas	1992
Ron Wiltshire	Canada	1992
Andy Bailey	Wyoming	1993
Leroy Beiterspacher	South Dakota	1993
Glenn Valbaugh	Wyoming	1993
Oscho Deal	North Carolina	1993
Jed Dillard	Florida	1993
Art Farley	Illinois	1993
Jon Ferguson	Kansas	1993
Walter Hunsuker	California	1993
Nola & Steve Kielboeker	Missouri	1993
Jim Maier	South Dakota	1993

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year
Bill & Jim Martin………..	West Virginia...	1993
Ian & Adam McKillop…...	Canada………..	1993
George & Robert Pingetzer	Wyoming……..	1993
Timothy D. Sufphin……	Virginia………	1993
James A. Theeck…………	Texas…………	1993
Gene Thiry……………….	Canada………..	1993
Fran & Beth Dobitz………	South Dakota...	1994
Bruce Hall………………..	South Dakota	1994
Lamar Ivey……………….	Alabama……...	1994
Gordon Mau……………...	Iowa…………..	1994
Randy Mills……………...	Kansas………..	1994
W.W. Oliver……………...	Virginia………	1994
Clint Reed………………..	Wyoming……..	1994
Stan Sears………………...	California……..	1994
Walter Carlee…………….	Alabama……...	1995
Nicholas Lee Carter……...	Kentucky……..	1995
Charles C. Clark, Jr………	Virginia………	1995
Greg & Mary Gunningham	Wyoming……..	1995
Robert & Cindy Hine…….	South Dakota…	1995
Walter Jr. & Evidean Major	Kentucky……..	1995
Delhert Ohnemus………...	Iowa…………..	1995
Henry Stone……………...	California……..	1995
Joe Thielen……………….	Kansas………..	1995
Jack Turnell……………...	Wyoming……..	1995
Tom Woodard…………...	Texas…………	1995
Jerry and Linda Bailey…...	North Dakota…	1996
Kory M. Bierle…………...	South Dakota...	1996
Mavis Dummermuth……..	Iowa…………	1996
Terry Stuart Forst………...	Oklahoma……	1996
Don W. Freeman…………	Alabama……...	1996
Lois & Frank Herbst……..	Wyoming……..	1996
Mr. George A. Horkan, Jr.	Virginia………	1996
David Howard……………	Illinois……….	1996
Virgil & Mary Jo Huseman	Kansas……….	1996
Q.S. Leonard……………..	North Carolina..	1996
Ken & Rosemary Mitchell	Canada………..	1996
James Sr. Petlik…………..	South Dakota…	1996
James & Jerry Petlik……..	South Dakota...	1996
Ken Risler…………………	Wisconsin…….	1996
Merlin Anderson…………	Kansas………..	1997
Joe C. Bailey……………..	North Carolina..	1997
William R. “Bill” Brockett	Virginia………	1997
Howard McAdams, Sr…..	North Carolina..	1997
Howard McAdams, Jr…...	North Carolina..	1997
Rob Orchard……………...	Wyoming……..	1997
David Petty………………	Iowa…………..	1997
Rosemary Rounds……….	South Dakota…	1997
Marc & Pam Scarborough	South Dakota…	1997
Morey & Pat Van Hoecke	Minnesota…….	1997
Randy & Judy Mills……...	Kansas………..	1998
Mike & Priscille Kasten….	Missouri………	1998
Amana Farms, Inc………..	Iowa…………..	1998
Terry & Dianne Crisp……	Canada………..	1998
Jim & Carol Faulstich……	South Dakota…	1998
James Gordon Fitzhugh….	Wyoming……..	1998
John B. Mitchell…………	Virginia………	1998
Holzapfel Family………...	California……..	1998
Mike Kitley………………	Illinois………..	1998
Wallace & Donald Schilke	North Dakota...	1998
Doug & Ann Deane……...	Colorado……...	1998

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year
Patricia R. Spearman…….	Colorado……...	1998
Glenn Baumann…………	North Dakota...	1999
Bill Boston………………	Illinois……….	1999
C-J-R-Christensen Ranches	Wyoming……..	1999
Ken Fear, Jr………………	Wyoming……..	1999
Giles Family……………...	Kansas………..	1999
Burt Guerrieri…………….	Colorado……...	1999
Karlen Family……………	South Dakota…	1999
Deseret Ranches of Alberta	Canada………..	1999
Nick & Mary Klintworth...	North Dakota	1999
MW Hereford Ranch…….	Nebraska……	1999
Mossy Creek Farm……….	Virginia………	1999
Iris, Bill, & Linda Lipscomb…………	Alabama ……..	1999
Amana Farms, Inc………..	Iowa…………..	1999
Tony Boothe……………..	Alabama……...	2000
Glenn Clabaugh…………	Wyoming……	2000
Connie, John & Terri Griffith…………….	Kansas ……….	2000
Frank B. Labato…………	Colorado……...	2000
Roger & Sharon Lamont…	South Dakota...	2000
Doug & Shawn Lamont….	South Dakota...	2000
Bill & Claudia Tucker….	Virginia………	2000
Wayne & Chip Unsicker...	Illinois………..	2000
Billy H. Bolding…………	Alabama…..…	2001
Mike and Tom Endress…	Illinois………..	2001
Henry & Hank Maxey…..	Virginia……...	2001
Paul McKee………………	Kansas……….	2001
Agri-Services Division, Department of Corrections	Oklahoma…….	2000
3-R Ranch………………..	Colorado……...	2002
Alpine Farms……………..	Virginia………	2002
Amana Farms…………….	Iowa…………..	2002
Griffin Seedstock……….	Kansas………..	2002
Indian Knoll Cattle Co…..	Illinois………..	2002
Miles Land & Livestock…	Wyoming……..	2002
Shovel Dot Ranch………..	Nebraska……...	2002
Torbert Farms……………	Alabama……...	2002
White Farms……………...	Iowa…………..	2002
Voyles Farms…………….	Indiana……….	2002
Clear Creek Cattle Co……	Wyoming……..	2003
Crider Salers……………..	North Dakota…	2003
Mike Goldwasser………...	Virginia………	2003
Patterson Ranch…………	Colorado…….	2003
W.S. Roberts & sons……..	Indiana……….	2003
Shriver Farms…………….	Ohio………….	2003
Stroud Farms……………..	Alabama……...	2003
Tailgate Ranch Company...	Kansas………..	2003
Burkhalter Cattle…………	Alabama……...	2004
Doler Farm……………….	Mississippi……	2004
LU Ranch………………...	Wyoming……..	2004
Namminga Angus………..	South Dakota…	2004
Nellwood Farms…………	Georgia……….	2004
Olsen Ranches, Inc………	Nebraska……...	2004
Prather Ranch (Ralphs Ranches)	California……..	2004
Blair Porteus & Sons……..	Ohio…………..	2004
Rx Ranch…………………	Missouri………	2004
Schuette Farms…………..	Illinois……….	2004
Valdez Ranches…………..	Colorado……...	2004
Wickstrum Farms Inc…….	Kansas………..	2004
CK Ranch………………...	Kansas………..	2005

