

ELEVATING THE INDUSTRY



BEEF IMPROVEMENT FEDERATION

50th Annual Research Symposium and Convention

June 20-23, 2018 · Loveland, Colorado



Sponsored by

ANIMAL SCIENCES
COLORADO STATE UNIVERSITY





Welcome to Colorado for the 50th Beef Improvement Federation Meeting!

The Colorado Cattlemen's Association, Colorado Livestock Association and Colorado State University are excited to host the landmark 50th Annual Meeting and Research Symposium.

In 1967 the idea for an organization to guide beef cattle performance recording and genetic improvement was hatched and, in 1968, the initial meeting of the Beef Improvement Federation was held here in Colorado. This year's meeting marks the 50th or golden anniversary of the inaugural event.

The founding members' vision to bring research to production in order to improve beef cattle genetics continues to be at the forefront of this meeting, with sessions on improving carcass traits, sustainability, EPDs and much more. Thursday morning provides a look at the future of beef production, genetic improvement and diversity in perspectives on where genetic improvement should focus. Friday morning spends considerable time addressing the value and use of data – an ever-growing resource to our industry. The afternoon subcommittee sessions offer a diversity of topics, often presenting a challenge for attendees deciding which one is on the “must-attend” list. Of course, the conversations in the hall, during breakfast and at the evening socials are just as important for moving the beef industry forward.

Along with the meetings, we hope you enjoy some Colorado hospitality. Starting Wednesday evening during the reception we will have some local brewers provide a special brew sampling of beers they have developed using Colorado-sourced ingredients for the summer and branded for this meeting. On Thursday, we will visit the new CSU Stadium Club for dinner. This state-of-the-art facility is less than one year old and offers some impressive views of Fort Collins and the Foothills as well. Saturday's tours provide variety to those looking to see more of Colorado. We'll head east to the large Five Rivers Feedlot at Kuner, then to a castle south of Denver at the Cherokee Ranch, and wrap up the day with dinner at Anheuser-Busch.

These meetings and events wouldn't be possible without the contributions from our generous sponsors, listed in the back of the program. Take some time to thank them for their support. We hope you enjoy your time in Colorado.

Sallie Miller
BIF 2018 Organizing Committee Chair



ADVANCING THE LEGACY



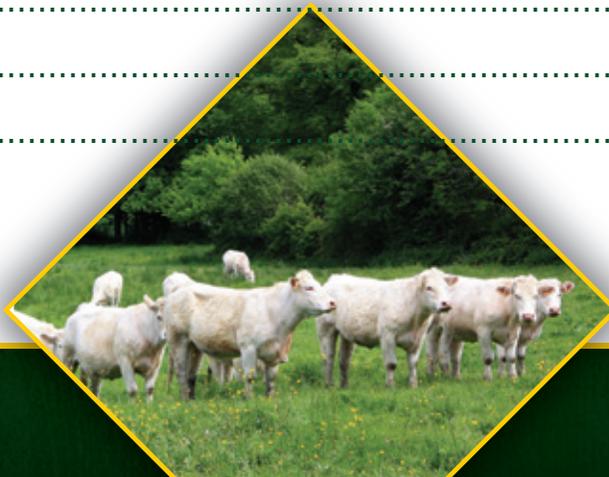
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SCHEDULE OF EVENTS

Wednesday, June 20

7:00 a.m. – 5:30 p.m. **GrowSafe Symposium**

8:00 a.m. – Noon **BIF Board Meeting • Carter Lake**

Noon – 7:00 p.m. **Registration • Conference Center Foyer**

Young Producers' Symposium • Goldenglow and Snowberry

- 1:00 p.m. Introduction to BIF and Speakers
Lee Leachman, Leachman Cattle of Colorado
- 1:15 p.m. The Road to the Future for the Beef Industry
Kevin Ochsner, Agcellerate Consulting, and Host of Cattleman to Cattleman
- 2:00 p.m. How Advanced Reproductive Technologies (ARTs) are Changing our Industry and Your Employment Opportunities
Dr. Mark Allan, Trans Ova Genetics
- 2:45 p.m. The Art and Science of Leading High Trust Teams
Richard Fagerlin, Founder of Peak Solutions
- 3:30 p.m. Round Table Q & A

5:30 – 8:00 p.m. Opening Reception • Mountain Holly & Canyon Maple

Geneseek Symposium • River Birch A/B Accelerating Progress in Beef Improvement

- 7:45 p.m. Welcome: Accelerating Progress in Beef Improvement
Dr. Stewart Bauck, Vice President, Neogen
- 8:00 p.m. Gene Editing Is at the Forefront
Dr. Mitch Abrahamsen, Executive Vice President, Recombinetics
- Selecting Seedstock at Minus 8 Months of Age
Matt Barten, Founder and President, Embruon
- Speeding Improvement of Commercial Cattle Through DNA Profiling
Dr. JR Tait, Director of Genetics Product Development, Neogen
- 9:00 p.m. Panel Discussion Q&A

Thursday, June 21

7:00 a.m. – 7:00 p.m. **Registration • Conference Center Foyer**

7:00 – 8:00 a.m. **Breakfast • Mountain Holly & Canyon Maple**

Morning Session • Pinyon Pine & River Birch Positioning for the Future of Beef Production

- 8:00 – 8:15 a.m. Welcome and Introductions
Dr. James Pritchett, Executive Associate Dean, College of Agricultural Sciences, Colorado State University
Donnell Brown, BIF President, R.A. Brown Ranch
- 8:15 – 8:45 a.m. Focus on Efficient Red Meat Production
Michael Genho, Director, Feedyard Business, Elanco Animal Health
- 8:45 – 9:15 a.m. Focus on Quality
Mark McCully, Vice-President, Certified Angus Beef
- 9:15 – 9:45 a.m. Focus on Sustainability
Dr. Sara Place, Sr. Director, Sustainable Beef Production Research, NCBA
- 9:45 – 10:15 a.m. Q&A
- 10:15 – 10:45 a.m. Break**
- 10:45 – 11:15 a.m. Focus on Traits Not Considered
Dr. Dorian Garrick, Professor and Chief Scientist, Massey University
- 11:15 – 11:45 a.m. Bringing it All Together: Alternative Selection Objectives
Dr. John Pollak, Emeritus Professor, Cornell University
- 11:45 a.m. – Noon Q&A