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year	Name	State	Year
Diamond V Ranch……….	North Dakota...	2005	Stuart Land & Cattle Co…	Virginia………	2007
Dover Ranch……………..	Montana………	2005	CL Ranches Ltd…………	Canada……….	2008
Gaines Farm……………...	Alabama……...	2005	Eatinger Cattle Co………..	Nebraska……...	2008
Hillwinds Farm…………..	Virginia………	2005	Frank Farms……………...	Colorado……...	2008
Krupps Farm……………..	Illinois………..	2005	Genereux Ranch…………	Montana………	2008
Jack & Ila Mae Larson…...	Colorado……..	2005	Jack Giltner………………	Iowa…………..	2008
Mule Creek Ranch……….	Kansas………..	2005	Hollow Hill Farm………...	Virginia………	2008
Paxton Ranch…………….	Nebraska……...	2005	JL Cattle Company………	Colorado……...	2008
Pontious Farms…………..	Ohio…………..	2005	Kniebel Farms & Cattle Co.	Kansas………..	2008
Prather Ranch…………….	California……..	2005	Otley Brothers Inc………..	Oregon………..	2008
Shovel Dot Ranch………..	Nebraska……..	2005	Toland's River Oak Ranch	Illinois………..	2008
Wintergreen Farm………..	Iowa…………..	2005	Tom Bengard Ranches…..	California……..	2008
Duck Farm Inc…………...	Virginia………	2006	Win Parmer………………	Alabama……...	2008
Hunt Hill Cattle Co………	Mississippi…...	2006	Anderson Land & Cattle…	Kansas………..	2009
McDorman Farms……….	Ohio…………..	2006	Tom Bengard Ranches…..	California……..	2009
Pitchfork Ranch…………	Illinois………..	2006	Joe Davis Cattle Farm…...	South Carolina..	2009
Rock Creek Ranch……….	Kansas……….	2006	Freedom Hills Ranch…….	Illinois………..	2009
Sutherland Ranches……...	Colorado……...	2006	JHL Ranch……………….	Nebraska……...	2009
Van Waarhuizen, Inc…….	Iowa…………	2006	Gale Rippey Farms………	Virginia………	2009
Broseco Ranch…………...	Texas………...	2007	Slusher Valley Farms…….	Virginia……...	2009
4Z Farms…………………	Kansas……….	2007	Stephens Farm……………	Alabama……..	2009
CK Ranch………………...	Kansas……….	2007	Stan & Lisa Buzzard……..	Illinois……….	2010
Barry Dowell Family…….	Illinois………..	2007	Downey Ranch…………...	Kansas………..	2010
Larry Dowell Family…….	Illinois……….	2007	G.W. Jones & Sons Farms	Alabama……...	2010
Eagle Rock Ranch………..	Colorado……..	2007	M&B Limousin…………..	Missouri………	2010
Eatinger Cattle Company...	Nebraska……..	2007	Duane Martin Livestock…	California…….	2010
JHL Ranch……………….	Nebraska……..	2007	Optimal Beef, LLC………	Virginia………	2010
Lacey Livestock…………	California……..	2007	Bambarger Cattle Farm…..	Alabama……...	2011
Lerwick Brothers LLC…..	Wyoming……..	2007	Durheim Ranch………….	North Dakota...	2011
MG Farms………………..	Mississippi……	2007	E. Roen Ranches…………	California……..	2011

Past Award Winners

Commercial Producer Honor Roll of Excellence

Name	State	Year
Larson Angus Ranch……..	Kansas………..	2011
Leavitt Lake Ranches…….	California……..	2011
Quinn Cow Company……	Nebraska……...	2011
Silver Spur Ranch……….	Wyoming……..	2011
Carswell-Nichols Herefords	Kansas………..	2011
Five Dot Ranch………….	California……..	2012
Glenmary Farm………….	Virginia………	2012
H&T Bies Cattle Company	South Dakota...	2012
Jones Brothers Farm…….	Alabama……...	2012
Kempfer Cattle Company..	Florida………..	2012
Maddux Cattle Company..	Nebraska……...	2012
Matador Cattle Company..	Kansas………..	2012
Slykhuis Farms…………..	Illinois………..	2012

Bradley 3 Ranch
Owners/Managers: Mary Lou Bradley-Henderson, Minnie Lou Bradley, and James Henderson
Memphis, Texas

Bradley 3 Ranch was started in 1955 with the purchase of 20 registered Angus cows. Today the herd is one of the few Angus herds in the country that has maintained over 200 registered Angus cows for more than fifty years.

Early on the Bradleys were committed to a disciplined approach to performance. As one of the first members of the American Beef Cattle Performance Registry, they maintained an emphasis on performance that is still the foundation of the herd today.

Bradley 3 Ranch is home to 400 registered Angus cows and 35 registered Charolais cows. The Charolais cows were added in 2009 to offer customers a cross breeding opportunity. All of the cows calve in a fall calving season and in normal moisture years, the only supplemental feed is protein supplement. They do not creep feed.

The ranch is located in the southeast part of the Texas Panhandle. Much of the ranch is rough with canyons, draws, mesquite and cedar trees. To complicate matters, the natural water on the ranch is very "gypy" and makes it difficult to introduce new genetics.

In 1986, the Bradleys started B3R Country Meats. In the next sixteen years, they built the all-natural meat company to a 125 per day harvest facility that harvested over 30,000 head in 2002, which was the year it was sold. Customers were both beef producers and beef consumers. The beef producers were part of one of the earliest value based marketing systems in the U.S. The experience gained at B3R Country Meats lends to a strong emphasis on muscle in their cattle today.

Bradley 3 Ranch is proudly nominated by the Texas Angus Association.

Coyote Hills Ranch
Owners/Managers: Ken and Sue Ann Holloway
Chattanooga, Oklahoma

Coyote Hills Ranch of Chattanooga, OK, is located in far southwest Oklahoma. The ranch has been owned and operated by Ken and Sue Ann Holloway and daughters, Shari and Shana, at this location for 41 years. The ranch consists of some 3,000 acres largely native grass and improved grasses with some 500 in cultivation mostly wheat and sorghum for silage.

The cowherd is made up of 250 cows, mostly Limousin and Lim-Flex cows with several registered Angus cows. It is a seedstock operation whose primary goal is production of bulls for the commercial rancher. A majority of the cowherd is fall calving (80%) and the balance is February and March. From the start, Ken was interested in evaluating bulls on performance and so he started one of the first performance tests in the Limousin breed in 1971.

Bulls are marketed through their annual March production sale and females in the annual April female sale. Bulls are also exhibited in The Yards at National Western to promote the herd to commercial and seedstock producers alike. Some heifers raised at Coyote Hills have gone on to win major shows across the country for juniors. The Holloways have always been champions of the junior program which both Shari and Shana were very successful in. Coyote Hills Ranch continues to help young people today in the show and help market the offspring of their projects.

The North American Limousin Foundation is proud to nominate Coyote Hills Ranch.

Hunt Limousin Ranch
Owners: Charles and Nancy Hunt
Managers: Charles and Daniel Hunt
Oxford, Nebraska

"Conserve the land for the future generations, keep current and knowledgeable on the leading cattle issues, high quality cattle for a fair price, and treat people with honesty and integrity." The Charles Hunt Family operation began in the 1960's after Charlie attended the University of Nebraska. With a love for God, family, the land, and cattle, Charlie and Nancy were ready for the opportunity to do what they enjoy.

The 4,500 acre diversified operation consists of dryland and irrigated corn, soybeans, alfalfa, wheat and grass land which supports 300 cows, marketable bulls, and replacement females. Genetics have been placed all over the globe including Argentina, Canada, Mexico, Australia, New Zealand, and 37 U.S. states. Bulls have been displayed at the National Western Stock Show for the past 30 years. The Hunts have attended many BIF, NCBA, and numerous other Ag conferences. Charlie has been the recipient of many awards including the first ever Commercial Marketing Supporter Award from the North American Limousin Foundation. One of the most prestigious awards was being inducted into the Nebraska Cattlemen's Hall of Fame. They have met some of their best friends in the cattle industry. Hunt Limousin Ranch has hosted tour groups and individuals from foreign countries who want to learn the "Hunt Way."

Charlie and Nancy have four children. They are blessed with nine grandchildren who keep the sparkle in their eyes and a smile on their faces. Their family is always ready and willing to offer a helping hand. One of their greatest honors is to have their son, Dan, follow in Charlie's footsteps. It is a joy having Dan, his wife Melinda, and their children living and working beside them, benefiting Hunt Limousin Ranch and the beef industry.

Hunt Limousin Ranch is proudly nominated by the Nebraska Cattlemen.

Little Windy Hill Farms
Owner/Manager: Doug Hughes
Max Meadows, Virginia

Little Windy Hill Farms, owned and operated by Doug and Sue Hughes and family, is located in the lush green hills of Southwest Virginia in the Blue Ridge Mountains near the town of Wytheville. Little Windy Hill has been breeding seedstock cattle for the purebred and commercial cattlemen all their lives. After being raised on a Polled Hereford operation and then having registered Charolais from the late 1970's until 1993, the Hughes family entered into the Gelbvieh seedstock business for the growth, maternal characteristics and black hide color the breed offered. As the Gelbvieh operation grew and demand for Gelbvieh Balancers increased, Angus were added to the operation which presently consists of 125 fall-calving registered Gelbvieh, Balancer, and Angus cows.

A whole-herd AI program was implemented, and prominent AI sires owned by Little Windy Hill are used as natural service sires. Little Windy Hill Farms hosts an annual on-farm bull sale each November, and have participated in the Virginia BCIA central bull test program since 1983. Elite seedstock are marketed through consignment sales, including the bull futurity at the National Western which Doug has provided leadership for serving two terms as chairman. Doug was also a founding member of the Virginia Gelbvieh Association, served as President of Virginia BCIA, and been an active member of American Gelbvieh Association committees.

The Virginia Beef Cattle Improvement Association is proud to nominate Little Windy Hill Farms.

Lyons Ranch

Owners: Jan & Frank Lyons and Karl & Amy Langvardt

Manager: Jan Lyons

Manhattan, Kansas

Lyons Ranch is an Angus seedstock operation located in the native Flint Hills of east central Kansas and headquartered near Manhattan. The ranch is owned and operated by Jan and Frank Lyons and their daughter and son-in-law, Amy and Karl Langvardt, along with their sons, Tanner and Trey. Jan grew up on an Angus farm in northeastern Ohio and always loved working around the cattle and showing steers and heifers in 4-H and local shows. She and Frank started Lyons Ranch in Manhattan in 1977.

They currently calve 300 females each year between the two ranches – Jan and Frank run the headquarters and Amy and Karl run the south ranch east of Alta Vista. Their goal is to raise Angus cattle with emphasis on traits that determine profit for all segments of the beef industry. They don't breed for extremes, but focus on the predictability of balanced traits, including fertility, calving ease, carcass value, performance and efficiency. Artificial insemination, natural herd sires and, to a lesser degree, embryo transfer are utilized in the breeding program.

Cowherd numbers are managed so they can relate on a personal level with their customers. Rather than hire additional personnel, they prefer to work one-on-one with their customers, which has built a high level of trust over the years. They maintain the highest level of integrity in all dealings and interactions with customers and in the reporting of data. They provide their customers with the up-to-date information about their cattle they need to be successful, including EPDs enhanced with DNA for higher accuracy.

Their first production sale was held in the fall of 1984. They celebrated their 25th annual bull sale in March of this year. They are gratified that many of their customers return year after year and are proud to own Lyons Ranch bulls, which speaks to their commitment to customers and their focus on helping them achieve their programs' goals.

Their motto is "Your Source for Superior Genetics." Their mission is to produce predictable Angus genetics to meet the needs of their customers and to ultimately satisfy the eating demands of the consumer.

The Kansas Livestock Association is proud to nominate Lyons Ranch.

Murphy's Angus

Owners/Managers: Francis Murphy, Kevin Murphy, and Stephen Murphy

Illiopolis, Illinois

Murphy's Angus is located in central Illinois and comprises parents, Francis and Suzanne; Kevin and Rosemarie and son Alec; and Steve and Jackie. The purebred black Angus cattle operation started as an outgrowth of the sons' (Kevin and Steve) 4-H youth steer projects. While the emphasis in the early years was to develop animals for the boys' projects, that changed and the farm has since focused on raising performance cattle with an emphasis on raising bulls for the purebred and commercial cow-calf industry.

The cattle operation consists of approximately twenty brood cows, and all animals born on the farm are the result of artificial insemination or embryo transfer. Cows are synchronized for breeding to calve in winter; calving starts in December and ends by March to allow time for bulls to be adequately developed for buyers. Murphy's Angus focuses on raising sound, functional calving-ease bulls that do not sacrifice performance, growth or carcass merit. All animals are weighed and ultrasounded with the data being processed through the A.H.I.R. program. DNA testing has begun to be used to further assist in identifying elite individuals. Bulls are sold through the Illinois Performance Tested Bull sale and private treaty, with females being sold by private treaty.

Management intensive grazing is utilized to maximize production from a fourteen acre grass-legume pasture. A break wire is used so that cows and calves are run in 1.4 acre paddocks, which typically provides thirty days of growth between grazing. An additional small hayfield provides supplemental forage.

Murphy's Angus is proudly nominated by the University of Illinois Extension and the Illinois Beef Association.

Past Award Winners

Seedstock Producer of the Year Award

Name	State	Year
John Crowe	California	1972
Mrs. R. W. Jones, Jr.	Georgia	1973
Carlton Corbin	Oklahoma	1974
Jack Cooper	Montana	1975
Leslie J. Holden	Montana	1975
Jorgenson Brothers	South Dakota	1976
Glenn Burrows	New Mexico	1977
James D. Bennett	Virginia	1978
Jim Wolf	Nebraska	1979
Bill Wolfe	Oregon	1980
Bob Dickinson	Kansas	1981
A.F. "Frankie" Flint	New Mexico	1982
Bill Borror	California	1983
Lee Nichols	Iowa	1984
Ric Hoyt	Oregon	1985
Leonard Lodoen	North Dakota	1986
Henry Gardiner	Kansas	1987
W.T. "Bill" Bennett	Washington	1988
Glynn Debter	Alabama	1989
Douglas & Molly Hoff	South Dakota	1990
Summitcrest Farms	Ohio	1991
Leonard Wulf & Sons	Minnesota	1992
J. David Nichols	Iowa	1993
R.A. "Rob" Brown	Texas	1993
Richard Janssen	Kansas	1994
Tom & Carolyn Perrier	Kansas	1995
Frank Felton	Missouri	1996
Bob & Gloria Thomas	Oregon	1997
Wehrmann Angus Ranch	Virginia	1997
Flying H Genetics	Nebraska	1998
Knoll Crest Farms	Virginia	1998
Morven Farms	Virginia	1998
Fink Beef Genetics	Kansas	1999
Sydenstricker Angus Farms	Missouri	2000
Circle A Ranch	Missouri	2001
Moser Ranch	Kansas	2002
Camp Cooley Ranch	Texas	2003
Rishel Angus	Nebraska	2005
Sauk Valley Angus	Illinois	2006
Pelton Simmental Red Angus	Kansas	2007
TC Ranch	Nebraska	2008
Champion Hill	Ohio	2009
Harrell Hereford Ranch	Oregon	2009
Sandhill Farms	Kansas	2010
Mushrush Red Angus	Kansas	2011
V8 Ranch	Texas	2012