Noon – 2:00 p.m. Awards Luncheon • Mountain Holly & Canyon Maple

- What I Heard This Morning
Dr. Trey Patterson, President and CEO, Padlock Ranch Company
- Presentation of BIF Commercial Producer, Pioneer and Ambassador Awards
- Presentation of Frank Baker and Larry Cundiff Scholarship Winners

SCHEDULE OF EVENTS

2:00 – 5:30 p.m. Afternoon Breakout Sessions

Advancements in End-Product Improvement • River Birch C

Chair: Dr. Tommy Perkins, International Brangus Breeders Association

2:00 – 3:00 p.m. Improving Carcass and Meat-Eating Quality Through Genetics: Experiences from Ireland

Dr. Andrew Cromie, Irish Cattle Breeding Society

3:00 – 4:00 p.m. Investigation of G x E Effects on Beef Quality Traits: Use of Genomics to Minimize the Impact of Mismanagement

Dr. Steven Shackelford, United States Meat Animal Research Center, ARS

4:15 – 4:45 p.m. Ultrasound Guidelines Council Update: Systems Review Committee

Dr. JR Tait, Neogen GeneSeek Operations

4:45 – 5:15 p.m. Ultrasound Guidelines Council Update: Field and Lab Certification Review

Dr. Mike MacNeil, Delta G and UGC Executive Director

Emerging Technologies • River Birch A/B

Chair: Dr. Megan Rolf, Assistant Professor, Kansas State University

2:00 – 2:35 p.m. Development of Grazing Distribution Phenotypes

Derek Bailey, New Mexico State University

2:35 – 3:10 p.m. Genomic Approaches to Improve Grazing Distribution

Dr. Milt Thomas, Professor and Rouse Chair, Colorado State University

3:10 – 3:25 p.m. Break

3:25 – 4:00 p.m. Laying the Computational Foundations of Image Analysis Tools for Application in Livestock Breeding

Catie McVey, M.S. Candidate, Colorado State University

4:00 – 4:35 p.m. Technology and Nutritional Approaches to Mitigating Enteric Methane

Dr. Sara Place, Director, Sustainable Beef Production Research, National Cattleman's Beef Association

4:35 – 5:10 p.m. DNA-Based Calf Registration: Challenges and Opportunities
Andrew Cromie, Irish Cattle Breeding Federation

Selection Decisions • Pinyon Pine

Chair: Dr. Bob Weaber, Professor/Cow-Calf Extension Specialist, Kansas State University

2:00 – 2:30 p.m. Development and Deployment of Selection Indexes Incorporating Breeder Input

Dr. Jason Archer, Consultant, AbacusBio LTD

2:30 – 3:00 p.m. Stitching 13 Breed Associations' Data Together

Steve McGuire, Chief Operation Officer, American Simmental Association

3:00 – 3:30 p.m. New Methods and Models for IGS EPDs
Dr. Bruce Golden, President and CEO, Theta Solutions LLC

3:30 – 4:00 p.m. New IGS EPDs are Really Better
Dr. Lauren Hyde, Lead Geneticist, International Genetic Solutions

4:00 – 4:30 p.m. Impact of Single-Step on Selection Indexes

Dr. Matt Spangler, Associate Professor, University of Nebraska-Lincoln

4:30 – 5:30 p.m. Breed Panel: Trials and Tribulations of Weekly Evaluations

Dr. Wade Schafer, CEO, American Simmental Association

Mr. Tom Brink, CEO, Red Angus of America Association

Mr. Shane Bedwell, COO, American Hereford Association

Ms. Kelli Retallick, Genetic Service Director, Angus Genetics, Inc.

Thursday Evening Dinner Night Out • Colorado State University Stadium Club

5:30 p.m. Buses begin departing to CSU from Embassy Suites

6:00 – 9:30 p.m. CSU Stadium Club Dinner

SCHEDULE OF EVENTS

Friday, June 22

7:00 a.m. – Noon Registration Open • Conference Center Foyer

7:00 – 8:00 a.m. Breakfast • Mountain Holly & Canyon Maple

Morning Session: • Pinyon Pine & River Birch Decision Time: Who Will Own Our Industry?

7:45 – 8:00 a.m. Announcements
Sallie Miller, Chair, BIF Organizing Committee; Croissant Red Angus

8:00 – 8:30 a.m. Value Driven by Information
Wade Small, President, Livestock Division, Agri Beef, Inc.

8:30 – 9:00 a.m. What I Learned from Pigs
Marty Ropp, Allied Genetic Resources

9:00 – 9:30 a.m. How Does the Dairy Industry Handle Information?
Chuck Sattler, Vice-President, Genetic Programs, Select Sires, Inc.

9:30 – 10:00 a.m. Break

10:00 – 11:30 a.m. Panel Discussion: Who Owns Your Data and Where Is It?
Moderator: Dr. Darrh Bullock, Extension Professor, University of Kentucky
Dr. Matt Cleveland, Director, Global Beef Product Development, Genus ABS
Dr. Dan Moser, President, Angus Genetics Inc., American Angus Association
Dr. Wade Shafer, Executive Vice President, American Simmental Association
Dr. Larry Benyshek, Benyshek and Hough Consulting Services
John Genho, Livestock Genetic Services, LLC

11:30 a.m. – Noon BIF Caucuses and Board Elections

Noon – 2:00 p.m. Awards Luncheon • Mountain Holly & Canyon Maple

What I Heard This Morning
Don Schiefelbein, Schiefelbein Farms
Presentation of BIF Continuing Service and Seedstock Awards
Presentation of Roy Wallace Scholarships

Introduction of New Directors and Officers

Outgoing President's Remarks

Invitation to BIF 2019

2:00 – 5:30 p.m. Afternoon Breakout Sessions

Genomics and Genetic Prediction • River Birch A/B

Chair: Dr. Mark Thallman, Research Geneticist, USDA-ARS U.S. Meat Animal Research Center

2:00 – 2:30 p.m. Experiences with Implementation of Single-Step at American Angus: One Year In

Dr. Steve Miller, Genetic Research Director, American Angus Association

2:30 – 3:15 p.m. Developments in Single-Step Beef Cattle Genomic Evaluation in the United States

Dr. Daniela Lourenco, Assistant Professor, Department of Animal and Dairy Science, University of Georgia

3:15 – 3:45 p.m. Getting it Right: Proper Contemporary Grouping Strategies for Beef Cattle Performance Programs

Dr. Bob Weaver, Professor/Cow-Calf Extension Specialist, Kansas State University

3:45 – 4:15 p.m. Model-Based Approaches to Improving Accuracy of Genetic Evaluations and Rewarding High Quality Data

Dr. Mark Thallman, Research Geneticist, USDA-ARS U.S. Meat Animal Research Center

4:15 – 5:00 p.m. Use of DNA Pooling for Validation of Genomic Predictions

Dr. Larry Kuehn, Research Geneticist, USDA-ARS U.S. Meat Animal Research Center

Producer Applications • Pinyon Pine

Chair: Dr. Darrh Bullock, Extension Professor, University of Kentucky

2:00 – 4:00 p.m. Bull Selection Workshop

Dr. Matt Spangler, Associate Professor of Animal Science/Extension Beef Genetics Specialist, University of Nebraska

SCHEDULE OF EVENTS

- 4:00 – 4:30 p.m. *Dr. Bob Weaver, Professor/Cow-Calf Extension Specialist, Kansas State University*
Dr. Darrh Bullock, Extension Professor, University of Kentucky
Impact of Reproduction Grant: Identification and Management of Alleles Impairing Heifer Fertility While Optimizing Genetic Gain in Cattle
Dr. Megan Rolf, Assistant Professor, Kansas State University
Dr. David Patterson, Professor, University of Missouri
- 4:30 – 5:30 p.m. Impact of Adaptability Grant: Identifying Local Adaptation and Creating Region-Specific Genomic Predictions in Beef Cattle
Dr. Jared Decker, Assistant Professor, University of Missouri

Efficiency and Adaptability • River Birch C

- 2:00 – 3:00 p.m. *Chair: Dr. R. Mark Enns, Professor, Colorado State University*
Understanding Pulmonary Hypertension in the Context of Arterial Pressures (PAP), Brisket Disease and Late-Term Feedlot Death
Dr. Tim Holt, Associate Professor, Clinical Sciences, Colorado State University
- 3:00 – 3:30 p.m. Development and Implementation of Pulmonary Arterial Pressure EPD
Dr. Scott Speidel, Assistant Professor, Colorado State University
- 3:30 – 4:15 p.m. Risk Management for Cow/Calf and Stocker Operators
Troy Applehans, Cow-Calf and Feeder Cattle Market Specialist, CattleFax
- 4:15 – 4:45 p.m. The Design, Development and Implementation of a Beef Cattle Breeding Simulation
Maria Haag, Ph.D. Candidate, University of Missouri
- 4:45 – 5:15 p.m. Approaches for Evaluating the Relationship Between Feedlot and Pasture Intake
Miranda Culbertson, Ph.D. Candidate, Colorado State University

5:30 p.m. **BIF Board of Directors Meeting and Photo**

Friday Evening

- 5:30 p.m. Leachman/Zinpro Dinner Out: \$Profit, Herdsires and Free Supper (must provide your own transportation)
2000 W. County Road 70, Fort Collins, Colorado
- 6:00 p.m. Dinner

Saturday, June 23

7:00 a.m. **Tour Buses Depart Embassy Suites**

8:00 a.m. **Kuner Feedlot, Five Rivers Cattle Feeding, Kersey, Colo.**

Five Rivers Cattle Feeding, LLC is owned by the investors of Pinnacle Arcadia Cattle Holdco, LLC. Five Rivers Cattle Feeding includes 11 feedlots and has a total feeding capacity estimated at 980,000 head, making it the largest cattle feeder in the world. The feeding operation traces its roots back to the 1920s with the Monfort family and now has yards in Arizona, Colorado, Idaho, Kansas, Oklahoma and Texas. The Kuner feedlot was constructed in 1974 and is currently managed by Tony Bryant. For more information, visit www.fiveriverscattle.com.

11:30 a.m. **Cherokee Ranch & Castle, Sedalia, Colo. (Lunch and Tour)**

"Tweet" Kimball pioneered Santa Gertrudis cattle in the Rocky Mountain Region. Established in 1954, the Scottish-inspired Cherokee Ranch & Castle rises high above 3,400 protected acres. The awesome 200-mile views – from Pike's Peak to Long's Peak and beyond – are renowned as best in the West. The ranch is a mere 30 minutes south of Denver and one of the unique venues in all of Colorado. For more information, visit www.cherokeeanch.org

4:00 p.m. **Anheuser-Busch Brewery Experience, Fort Collins, Colo. (Tour and Dinner)**

The Fort Collins Brewery opened in 1988 and is vital to the distribution of fresh beers to western states, including Arizona, California, New Mexico, Utah and more. With a panoramic view of the scenic Foothills, the brewery tour is an immersive experience where you can hear, smell, touch and taste the components that go into some of the world's most popular beers. Enjoy a stunning view of the mountainside while you kick back and enjoy a variety of Anheuser-Busch beers and dinner in the Biergarten. For more information, visit www.budweisertours.com.

GENERAL SESSION SPEAKERS

Young Producers' Symposium



Kevin Oschner, M.S., was born and raised on an irrigated farm and registered cattle operation in Fort Collins, Colo. He attended Colorado State University (CSU) where he was a member of the CSU livestock judging team and was actively involved in FFA, serving as a National FFA officer in 1987-88. In 1997, Kevin earned a master's degree in management from the

Krannert School of Business at Purdue University.

Kevin spent more than two decades working for the Indianapolis-based consulting firm Agri Business Group/Adayana before founding his own consulting practice, Agcellerate, LLC. Over the past 27 years, he has had the privilege of providing strategic planning, marketing consulting, sales/management training and keynote speaking services to some of the country's largest animal health, crop protection, seed, feed and farm machinery companies.

In addition to his consulting and TV hosting responsibilities at NCBA's Cattlemen to Cattlemen, Kevin manages his family operation consisting of 130 registered Limousin and Lim-Flex cows and irrigated corn, alfalfa and grass hay along the South Platte River.