2013 Nominees

Bradley 3 Ranch

Coyote Hills Ranch

Hunt Limousin Ranch

Little Windy Hills Farms

Lyons Ranch

Murphy's Angus

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year	Name	State	Year
Billy L. Easley…………..	Kentucky……..	1972	Frank Kubik, Jr…………..	North Dakota…	1975
Dale H. Davis…………….	Montana………	1972	George Chiga…………….	Oklahoma…….	1975
Elliot Humphrey…………	Arizona……….	1972	Glenn Burrows…………..	New Mexico….	1975
Harold A. Demorest…..…	Ohio………….	1972	Howard Collins…….…….	Missouri………	1975
James D. Bennett………...	Virginia………	1972	Jack Cooper……………...	Montana………	1975
Jerry Moore………………	Ohio………….	1972	Joseph P. Dittmer………..	Iowa…………..	1975
John Crowe ……………..	California……..	1972	Leslie J. Holden…………	Montana………	1975
Marshall A. Mohler……...	Indiana………..	1972	Licking Angus Ranch……	Nebraska……...	1975
Albert West III…………...	Texas…………	1973	Louis Chestnut…………...	Washington…..	1975
C. Scott Holden…………..	Montana……...	1973	Robert Arbuthnot………...	Kansas………..	1975
Carlton Corbin…………...	Oklahoma…….	1973	Robert D. Keefer………..	Montana………	1975
Clyde Barks……………..	North Dakota…	1973	Walter S. Markham………	California……..	1975
Heathman Herefords……..	Washington…..	1973	Ancel Armstrong………...	Virginia………	1976
James D. Hemmingsen…..	Iowa…………..	1973	Gerhard Mittnes…………	Kansas………..	1976
Messersmith Herefords…..	Nebraska……...	1973	Healey Brothers…………	Oklahoma…….	1976
Mrs. R. W. Jones, Jr……...	Georgia……….	1973	Jackie Davis……………...	California……..	1976
Raymond Meyer…………	South Dakota...	1973	Jay Pearson………………	Idaho…………	1976
Robert Miller……………..	Minnesota…….	1973	L. Dale Porter…………….	Iowa…………	1976
William F. Borrow……….	California……..	1973	Lowellyn Tewksbury…….	North Dakota…	1976
Bert Crame……………….	California……..	1974	M.D. Shepherd…………...	North Dakota...	1976
Bert Sackman…………….	North Dakota…	1974	Robert Sallstrom…………	Minnesota…….	1976
Dover Sindelar…………...	Montana………	1974	Sam Friend………………	Missouri………	1976
Burwell M. Bates………...	Oklahoma…….	1974	Stan Lund………………...	Montana………	1976
Charles Descheemacher….	Montana……...	1974	Bill Wolfe………………..	Oregon………..	1977
J. David Nichols…………	Iowa…………..	1974	Bob Sitz…………………..	Montana………	1977
Jorgensen Brothers……….	South Dakota…	1974	Clair Percel………………	Kansas………..	1977
Marvin Bohmont…..……..	Nebraska……...	1974	Floyd Hawkins…………...	Missouri……...	1977
Maurice Mitchell………...	Minnesota…….	1974	Frank Ramackers, Jr……..	Nebraska……..	1977
Wilfred Dugan…………...	Missouri………	1974	Glen Burrows…………….	New Mexico….	1977
Dale Engler………………	Kansas………..	1975	Henry & Jeanette Chitty…	New Mexico….	1977

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year	Name	State	Year
Hubert R. Freise	North Dakota	1977	Peg Allen	Montana	1979
James Volz	Minnesota	1977	Rex & Joann James	Iowa	1979
Lloyd DeBruycker	North Dakota	1977	Bill Wolfe	Oregon	1980
Loren Schlipf	Illinois	1977	Blythe Gardner	Utah	1980
Marshall A. Mohler	Indiana	1977	Bob Laflin	Kansas	1980
Robert Brown	Texas	1977	Charlie Richards	Iowa	1980
Tom & Mary Shaw	Idaho	1977	Donald Barton	Utah	1980
Tom Dashiell	Washington	1977	Floyd Dominy	Virginia	1980
Wayne Eshelman	Washington	1977	Frank Felton	Missouri	1980
Harold Anderson	South Dakota	1977	Frank Hay	California	1980
William Borror	California	1977	James Bryany	Minnesota	1980
A.L. Frau	N/A	1978	John Masters	Kentucky	1980
Bill Wolfe	Oregon	1978	Mark Keffeler	South Dakota	1980
Bill Womack, Jr	Alabama	1978	Paul Mydland	Montana	1980
Buddy Cobb	Montana	1978	Richard McLaughlin	Illinois	1980
Frank Harpster	Missouri	1978	Richard Tokach	North Dakota	1980
George Becker	North Dakota	1978	Roy & Don Udelhoven	Wisconsin	1980
Healey Brothers	Oklahoma	1978	Bob & Gloria Thomas	Oregon	1981
Jack Delaney	Minnesota	1978	Bob Dickinson	Kansas	1981
James D. Bennett	Virginia	1978	Clarence Burch	Oklahoma	1981
Larry Berg	Iowa	1978	Clayton Canning	California	1981
Roy Hunst	Pennsylvania	1978	Dwight Houff	Virginia	1981
Bill Wolfe	Oregon	1979	G.W. Cronwell	Iowa	1981
Del Krumweid	North Dakota	1979	Harold Thompson	Washington	1981
Floyd Metter	Missouri	1979	Herman Schaefer	Illinois	1981
Frank & Jim Wilson	South Dakota	1979	J. Morgan Donelson	Missouri	1981
Glenn & David Gibb	Illinois	1979	Jack Ragsdale	Kentucky	1981
Jack Ragsdale	Kentucky	1979	James Leachman	Montana	1981
Jim Wolf	Nebraska	1979	Lynn Frey	North Dakota	1981
Leo Schuster Family	Minnesota	1979	Myron Autfathr	Minnesota	1981

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year	Name	State	Year
Roy Beeby	Oklahoma	1981	Stanley Nesemeier	Illinois	1983
Russ Denowh	Montana	1981	A. Harvey Lemmon	Georgia	1984
Bob Thomas	Oregon	1982	Charles W. Druin	Kentucky	1984
Clare GeddesDavid A.	California	1982	Clair K. Parcel	Kansas	1984
Breiner	Kansas	1982	Donn & Sylvia Mitchell	Canada	1984
Frankie Flint	New Mexico	1982	Earl Kindig	Virginia	1984
Garold Parks	Iowa	1982	Floyd Richard	North Dakota	1984
Gary & Gerald Carlson	North Dakota	1982	Fred H. Johnson	Ohio	1984
Harlin Hecht	Minnesota	1982	Glen Klippenstein	Missouri	1984
Howard Krog	Minnesota	1982	Jack Farmer	California	1984
Joseph S. Bray	Kentucky	1982	Jerry Chappel	Virginia	1984
Larry Leonhardt	Montana	1982	Joe C. Powell	North Carolina	1984
Orville Stangl	South Dakota	1982	John B. Green	Louisiana	1984
W.B. Williams	Illinois	1982	Lawrence Meyer	Illinois	1984
William Kottwitz	Missouri	1982	Lee Nichols	Iowa	1984
Alex Stauffer	Wisconsin	1983	Phillip A. Abrahamson	Minnesota	1984
Bill Borror	California	1983	Ric Hoyt	Oregon	1984
C. Ancel Armstrong	Kansas	1983	Robert L. Sitz	Montana	1984
Charles E. Boyd	Kentucky	1983	Ron Beiber	South Dakota	1984
D. John & Lebert Schultz	Missouri	1983	Arnold Wienk	South Dakota	1985
E.A. Keithley	Missouri	1983	Bernard F. Pedretti	Wisconsin	1985
Frank Myatt	Iowa	1983	David McGehee	Kentucky	1985
Harvey Lemmon	Georgia	1983	Don W. Schoene	Missouri	1985
J. Earl Kindig	Missouri	1983	Earl Schafer	Minnesota	1985
Jake Larson	North Dakota	1983	Everett & Ron Batho	Canada	1985
John Bruner	South Dakota	1983	Fred Killam	Illinois	1985
Leness Hall	Washington	1983	George B. Halternan	West Virginia	1985
Ric Hoyt	Oregon	1983	Glenn L. Brinkman	Texas	1985
Robert H. Schafer	Minnesota	1983	Gordon Booth	Wyoming	1985
Russ Pepper	Montana	1983	J. Newill Miller	Virginia	1985