Mark F. Allan, Ph.D., presently serves as the director of genetic technology for Trans Ova Genetics, Sioux Center, Iowa. In this role he oversees R&D for genetics, genetic marketing opportunities and new product development activities. From 2003 to 2008, Mark served as a research geneticist for the USDA's Agricultural Research Service at the U.S. Meat Animal Research

Center in Clay Center, Neb. From 2008 to 2011, he served as the associate director of global technical services for Pfizer Animal Health-Genetics. Additionally, from 2006-2011 he served as an adjunct faculty member at the University of Nebraska Animal Science Department.

Mark has delivered numerous invited symposium talks in North America and abroad. He has received multiple industry awards, including being named one of the "Top Ten Industry Leaders Under 40" by *Cattle Business Weekly* and receiving the Trail Blazers Teachers and Researchers honor from the American Angus Association.



Richard Fagerlin is the founder and president of Peak Solutions. With over 20 years of leadership and organizational development experience, he is a sought-after speaker, consultant and facilitator. Richard is one of the leading authorities on the topic of trust, travelling internationally, helping clients create a culture of high trust and develop leaders at all

organizational levels. He will provide insight that will benefit you in both your personal and professional life, as well as give you new and impactful ways to think about all of your relationships.

Thursday, June 21 • Morning Session



Michael Genho, M.S., MBA, joined Elanco Animal Health in 2011 and currently manages all commercial operations for Elanco's U.S. beef feedyard business. In this capacity he directs all feedyard sales of Elanco's feed additive, vaccine and antibacterial portfolio. He also leads a team of statisticians and economists who provide value-added analytical services

to U.S. beef industry live production and packing customers. They offer performance, animal health and financial analyses for feedyards representing approximately 40 percent of total U.S. cattle on feed.

Michael completed his bachelor's degree in animal science from Brigham Young University, earned his master's degree with emphasis in meat science from Colorado State University and an MBA/MA from the Wharton School at the University of Pennsylvania.

Michael worked at Conagra Foods as a food scientist for four years, developing protein product lines for their branded frozen foods business. He later worked as a strategy consultant for Ascendant Partners, a Denver-based food- and agribusiness-focused consultancy and investment bank. In this role, Michael led due diligence, feasibility analysis, forecasting and capital-raising efforts for over 25 firms in the food, renewable energy and agribusiness industries.

Mark McCully, M.S., vice president of production at Certified Angus Beef LLC, is responsible for the brand's supply chain efforts. He leads strategies incorporating the seedstock, cow-calf, feeding and packing sectors to raise

GENERAL SESSION SPEAKERS



and process high quality Angus cattle with the brand's unrivaled quality standards.

Mark joined the company in 2000 as director of packing. In June 2002, he helped develop and then coordinate a regional sales team to serve retail, foodservice and international business partners. In March 2005, he transitioned to supply

development and production.

Before these endeavors, Mark worked for Southern States Cooperative in Virginia. He earned a bachelor's degree in agricultural science from Western Illinois University and followed with a master's program in ruminant nutrition at Michigan State University.



Sara Place, Ph.D., is the senior director of sustainable beef production research at the National Cattlemen's Beef Association (NCBA). Her role is to oversee the Beef Checkoff-funded sustainability program, including using lifecycle assessment to benchmark the U.S. beef industry's sustainability. She received her doctorate in animal biology from University

of California, Davis and a bachelor's degree in animal science from Cornell University.

Prior to joining NCBA, she was an assistant professor of sustainable beef cattle systems at Oklahoma State University (OSU) for four years, with a split research and teaching appointment. At OSU, her research program focused on the measurement of enteric methane emissions from cattle. Her teaching responsibilities included animal nutrition, dairy cattle science, ethics and professionalism, and sustainable animal agriculture. From 2014 to 2015, she served on the National Academies of Sciences Committee on Considerations for the Future of Animal Science Research that published the report, *The Critical Role of Animal Science Research in Food Security and Sustainability*.

Dorian Garrick, Ph.D., is chief scientist at the AL Rae Center in the School of Agriculture at Massey University, located at the Ruakura Research Centre in Hamilton, New Zealand. He received a first-class honors degree in agricultural science from Massey University in 1981, then worked in sheep and pig breeding research for four years before earning a doctorate degree from Cornell University in 1988.



He held the inaugural appointment to the prestigious Jay Lush Endowed Chair in Animal Breeding and Genetics at Iowa State University for 10 years and spent five years at Colorado State University.

Dorian's recent work has focused on theoretical and applied aspects of using genomic information to predict

performance in a variety of species.

Dorian is a founding partner of U.S.-based Theta Solutions LLC, which licenses innovative BOLT software for national and international genetic and genomic evaluations. That software is used for the largest North American single-step beef cattle evaluation used by International Genetics Solutions, as well as ABRI for the North American Hereford evaluation.



John Pollak, Ph.D., received his bachelor's degree in animal science from Cornell University and his master's and doctorate degrees in animal breeding from Iowa State University. He joined the faculty at the University of California, Davis working as a beef cattle geneticist before moving to Cornell University.

At Cornell he and his colleague, Richard Quaas, Ph.D., worked

on methodology for beef cattle genetic evaluation with the American Simmental Association to produce EPDs for Simmental cattle. John was director of the National Beef Cattle Evaluation Consortium (NBCEC) from 2003 to 2010.

In 2010, he retired from Cornell and assumed the role of director of the U.S. Meat Animal Research Center in Clay Center, Neb., until he retired in May 2017.

He has been recognized for his contributions to the beef industry and animal breeding, having received the Pioneer and Continuing Service Award from the Beef Improvement Federation; the Rockefeller Prentice Memorial Award in Animal Breeding and Genetics from the American Society of Animal Science; Educator of the Year Award and Presidents Award from the New York Beef Producers Association; and the Industry Service Award from the Nebraska Cattlemen association. In 2013, Pollak and Quaas were selected by *BEEF* magazine as two of the 50 most influential people in the beef industry during the last 50 years, based on their research into the development and implementation of EPDs.

GENERAL SESSION SPEAKERS

Friday, June 22 • Morning Session



Wade Small, M.S., graduated from Oregon State University with a bachelor's degree in animal sciences and received a master's degree from the University of Wyoming in animal and veterinary science. He interned with Agri Beef Co. (AB) in 2001 at their El Oro Feedyard in Moses Lake, Wash. He joined Agri Beef full time in 2004 as feed manager at Snake

River Cattle Feeders in American Falls.

Wade has over 15 years of practical livestock experience in several facets of the industry, including ranching, responsibility of the company's seedstock and genetic programs, feedyard management, cattle and commodity procurement, as well as serving as director of cattle procurement until 2013.

Wade has been in his current role as Agri Beef Livestock president since February 2013. He is responsible for Agri Beef's feedyards, assuring adequate supply to AB Foods, Washington Beef Plant, Agri Beef's genetic program and strategizing with AB's Risk Management Division.



Marty Ropp, M.S., is founder and executive officer of Allied Genetic Resources. Originally from Normal, Ill. – the current home office of Allied – Marty grew up in the swine seedstock business, but left Illinois in 1982 to pursue a bachelor's degree from Kansas State University, followed by a master's degree from the University of Missouri (UM). Marty also coached UM's

livestock and meat animal evaluation teams during his five-year teaching tenure there. He then held positions as Extension regional livestock specialist at UM and Michigan State University before working as director of field services at the American Simmental Association for 12 years.

Marty founded Allied Genetic Resources in June 2010. With more than 90 owners specializing in the genetic improvement, production and marketing of SimAngus and Simmental as well as Red Angus, Angus, Gelbvieh Balancer and now Shorthorn commercial bulls, Allied is one of the largest coordinated seedstock service businesses in the United States, with owners marketing nearly 10,000 bulls annually. Marty is also a BIF past president and has served on its board of directors for the past six years.

Although work is his primary occupation and hobby, Marty does find time to do a little hunting and fishing during his travels. He also enjoys the time he spends working with educational and youth livestock programs.



Charles G. (Chuck) Sattler, M.S., is vice president of genetic programs at Select Sires. He has been with Select Sires for 18 years and previously served as the director of progeny testing. Chuck grew up on a dairy farm in Wisconsin where they had a registered Guernsey herd. He received a bachelor's degree in dairy science and a master's degree in dairy cattle breeding

from the University of Wisconsin-Madison.

Chuck served as the genetic programs administrator for the National Association of Animal Breeders for 12 years prior to joining Select Sires. He currently serves as chairman of the NAAB Board of Directors and is a member of the Council of Dairy Cattle Breeding Board of Directors. Previously, Sattler served on the National Dairy Shrine Board of Directors, the Holstein Foundation's Young Dairy Leaders Institute Advisory Committee and USDA's National Animal Germplasm Program Advisory Committee.



Matthew A. Cleveland, Ph.D., is director of global beef product development for Genus ABS, at De Forest, Wis. After earning a doctorate degree in animal breeding and genetics from Colorado State University in 2006, Matthew joined Genus, a world leader in animal genetic improvement, as a quantitative research scientist. His early career focused on developing

statistical methodologies to incorporate genomics into the genetic improvement program at Genus' subsidiary PIC. He was then tasked with building the scientific computing organization to ensure Genus was efficiently leveraging their science computing capabilities.

For the last four years, Matthew has led the Global Beef Product Development team at ABS, which is tasked with delivering improved beef genetics with demonstrated customer value around the world.

GENERAL SESSION SPEAKERS



Dan Moser, Ph.D., is president of Angus Genetics Inc. (AGI), and director of performance programs for the American Angus Association, headquartered in St. Joseph, Mo. Dan was raised on a small seedstock cattle operation in northeast Kansas. He earned his bachelor's degree in animal science from Kansas State University, and his master's

and doctorate degrees in beef cattle genetics from the University of Georgia.

For 20 years, as a faculty member at the University of Georgia, the University of Nebraska-Lincoln and Kansas State University, he taught courses in animal management, genetics and animal breeding; conducted applied research; advised undergraduate and graduate students; and coordinated university seedstock cattle herds.

In his current role, he oversees genetic evaluation programs, genomic testing services, research initiatives, business activities and member education efforts for AGI and the American Angus Association. He is a frequent speaker at beef industry events throughout the United States, and internationally. He has served the beef industry in a variety of leadership roles and is currently on the BIF Board of Directors.



Wade Shafer, Ph.D., grew up on the Shoestring Ranch, a small seedstock operation in Detroit Lakes, Minn. Shafer completed his bachelor's degree in animal science at North Dakota State University, followed by master's and doctorate degrees in animal breeding and genetics from Colorado State University.

While at Colorado State, Shafer did extensive work in the area

of bio-economic simulation modeling. Following his formal education, he expanded Shoestring Ranch to more than 500 cows, with cooperator herds representing another 500-plus cows. The ranch sold up to 200 bulls annually.

After selling his cow herd, Shafer joined the American Simmental Association (ASA) in 2003 as director of breed improvement. In 2011, he was named ASA's chief operations officer and, in 2013, became ASA executive vice president.



Larry Benyshek, Ph.D., began his career in beef cattle genetic improvement as director of research and education for the North American Limousin Foundation in 1973.

In 1976, Larry was appointed to the faculty at the University of Georgia (UGA) with teaching and research responsibilities in animal breeding. His vision

for the beef cattle industry led to the formation of a team of scientists who provided a research arm and genetic evaluations for many major breeds of beef cattle in the U.S., Canada and South America. In his role as the group's research leader, he presented research results concerning National Cattle Evaluation in almost every state in the United States. He has authored or co-authored numerous scientific and trade publications.

He served as the UGA Animal and Dairy Science Department head and on the American Society of Animal Science Board of Directors.

After retiring from UGA, Larry founded Benyshek and Hough Consulting Services, Inc., with John Hough, Ph.D. As company president, he oversees the development and maintenance of a state-of-the-art, Web-based data management system for beef cattle that's utilized by some 125 beef cattle operations throughout the United States and Canada. The system provides for accurate data collection for both commercial and registered cattle operations, and facilitates interaction between different databases, including those at several breed associations. The company provides individual training and support so that clients can have the best possible experience in data management.



John Genho, M.S., MBA, is a geneticist and beef producer based in Sperryville, Virginia. His company, Livestock Genetic Services, runs genetic evaluations for multiple breed associations including commercial ranches and other commercial entities. He has a Masters of Science in Animal Breeding and Genetics from Cornell University, a Master of Business Administration from

Duke University, and a Bachelors of Science in Animal Science from Brigham Young University. In addition to his education, he has spent his life in commercial beef production.