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year
Marvin Knowles	California	1985
R.C. Price	Alabama	1985
Tom Perrier	Kansas	1985
A. Lloyd Grau	New Mexico	1986
Clarence Vandyke	Montana	1986
Clifford & Bruce Betzold	Illinois	1986
Delton W. Jubert	Kansas	1986
Dick & Ellie Larson	Wisconsin	1986
Evin & Verne Dunn	Canada	1986
Gerald Hoffman	South Dakota	1986
Glenn L. Brinkman	Texas	1986
Henry & Jeanette Chitty	Florida	1986
J.H. Steward	Pennsylvania	1986
P.C. Morrissey	Pennsylvania	1986
Jack & Gina Chase	Wyoming	1986
John H. Wood	South Carolina	1986
Lawrence H. Graham	Kentucky	1986
Leonard Lodden	North Dakota	1986
Leonard Wulf	Minnesota	1986
Matthew Warren Hall	Alabama	1986
Ralph McDanolds	Virginia	1986
Richard J. Putman	North Carolina	1986
Roy D. McPhee	California	1986
W.D. Morris/ James Pipkin	Missouri	1986
Charles & Wynder Smith	Georgia	1987
Clayton Canning	Canada	1987
Eldon & Richard Wiese	Minnesota	1987
Forrest Byergo	Missouri	1987
Gary Klein	North Dakota	1987
Harold E. Pate	Illinois	1987
Henry Gardiner	Kansas	1987
Ivan & Frank Rincker	Illinois	1987
James Bush	South Dakota	1987
Larry D. Leonhardt	Wyoming	1987
Lyall Edgerton	Canada	1987
R.J. Steward	Minnesota	1987
P.C. Morrisey	Minnesota	1987
Tommy Brandenberger	Texas	1987
Bill Bennett	Washington	1988
Darold Bauman	Wyoming	1988
David & Carol Guilford	Canada	1988
David Luhman	Minnesota	1988
Don & Dian Guilford	Canada	1988
Donn & Sylvia Mitchell	Canada	1988
Douglas D. Bennett	Texas	1988
George Schlickau	Kansas	1988
Gino Pedretti	California	1988
Glenn Debter	Alabama	1988
Hansell Pile	Kentucky	1988
Jay P. Book	Illinois	1988
Kans Ulrich	Canada	1988
Kenneth Gillig	Missouri	1988
Leonard Lorenzen	Oregon	1988
Robert E. Walton	Washington	1988
Scott Burtner	Virginia	1988
Willowam Glanz	Wyoming	1988
Bob R. Whitmire	Georgia	1989
Donald Fawcett	South Dakota	1989
Ed Albaugh	California	1989
Glynn Debter	Alabama	1989

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year
Harry Airey	Canada	1989
Jack & Nancy Baker	Missouri	1989
Jerry Allen Burner	Virginia	1989
Kenneth D. Lowe	Kentucky	1989
Leonard A. Lorenzen	Oregon	1989
Lester H. Schafer	Minnesota	1989
Lynn Pelton	Kansas	1989
Orrin Hart	Canada	1989
Ron Bowman	North Dakota	1989
Sherm & Charlie Ewing	Canada	1989
Tom Mercer	Wyoming	1989
Bob Thomas Family	Oregon	1990
Boyd Broyles	Kentucky	1990
Charles & Rudy Simpson	Canada	1990
Doug Faser	Canada	1990
Douglas & Molly Hoff	South Dakota	1990
Dr. Burleigh Anderson	Pennsylvania	1990
Gerhard Gueggenberger	California	1990
John & Chris Oltman	Wisconsin	1990
John Ragsdale	Kentucky	1990
Larry Erahart	Wyoming	1990
Otto & Otis Rincker	Illinois	1990
Paul E. Keffaber	Indiana	1990
Richard Janssen	Kansas	1990
Steven Forrester	Michigan	1990
T.D. & Roger Steele	Virginia	1990
Ann Upchurch	Alabama	1991
Dave & Carol Guilford	Canada	1991
Jack & Gina Chase	Wyoming	1991
Jack Cowley	California	1991
James Burnes & Sons	Wisconsin	1991
James R. O'Neill	Iowa	1991
Jim Taylor	Kansas	1991
John Bruner	South Dakota	1991
Larry Wakefield	Minnesota	1991
N. Wehrmann/R. McClung	Virginia	1991
R.A. Brown	Texas	1991
R.M. Felts & Son Farm	Tennessee	1991
Ralph Bridges	Georgia	1991
Richard and Sharon Beitelspacher	South Dakota	1991
Rob & Gloria Thomas	Oregon	1991
Steve & Bill Florschcuetz	Illinois	1991
Summitcrest Farms	Ohio	1991
Tom Sonderup	Nebraska	1991
A.W. Compton, Jr.	Alabama	1992
Bill Rea	Pennsylvania	1992
Bob Buchanan Family	Oregon	1992
Calvin & Gary Sandmeier	South Dakota	1992
Dennis, David, & Danny Geffert	Wisconsin	1992
Dick Montague	California	1992
Eugene B. Hook	Minnesota	1992
Francis & Karol Bormann	Iowa	1992
Glenn Brinkman	Texas	1992
Harold Dickson	Missouri	1992
Leonard Wulf & Sons	Minnesota	1992
Robert Elliot & Sons	Tennessee	1992
Tom & Ruth Clark	Virginia	1992
Tom Drake	Oklahoma	1992
Bob Zarn	Minnesota	1993

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year
Clarence, Elaine & Adam Dean	South Carolina	1993
Collin Sander	South Dakota	1993
D. Eldridge & Y. Aycock	Oklahoma	1993
Harrell Watts	Alabama	1993
J. David Nichols	Iowa	1993
J. Newbill Miller	Virginia	1993
Joseph Freund	Colorado	1993
Lynn Pelton	Kansas	1993
Miles P. "Buck" Pangburn	Iowa	1993
Norman Bruce	Illinois	1993
R.A. Brown	Texas	1993
R.B. Jarrell	Tennessee	1993
Rueben Leroy	South Dakota	1993
Bob Littau South	Dakota	1993
Ted Seely	Wyoming	1993
Wes & Fran Cook	North Carolina	1993
Bobby F. Hayes	Alabama	1994
Bruce Orvis	California	1994
Buell Jackson	Iowa	1994
Calvin & Gary Sandmeier	South Dakota	1994
Dave Taylor & Gary Parker	Wyoming	1994
Jere Caldwell	Kentucky	1994
John Blankers	Minnesota	1994
John Pfeiffer Family	Oklahoma	1994
Ken & Bonnie Bieber	South Dakota	1994
Mary Howe di'Zerega	Virginia	1994
Richard Janssen	Kansas	1994
Ron & Wayne Hanson	Canada	1994
Bobby Aldridge	North Carolina	1995
Chris & John Christensen	South Dakota	1995
Donald J. Hargrave	Canada	1995
Gene Bedwell	Iowa	1995
Gordon & Mary Ann Booth	Wyoming	1995
Howard & JoAnne Hillman	South Dakota	1995
John Robbins	Montana	1995
Billy Mack& Tom Maples	Alabama	1995
Mary Howe de'Zerga	Virginia	1995
Maurice Grogan	Minnesota	1995
Thomas Simmons	Virginia	1995
Tom Perrier	Kansas	1995
Ward Burroughs	California	1995
C. Knight & B. Jacobs	Oklahoma	1996
C.W. Pratt	Virginia	1996
Cam Spike & Sally Forbes	Wyoming	1996
Chris and John Christensen	South Dakota	1996
D. Borgen & B. McCulloh	Wisconsin	1996
Frank Felton	Missouri	1996
Frank Schiefelbein	Minnesota	1996
Galen & Lori Fink	Kansas	1996
Gerald & Lois Neher	Illinois	1996
Ingrid & Willy Volk	North Carolina	1996
Mose & Dave Hebbert	Nebraska	1996
Robert C. Miller	Minnesota	1996
Williowam A. Womack Jr.	Alabama	1996
Alan Albers	Kansas	1997
Blaine & Pauline Canning	California	1997
Bob & Gloria Thomas	Oregon	1997
Darel Spader	South Dakota	1997