SEEDSTOCK PRODUCER OF THE YEAR NOMINEES

Altenburg Super Baldy Ranch

Owners: William and Sharon Altenburg

Manager: Russ Princ

Fort Collins, Colorado

Altenburg Super Baldy Ranch (ASBR) is located in northern Colorado, near the Wyoming border. Their seedstock herd is comprised of 200 spring-calving cows and 40 fall-calving cows, mostly Simmental with some Angus (both black and Red Angus) influence. The registered cows are used to produce both fullblood bulls as well as composite F1 SimAngus bulls for the commercial market. The cow herd is 75 percent black and 25 percent red. Ranch elevation ranges from 5,500 feet in the winter to 6,500-7,500 feet in summer range; therefore, PAP testing is done with the help of Dr. Tim Holt of Colorado State University. PAP scores are provided on every sale bull.

A family-owned operation, ASBR provides much of the management and labor, along with Russ Princ, manager. Their genetic program's success is due in large part to an extensive artificial insemination (AI) and embryo transfer program. Replacement heifers are synchronized and AI-bred two times in the spring. Cows are exposed one time to AI and turned out with individual bulls before going to the "high country" for the summer. Calves are weaned in late September or early October. The mature cows will remain on native grass until Feb. 1 and brought home just before calving starts the middle of February.

The Altenburgs hold a bull sale the third Saturday of March, selling approximately 120 bulls. Customers are primarily Colorado, Wyoming, Nebraska and Kansas commercial herds. Embryos have also been sold to a long-time customer in Australia for several years.

The Altenburg Super Baldy Ranch is proudly nominated by the Colorado Cattlemen's Association.



JH Graydon Farm

Owners/Managers: Rusty and Debbie Graydon

Montgomery, Alabama

JH Graydon Farm, located in Montgomery, Ala., is owned and operated by true partners, husband and wife team Rusty and Debbie Graydon. This partnership has produced Angus seedstock for the past 30 years. The herd consists of 70 mature cow-calf pairs, 30 yearling to two-year-old bulls, and 15-20 yearling heifers. The farm operates on 200 owned and 300 acres of leased pastureland. A fall calving season from September through November best utilizes grass supply, weather and age preference of their buyers. JH Graydon Farm markets around 25-30 bulls per year. Using proven genetics, the Graydons strive to produce bulls that will perform in the Southeast's high humidity, hot temperatures and native grasses to produce genetics that complement the Angus breed and their customers.

The Graydons believe continuous genetic improvement is the foundation of success. All EPD values of potential AI sires and donors are analyzed, focusing on weaning, milk and carcass data, and combined with cow production records, to produce calves that meet expectations in adding value. An overall operational goal is the cattle herd must be financially self-supporting, so planning and selecting AI sires and donor cows is crucial to the farm's financial success.

JH Graydon Farm has utilized the Angus Herd Improvement Record (AHIR) system since the late 1980s to record, maintain and analyze all performance records. The Graydons are also active leaders in the Alabama Angus Association, Alabama Beef Cattle Improvement Association and their local county cattlemen's association.

The Alabama Beef Cattle Improvement Association is proud to nominate JH Graydon Farm.



SEEDSTOCK PRODUCER OF THE YEAR NOMINEES

Jungels Shorthorn Farms

**Owners/Managers: Derek and Brock Jungels
Kathryn, North Dakota**

Jungels Shorthorn Farms (JSF) was established in 1953 with the purchase of a registered Shorthorn heifer. She was added to a herd of commercial cows as a 4-H project for Derek Jungel's uncle, LeRoy. From there, the herd grew to a base of 50 registered Shorthorn cows. Top bulls were purchased throughout the years from national sales and the family was one of the first in the area to employ performance testing. In 1974, Dennis and Rita Jungels purchased the farm and cow herd of long-time North Dakota Shorthorn breeder Melvin Dronen.

The 50-head cow herd was maintained for the next 25 years with performance testing at the core of selection. Expansion began in 2000 when Dennis and Rita's son, Derek, graduated from college and began to aggressively seek the best real-world, industry-driven genetics available in the Shorthorn breed to enhance their existing core cow herd. In 2002, Derek purchased a farmstead along the banks of the Sheyenne River Valley south of Valley City, N.D. What started with a couple of pole buildings and two pens has evolved into a bustling ranch headquarters where the females and bulls for their production sales are housed, as well as display pens and a sale facility.

In 2007, Derek took a risk that would later become a boon to the operation. In an effort to reintroduce Shorthorns to the industry, Derek took as many as 50 bulls to the National Western Stock Show in Denver, not only displaying them but auctioning them off after. This later grew into a fixture at the National Western and effectively put JSF on the map with commercially focused Shorthorn genetics on a national stage.

In 2009, Derek purchased property two miles from the headquarters. Much like his initial acquisition in 2002, this location has been transformed. Today, it supports a state-of-the-art, 999-head capacity backgrounding feedlot along with barns for calving and staging new pairs, as well as working facilities. In 2013, Derek was presented with a unique opportunity to acquire 860 acres of cropland, pasture, and irrigated land, all within a two-mile radius of the ranch headquarters. While this was a substantial undertaking, it has set JSF up to grow with a strong, efficient base of 1,050 acres of owned tillable, pasture and irrigated land utilized for feed production, alfalfa sales and residual grazing. This location currently supports winter grazing and feeding of 225 head of registered Shorthorn and Shorthorn Plus cows, plus the development of 100 purebred and composite Shorthorn heifers. In addition to the core Shorthorn herd, JSF also maintains separate registered herds of 50 Angus, 50 Red Angus and 75 Simmental cows. These females are mated exclusively to JSF Shorthorn bulls for the development of unique composite cattle, marketed with the commercial producer in mind.

In addition to the cow-calf operation, JSF acquires heifer calves from their bull customers. These females are developed and then AI'd to Shorthorn or Red Angus bulls. These bred heifers are marketed in groups, based on calving date, at their annual bull sale. At any one time, Jungels Shorthorn Farm supports 400 registered cows from four breed associations, plus approximately 1,000 commercial females and backgrounded steers. The operation spans over 3,300 acres, a combination of owned and rented land. JSF currently holds two sales annually, "Durham Nation" the last Saturday of October and "Durhams in the Dakotas" the first Tuesday in February.