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year
E. David Pease	California	1997
Gregg & Diane Butman	Minnesota	1997
Harold Pate	Alabama	1997
James I. Smith	North Carolina	1997
Jim & JoAnn Enos	Illinois	1997
Juan Reyes	Wyoming	1997
Nicholas Wehrmann	Virginia	1997
Richard McClung	Virginia	1997
Abilgail & Mark Nelson	California	1998
Adrian Weaver & Family	Colorado	1998
Airey Family	Canada	1998
Dallis & Tammy Basel	South Dakota	1998
Dave & Cindy Judd	Kansas	1998
Dick & Bonnie Helms	Nebraska	1998
Duane L. Kruse Family	Illinois	1998
Earl & Neadra McKarns	Ohio	1998
James D. Benett Family	Virginia	1998
Tom Shaw	Idaho	1998
Wilbur & Melva Stewart	Canada	1998
Duane Schieffer	Montana	1999
John Kluge	Virginia	1999
Kelly & Lori Darr	Wyoming	1999
Kent Kline	South Dakota	1999
Kramer Farms	Illinois	1999
Lynn & Gary Pelton	Kansas	1999
Noller & Frank Charolais	Iowa	1999
Rausch Herefords	South Dakota	1999
Steve Munger	South Dakota	1999
Terry O'Neill	Montana	1999
Tony Walden	Alabama	1999

Name	State	Year
Alan & Deb Vedvei	South Dakota	000
Banks & Margo Hernon	Alabama	2000
Blane & Cindy Nagel	South Dakota	2000
Galen, Lori, & Megan Fink	Kansas	2000
Harlin & Susan Hecht	Minnesota	2000
Jim & Janet Listen	Wyoming	2000
John & Betty Botert	Missouri	2000
John C. Curtin	Illinois	2000
Kent Kline	South Dakota	2000
Steve Munger	South Dakota	2000
Larry & Jean Croissant	Colorado	2000
Mike & T.K. McDowell	Virginia	2000
Ralph Sr., Ralph Jr. & David Blalock	North Carolina	2000
Vaughn Meyer & Family	South Dakota	2000
Blane & Cindy Nagel	South Dakota	2001
Bob & Nedra Funk	Oklahoma	2001
Dale, Don & Mike Spencer	Nebraska	2001
Don & Priscilla Nielsen	Colorado	2001
Eddie L. Sydenstricker	Missouri	2001
George W. Lemm	Virginia	2001
Ken Stielow & Family	Kansas	2001
Kevin, Jessica & Dakota		
Emily Moore	Texas	2001
Marvin & Katheryn Robertson	Virginia	2001
MCallen Ranch	Texas	2001
Steve Hillman & Family	Illinois	2001
Tom Lovell	Alabama	2001

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year
DeBruycker Charolais	Montana	2002
Ellis Farms	Illinois	2002
Holly Hill Farm	Virginia	2002
Isa Cattle Co., Inc.	Texas	2002
Lyons Ranch	Kansas	2002
Noller & Frank Charolais	Iowa	2002
Rishel Angus	Nebraska	2002
Running Creek Ranch	Colorado	2002
Shamrock Angus	Wyoming	2002
Stewart Angus	Indiana	2002
Triple “M” Farm	Alabama	2002
Bedwell Charolais	Iowa	2003
Boyd Farm	Alabama	2003
Camp Cooley Ranch	Texas	2003
Hilltop Ranch	Texas	2003
Moser Ranch	Kansas	2003
Mystic Hill Farms	Virginia	2003
Pingetzer’s Six Iron Ranch	Wyoming	2003
San Isabel Ranch	Colorado	2003
Shamrock Vale Farms	Ohio	2003
Adams Angus Farm	Alabama	2004
Byland Polled Shorthorns	Ohio	2004
Camp Cooley Ranch	Texas	2004
Eaton Charlais	Montana	2004
Flat Branch Cattle Co.	Illinois	2004
Judd Ranch, Inc.	Kansas	2004
Rausch Herefords	South Dakota	2004
Reynolds Ranch	Colorado	2004
Silveira Brothers Angus & Diversified Farming	California	2004
Symens Brothers Limousin	South Dakota	2004
Touchstone Angus	Wyoming	2004
Triple U Ranch	Iowa	2004
Altenburg Super Baldy	Colorado	2005
Bar S Ranch	Kansas	2005
Ellis Farms	Illinois	2005
Ingram Cattle Company	Mississippi	2005
Moore Farms	Alabama	2005
Morrison Stock Farm	Ohio	2005
Pangburn Stock Farm	Iowa	2005
Rishel Angus	Nebraska	2005
Rogers Bar HR	Mississippi	2005
Soldiers’ Hill Angus Farm	Virginia	2005
Sunnyhill Angus Farm	Illinois	2005
Waukaru Farms, Inc.	Indiana	2005
Benoit Angus Ranch	Kansas	2006
Champion Hill	Ohio	2006
EE Ranches, Inc.	Mississippi	2006
Earhart Farms	Wyoming	2006
Figure 4 Cattle Company/ Volk Ranch LLLP	Colorado	2006
Lawler Farm	Alabama	2006
Powder Creek Simmentals	Georgia	2006
Quaker Hill Farm LLC	Virginia	2006
Sauk Valley Angus	Illinois	2006
Thomas Charolais, Inc.	Texas	2006
Vorthmann Limousin	Iowa	2006
Waukaru Farms, Inc.	Indiana	2006
Pelton Simmental	Kansas	2007
5L Red Angus	Montana	2007