Jungels Shorthorn Farms is proudly nominated by the American Shorthorn Association.



SEEDSTOCK PRODUCER OF THE YEAR NOMINEES

Van Newkirk Herefords

Owners: Joe and Cyndi Van Newkirk

Manager: Joe Van Newkirk

Oshkosh, Nebraska

Van Newkirk Herefords, Oshkosh, Neb., is a family-owned ranching operation dating back to 1892 when Lorenzo Van Newkirk started mating Hereford bulls to his longhorn cows. In 1942, A.J. (Bud) Van Newkirk started the registered herd of Herefords.

Today, Van Newkirk Herefords is operated by the third and fourth generations, including Joe and wife, Cyndi; sons, Kolby and Nick; and daughter, Sara. They, along with longtime hired man, Travis Kezar, are passionate about breeding quality Hereford genetics.

The ranch's herd has grown from five to 600 registered cows they manage today. Center pivots and efficient use of surface irrigation have been utilized, making it possible for the Van Newkirks to produce 90 percent of their winter feed supply. Summer grazing is on native Sandhills pasture.

The Van Newkirks believe in gathering accurate, timely performance data. For more than 45 years, performance testing has been a high priority that continues to evolve with technology. They began weighing calves individually in 1969, and in the 1980s, they started ultrasounding them. Since the 1980s, they have fed out cull heifers and steers, collecting feedlot and carcass data. In the 1990s, they implemented genetic testing.

The Van Newkirk family is passionate about improving Hereford genetics and strives to strengthen the beef industry by offering superior genetics, utilizing sustainable management practices and being good environmental stewards. They will host their 46th annual sale on Jan. 21, 2019, selling 210 bulls and 260 heifers. Demand for Van Newkirk genetics has grown over the years. They attribute their success to repeat customers.

The American Hereford Association is proud to nominate Van Newkirk Herefords.



Wedel Beef Genetics

Owners: Frank and Susan Wedel

Manager: Frank Wedel

Leoti, Kansas

Wedel Beef Genetics is located in the short-grass country known as the High Plains of western Kansas. Frank and Susan Wedel own the seedstock operation, which is located 15 miles northwest of Leoti, Kansas. Their introduction to Red Angus began in 1989 when they purchased their first Red Angus bulls to help solve calving-ease problems in their commercial cow herd.

They purchased their first Red Angus heifers in 1990 and began selling bulls in 1993. The first few years, they sold 30 to 40 bulls per year private treaty. In 2001, they held their first production sale. At that time, they determined that to be a viable seedstock supplier, they needed to expand their business. They sold their commercial cows and focused on the seedstock business. This year, they will sell more than 150 bulls and make 600 matings.

The Wedel cow herd includes Red Angus as well as Sim/Red Angus and Char/Red Angus hybrids. The mature cows graze year-round northeast of Wallace, Kan., using an intensive rotational grazing program. Young heifers spend their first two years at Leoti until their first calf is weaned, then join the mature cows.

Each year, they purchase steer and heifer calves from their bull customers. The steers are finished at commercial feedyards and heifers are developed for replacements. Those that don't make the cut are finished, and carcass and performance data are collected and shared with producers. They sell 150-160 heifers in their production sale each year and about that many are bred and sold in the fall. Knowing their customers is the Wedel family's highest priority because their customers' success becomes their success.

Wedel Beef Genetics is proudly nominated by the Kansas Livestock Association.



PAST BIF SEEDSTOCK PRODUCERS OF THE YEAR

- 2017:** Hunt Limousin Ranch, Nebraska
- 2016:** Shaw Cattle Company, Idaho
- 2015:** McCurry Angus Ranch, Kansas
- 2014:** Schuler Red Angus, Nebraska
- 2013:** Bradley 3 Ranch, Texas
- 2012:** V8 Ranch, Texas
- 2011:** Mushrush Red Angus, Kansas
- 2010:** Sandhill Farms, Kansas
- 2009:** Harrell Hereford Ranch, Oregon
- 2009:** Champion Hill, Ohio
- 2008:** TC Ranch, Nebraska
- 2007:** Pelton Simmental Red Angus, Kansas
- 2006:** Sauk Valley Angus, Illinois
- 2005:** Rishel Angus, Nebraska
- 2004:** Camp Cooley Ranch, Texas
- 2003:** Moser Ranch, Kansas
- 2002:** Circle A Ranch, Missouri
- 2001:** Sydenstricker Genetics, Missouri
- 2000:** Fink Beef Genetics, Kansas
- 1999:** Morven Farms, Virginia
- 1998:** Knoll Crest Farms, Virginia
- 1998:** Flying H Genetics, Nebraska
- 1997:** Wehrmann Angus Ranch, Virginia
- 1997:** Bob & Gloria Thomas, Oregon
- 1996:** Frank Felton, Missouri
- 1995:** Tom & Carolyn Perrier, Kansas
- 1994:** Richard Janssen, Kansas
- 1993:** R.A. "Rob" Brown, Texas
- 1993:** J. David Nichols, Iowa
- 1992:** Leonard Wulf & Sons, Minnesota
- 1991:** Summitcrest Farms, Ohio
- 1990:** Douglas & Molly Hoff, South Dakota
- 1989:** Glynn Debter, Alabama
- 1988:** W.T. "Bill" Bennett, Washington
- 1987:** Henry Gardiner, Kansas
- 1986:** Leonard Lodoen, North Dakota
- 1985:** Ric Hoyt, Oregon
- 1984:** Lee Nichols, Iowa
- 1983:** Bill Borrer, California
- 1982:** A.F. "Frankie" Flint, New Mexico
- 1981:** Bob Dickinson, Kansas
- 1980:** Bill Wolfe, Oregon
- 1979:** Jim Wolf, Nebraska
- 1978:** James D. Bennett, Virginia
- 1977:** Glenn Burrows, New Mexico
- 1976:** Jorgenson Brothers, South Dakota
- 1975:** Leslie J. Holden, Montana
- 1975:** Jack Cooper, Montana
- 1974:** Carlton Corbin, Oklahoma
- 1973:** Mrs. R. W. Jones, Jr., Georgia
- 1972:** John Crowe, California

2017 BIF SEEDSTOCK PRODUCER OF THE YEAR



Hunt Limousin Ranch, Oxford, Neb., was named the 2017 Beef Improvement Federation Seedstock Producer of the Year during an awards ceremony June 2 in Athens, Ga. Pictured (from left) are: Marty Ropp, Normal, Ill., 2016-2017 BIF president; with recipients Charlie Hunt, Jenna Hunt and Daniel Hunt; along with Jay Carlson, *BEEF* magazine, award sponsor.