Past Award Winners

Seedstock Producer Honor Roll of Excellence

Name	State	Year
Bridle Bit Simmentals	Colorado	2007
Echo Ridge Farm	Virginia	2007
Heartland Cattle Company	Iowa	2007
Lindskov-Thiel Ranch	South Dakota	2007
Star Lake Cattle Ranch	Oklahoma	2007
TC Ranch	Nebraska	2007
Tinney Farms	Alabama	2007
Tomlinson Farms	Illinois	2007
Andras Stock Farm	Illinois	2008
Croissant Red Angus	Colorado	2008
Harms Plainview Ranch	Kansas	2008
Little Mountain Farm	Alabama	2008
C. H. Morris & Sons	Virginia	2008
Nolin Red Angus	Iowa	2008
Schott Limousin Ranch	South Dakota	2008
TC Ranch	Nebraska	2008
Thomas Ranch	South Dakota	2008
Calyx Star Ranch	Mississippi	2009
Champion Hill	Ohio	2009
Gibbs Farms	Alabama	2009
Harrell Hereford Ranch	Oregon	2009
Musgrave Angus	Illinois	2009
Oak Meadow Farm Simmentals	Minnesota	2009
Oak Ridge Angus	California	2009
Quaker Hill Farm	Virginia	2009
Skarda Farms	Iowa	2009
Stucky Ranch	Kansas	2009
Circle Ranch	California	2010
Edgewood Angus	Virginia	2010
McBee Cattle Company	Missouri	2010
Rincker Simmentals	Illinois	2010
Sandhill Farms	Kansas	2010
Schuler Red Angus	Nebraska	2010
Spring Creeks Cattle Co.	Wisconsin	2010
Windy Hill Angus Farm	Alabama	2010
Bar T Bar Ranch	Arizona	2011
GV Limousin	Kansas	2011
Jungels Shorthorn Farms	North Dakota	2011
McDonald Farms	Virginia	2011
Monogram Farms	Mississippi	2011
Mushrush Red Angus	Kansas	2011
Panther Creek Angus	Illinois	2011
Ridgefield Farm	North Carolina.	2011
Schuler Red Angus	Nebraska	2011
Sunshine Farms	Alabama	2011
Bianchi Ranches	California	2012
EJ Shepherd Charolais	Iowa	2012
HeartBrand Beef	Texas	2012
Hounshell Farms	Virginia	2012
Liberty Ranch	Kansas	2012
McCurry Brothers Angus	Kansas	2012
Perks Ranch	Illinois	2012
Schuler Red Angus	Nebraska	2012
Springfield Angus	North Carolina.	2012
Tanner Farms	Mississippi	2012
V8 Ranch	Texas	2012
Williams Angus Farm	Alabama	2012

Northern Oklahoma BIF Tour

Robert Kerr Food and Agriculture Products Center

The Robert M. Kerr Food & Agricultural Products Center, also known as FAPC, began in 1997 . It is located on the Oklahoma State University campus in Stillwater, OK and directed by J. Roy Excoubas. FAPC possesses animal harvesting, food manufacturing, grain milling, sensory profiling, food microbiology and analytical laboratory facilities. The center focuses on boosting the economy by helping Oklahoma businesses thrive.

FAPC offers the knowledge it collects from its research laboratories and pilot-processing facilities to businesses throughout Oklahoma, as well as many other states, through seminars, workshops, and other educational programs. The center has a team of specialists, engineers, economists, and scientists that work closely with both individuals and companies to help develop Oklahoma's food and agricultural industries. Whether it is reducing drying time for jerky products or helping to develop a new type of steak, FAPC is always searching for ways to aid Oklahoma food and agricultural industries.

FAPC supports the innovation and growth of food and agricultural businesses, aids in increasing food safety and supports students who seek careers in the Oklahoma food industry. The 96,000 sq. ft. Food and Agricultural Products Center building is truly impressive, and FAPC is always on the forefront of processing and technology. Come see what the center has to offer!

Oklahoma State Willard Sparks Beef Research Center

The Willard Sparks Beef Research Center, located west of Stillwater, OK, is a leader in cattle research and education and is one of the finest cattle feeding research facilities in the nation. Research information developed at the Sparks Center has been instrumental in advancing the cattle feeding industry throughout the nation.

The *Oklahoma Cowman Magazine* described the mission of the facility very clearly and accurately in an article when it wrote that the goals of the center are "to improve production efficiency of cattle, have a positive effect on beef quality and have a positive economical effect on all farmers and ranchers."

The Sparks Center has a one time capacity of 980 cattle and is designed to have multiple research experiments conducted simultaneously. Recently, an Insentec feeding system was added to aid in collection of individual feed intake information in a group feeding setting.

The William Sparks Beef Research Center is a valuable asset to the animal science research efforts Oklahoma State University. The research information generated at the facility has been instrumental in improving the efficiency of gain for the cattle feeding industry. Developed through major contributions of a variety of donors as well as grant funds, the Sparks Center is an impressive testament of Oklahoma's drive to advance the cattle feeding industry throughout the nation.

Northern Oklahoma BIF Tour

M&M Charolais

M&M Charolais is a leading seedstock Charolais cattle breeding operation in Perry, Oklahoma. From a meager beginning of 15 head of percentage Charolais females bred to purebred Charolais bulls, Mary Elizabeth Malzahn and her brother, Ward Corneil, initiated a 60 year breeding program that has added to the overall genetic improvement of the Charolais breed.

Her breeding philosophy centered on the advice of Oklahoma's beloved Will Rogers who once said, "If you are selling something, try to make it so good that you would rather be the person who bought it than the person who sold it."

Over 30 years ago, Mary hired Kevin Wiley to manage the 4,000 acre, 350 cow operation with the single challenge of producing genetically superior Charolais cattle that would gain the respect and admiration of fellow breeders in the show ring, in the sale arena and on working commercial and purebred ranches throughout the nation and internationally. To date, M&M Charolais has sold cattle into over 25 states and into Canada and Mexico.

M&M Charolais, the 43rd National Show Dedicatee Award recipient, has bred and exhibited two Show Females of the Year in the Charolais breed, and has been recognized as a global leader in performance and genetic improvement through artificial insemination and embryo transfer. Even though the founder, Mary Malzhan, has recently deceased, her husband, Ed Malzhan, President and CEO of Charles Machine Works and the herd manager, Kevin Wiley, continues her legacy through producing cattle that can compete in the pasture as well as in the show ring, focusing on raising bulls with lower birth weights and high performance that commercial and seedsock producers prefer.

Pollard Angus Farms

Pollard Angus Farms, located in Waukomis, Oklahoma, is owned nd operated by Dr. Barry and Roxanne Pollard. Their primary breeding objective has always been to produce Angus cattle with balanced, quality genetics that are constantly in demand by both seedstock and commercial cattle producers. Their mission statement details their breeding philosophy: "At Pollard Farms, we will dedicate the time, knowledge and resources necessary to create cattle that excel in phenotype, performance and carcass traits. Our mission is to produce Angus cattle with balanced traits while providing you with "The Best" in customer service."

Through the use of genetic information collected through an intensive performance evaluation program, Pollard Angus has developed an elite Angus herd that provides superior breeding animals to many seedstock program throughout the U.S. and an impressive group of commercial bulls on an annual basis that are in demand by area commercial cow-calf producers.

Dr. Pollard, a renowned neurosurgeon, has utilized his knowledge of science to develop his herd through an extensive in-herd selection program coupled with advances in artificial insemination, embryo transfer and cloning. His scientific curiosity has stimulated his interest in in replicating the characteristics he desired in his cattle. His ultimate goal is to create a genetic herd of Angus cattle that gain more weight on less feed and produce a meat product that will be in demand by today's consumer. Without question, Pollard Angus has accomplished their goal as evidenced by their annual production sale being one of the top sales throughout the Angus nation with their production being purchased by breeders from coast to coast.

Northern Oklahoma BIF Tour

Chain Ranch

Chain Ranch is a versatile company that combines farming, cattle, and hunting. Originating in 1893 with the acquisition of 160 acres in Dewey County, Oklahoma, the ranch has become a six generation owned and operated family business with four ranches in Oklahoma and three ranches in Kansas. The Chain Ranch was recognized as the Regional winner of the 2004 Environmental Stewardship Award Program (ESAP). Also in 2004, Ralph Chain was named to the Oklahoma Agriculture Hall of Fame at the Governor's Conference on Agriculture and Economic Growth.

The Chain Ranch farms over 10,000 acres, growing mostly wheat and alfalfa. Through practices like "no till" and "minimal till," the Chain Ranch works on reducing erosion and conserving the soil moisture to protect the environment. Other progressive techniques the farm uses are its brush control program and its crop rotation program, in which they incorporate canola, millet, and milo. Chain Ranch produces an average of 2000 tons of hay a year.

The Chain Ranch cattle operation consist of 4,500 mother cows and they routinely run 7,000 to 8,000 stocker cattle on an annual basis. Through their intensive retained ownership program, the Chain Ranch has developed an outstanding reputation as a source of superior cattle from the pasture to the plate. A selective crossbreeding program that incorporates Black Angus, Red Angus, Hereford and Limousin cattle has been employed to create a systematic crossbred animal that excels in reproductive efficiency, growth and carcass merit in their environment.

Their hunting operation is environmentally-friendly and they work hard to preserve and manage the local wildlife. Primarily focused on their Kansas ranches, hunts of whitetail deer, dove, upland fowl, and waterfowl hunts are planned to provide "ultimate outdoor experience."

This progressive ranch's techniques and programs are remarkable. If you have an interest in farming, cattle, or hunting, the Chain Ranch should be on your list of places to see.

Lunch Sponsored by Pollard Farms

Southern Oklahoma BIF Tour

Oklahoma City Stockyards

The Oklahoma City Stockyard was founded in 1910 on 120 acres and became the state's first major industry, focusing on providing central marketing facility for livestock. In 1915, packing facilities were constructed to harvest cattle, hogs, and sheep that were transported to the Oklahoma City facility. The packing plants closed in the 1960s, but the stockyards have continued operation for over 100 years. Since it was founded, the Stockyard has sold over 100 million head of livestock. Today, the stockyard is the largest feeder and stocker cattle market in the United States, typically marketing 10,000 – 12,000 head on a weekly basis. The stockyards will market 500,000 to 600,000 head on an annual basis.

The Stockyard area is part of the Oklahoma Main Street program and is on the National Register of Historic Places. It also serves as the headquarters for the International Professional Rodeo Association (IPRA), which manages over 400 rodeo events annually. The stockyard area is also the home for many businesses, featuring western apparel, equipment and supplies. Many skilled craftsmen reside in the stockyards area, creating custom hats, saddles and other ranch gear. The historical Cattlemen's Steakhouse was established in 1910 and still serves an excellent steak to hundreds of customers on a daily basis.

The Oklahoma City Stockyard is filled with great historical significance for the state and retains its early 1900s appeal. Take a step into history with a visit to the Oklahoma City National Stockyard.

Raber's Saddlery

Raber's Saddlery is small business located in Coalgate, Oklahoma. Owner Robert Raber is known for the quality craftsmanship of the saddles, reins, and harnesses he makes.

Robert Raber started out working in his father's boot shop where he sewed boot soles. He started his business at the age of 18 and made his first saddle at 19 years of age. Mr. Raber takes pride in the quality of the products he creates.

Raber says, "To create a quality product you have to start out with quality leather. The most important thing is that we start out using only the finest steer hides. All of our harness leather comes from U.S. steer hides that are tanned in the U.S. by Hermann Oak. We have a special tannage done just for us at the tannery that has added oils. Our harness leather is a little bit firmer than a lot of leathers, but that adds to the longevity of it. We also have our own proprietary oil mixture that has a blend of neatsfoot oil in it, and each piece goes through an oiling process when it gets to the shop that we feel adds life to the product. That's the most important part, we build a product that not only looks good, but is very functional, and will stay that way for a long time."

Raber's Saddlery has refined its techniques and takes great steps to ensure that the products created in its shop are of the highest quality. The products are made with a sense of pride and the knowledge that they need to be made to last. The company cares about its customers and will even take the time to sit down with them to create custom pieces. Robert Raber's products are beautifully made and a true delight for ranchers.

Southern Oklahoma BIF Tour

Samuel Roberts Noble Foundation

The Samuel Roberts Noble Foundation is the largest private foundation in Oklahoma and is ranked in the top 44 foundations in the country. A nonprofit institute, the Noble Foundation was started in 1945 and is located in the town Ardmore, OK. The foundation focuses on trying to help the agricultural community through its research, such as using new methods to build disease resistant crops.

Their facility has 21 primary research laboratories that focus on plant research. Over the last year alone, the center has held 87 agriculture educational events and published more than 115 peer-reviewed papers in international journals. The Noble Foundation also supports nonprofit charities and educational/ health-related organizations through its grant making program and supports the Noble Foundation Junior Beef Excellence Program, a carcass quality contest that involves 4-H and FFA members.

The foundation has three main divisions: Agricultural, Plant Biology, and Forage Improvement. The Agricultural Division assists over 1,700 farmers and ranchers reach their individual goals, whether they be financial, production, or stewardship. The Plant biology Division researches ways to improve crop productivity and value. It also looks for ways to improve the health of both animals and humans. The Forage Improvement Division uses plant science research to help agricultural producers. It makes efforts to improve forages for harvesting and grazing.

The Samuels Roberts Noble Foundation has taken great strides through its own research to provide knowledge and support to the agricultural and animal science community. Its impressive facilities and programs are a must see for both the research enthusiast and the general public.

Stuart 7S Ranch

Quiet, modest and delightful, Terry Stuart Forst is a rancher, mother, businesswoman and trailblazer who truly has been a real “difference maker” in our industry. As the owner and manager of 7S Stuart Ranch, the oldest ranch in the state of Oklahoma under continuous family ownership since 1868, Terry epitomizes the western heritage saying, “Riding for the Brand”.

Her 45,000 acre ranch with locations in Caddo and Waurika, Oklahoma, is widely recognized as one of the nation’s most respected and best managed horse and cattle ranches and has added an outfitting division, featuring deer, turkey and wild hog hunts. After graduation from OSU in 1976, Terry returned to the ranch, working with her father, R.T. Stuart. When offered the ranch management position in the mid 1980’s, Terry took a somewhat different approach to making the 7S Stuart Ranch more efficient and profitable, she went back to school. Newly widowed and the mother of two young boys, Terry enrolled in the TCU Ranch Management Program. After graduating No. 1 in her class in 1992, she returned to the ranch to fulfill her legacy as a rancher and steward of the land. She developed a comprehensive plan designed to revitalize the cattle operation. In addition, she forged forward on a horse breeding program designed to produce top ranch horses that were also winners in the show ring. Because of her planning, determination, perseverance and motivation to succeed, 7S Stuart Ranch is an exceptional operation and the recipient of numerous awards, including the 1996 BIF Commercial Producer of the Year, 1996 AQHA Best Remuda Award and the 2003 Society of Range Management’s Excellence Award. Under Terry’s leadership and guidance, 7S Stuart Ranch calves and horses are widely recognized as industry elite livestock. Two Super horses, the highest AQHA honor, carry the 7S brand, Genuine Redbud in 1995 and Real Gun in 2004.

Terry Stuart Forst has been honored as a Master Breeder by the Department of Animal Science, was inducted into the National Cowgirl Hall of Fame, was named one of the Top 50 Women in Oklahoma in 2008, was elected as the first female President of the Oklahoma Cattlemen’s Association in 2009 and has been honored as a Distinguished Alumni of both the Animal Science Department as well as the College of Agricultural Sciences and Natural Resources at OSU. Early this year, 7S Stuart Ranch became the first ranch to be inducted into the Oklahoma Quarter Horse Hall of Fame. Whether your interest is cattle, horses, or hunting, the 7S Stuart Ranch is a must-see. The Oklahoma ranch is filled with historical significance and continues to succeed time and time again.

Lunch Sponsored by Noble Foundation