COMMERCIAL PRODUCER OF THE YEAR NOMINEES

Auburn Gulf Coast Research and Extension Center

Owner: Auburn University
Manager: Malcomb Pegues
Fairhope, Alabama

The Auburn University Gulf Coast Research and Extension Center (GCREC) is located in Fairhope, Ala., about one mile east of Mobile Bay and approximately 30 miles north of the Gulf of Mexico. It is one of the original five research centers of the Alabama Agricultural Experiment Station system, established in 1929-30. The climate is mild, with an average of 67 inches of annual rainfall. The center represents an 800-acre diversified operation, including beef cattle, row crops, small fruits and pecans. The Simmental- and Angus-cross herd maintains about 85 mature cows and 30 replacement heifers, operating with a 75-day fall calving season from mid-September to November. The climate enables the GCREC to provide forages for cattle approximately 320 days a year. Cattle are integrated into the row crop operation by planting annual ryegrass behind summer crops. This ability to grow forages determines the genetic focus of the herd by allowing high emphasis on maternal milk and growth.

The GCREC has been an active participant in the Alabama Beef Cattle Improvement Association (BCIA) Commercial Record Keeping Program for the past 25 years and has earned numerous top weaning weight and Gold Star Cow awards. Calf and individual cow performance data is the baseline to continually evaluate herd productivity. Internet-based recordkeeping of individual animal production and health treatments is an integral management tool at the GCREC. The center is active in demonstrations of estrus synchronization and fixed-time artificial insemination, and is currently engaged in research for biomarkers of infertility in beef heifers.

The Auburn Gulf Coast Research and Extension Center is proudly nominated by the Alabama Beef Cattle Improvement Association.



Hansen Family Ranches

Owners: Circle Ranches – Ed & Marilyn Hansen;
Lone Pine Livestock – Carl & Debbie Hansen;
Quarter Circle Lazy H Ranch – Chris & Janeth Hansen;

D Dart Ranch – Cheri & Scott Dent

Manager: Hansen Family
Livermore, Colorado

The Hansen Family, from Livermore, Colo., is a fifth-generation family ranch originally purchased in 1940 by Sam and Castor Hansen, father and grandfather of Ed Hansen and grandfather and great-grandfather of Carl, Cheri and Chris. The ranch headquarters have been located in Livermore since 1940. In 1994, the Hansen family acquired a summer ranch in Grover, Colo., replacing summer forest permits. The Grover Ranch consists of approximately 15,000 acres and provides reliable pasture and more flexible management. Currently, the herd consists of 250 Angus cattle. A few years ago, due to extreme drought, the family was forced to reduce one-third of the herd. They raise grass hay – 700-800 tons – to use for winter feed and sell for supplemental income. They also raise replacement heifers. The calving season runs from Jan. 15 to March 15.

What makes the Hansens unique is that they utilize a 100-percent AI breeding program. They raise their own clean-up bulls and purchase high-quality bulls, which they collect semen from and then use for inseminating the herd. This allows them to spread bull costs over more cows, and, consequently, pay a higher dollar for quality sires. The cow herd spends from June 1 through Oct. 15 at the Grover Ranch, where calves are sold and shipped. The cows spend the balance of the year at the home ranch in Livermore for calving and breeding. There are three generations involved in showing livestock at various expositions throughout the state.

The Colorado Cattlemen's Association is proud to nominate Hansen Family Ranches.



COMMERCIAL PRODUCER OF THE YEAR NOMINEES

Woolfolk Ranch

**Owners/Managers: Kent and Tyler Woolfolk
Protection, Kansas**

Woolfolk Ranch LLC is located in southwestern Comanche County, Kan., and northeastern Harper County, Okla. Kent Woolfolk and his son, Tyler, represent the fourth and fifth generations to operate the ranch. The ranch encompasses about 17,000 owned and leased acres of grass and around 1,000 acres of cropland.

The Woolfolks maintain around 1,100 Angus-based cows that calve in the spring, starting about March 15. They also take in nearly 150 Angus cows year-round on a custom, per-head basis. The cows are managed alongside their personal herd. Depending on moisture availability, the ranch also will custom-graze 750 to 1,200 yearlings each year. In 2014, the Woolfolk family began constructing a feeding facility to use for weaning purposes and as a drylot for cows during the fall and winter, to allow them to feed a low-cost maintenance ration.

The feedyard lets the Woolfolks develop and market their own replacement heifers, grow steers to feeder weight and custom develop heifers for other ranches. It also is used as part of a drought plan that enables the ranch to destock pastures much quicker if the need arises.

The cow herd is rotated during the grazing months using a three-pasture rotation system. This provides adequate rest between grazing cycles prior to weaning, which begins in early September.

All cattle are handled horseback using low-stress cattle-handling techniques, which allows the growing sixth generation to help when available. The Woolfolk family, while always looking for new management techniques and technology to improve cattle efficiency, still prides itself on ranching traditions passed down from previous generations.

The Woolfolk Ranch is proudly nominated by the Kansas Livestock Association.



2017 BIF COMMERCIAL PRODUCER OF THE YEAR



Mundhenke Beef, Lewis, Kan., was named the 2017 Beef Improvement Federation Commercial Producer of the Year during an awards ceremony June 1 in Athens, Georgia. Pictured (from left) are: John and Gina Mundhenke of Mundhenke Beef and Jay Carlson of *BEEF* magazine, award sponsor.

PAST BIF COMMERCIAL PRODUCERS OF THE YEAR

- 2017:** Mundhenke Beef, Kansas
2016: Plum Thicket Farms, Nebraska
2015: Woodbury Farms, Kansas
2014: CB Farms Family Partnership, Kansas
2013: Darnall Ranch, Inc., Nebraska
2012: Maddux Cattle Company, Nebraska
2011: Quinn Cow Company, Nebraska
2010: Downey Ranch, Kansas
2009: JHL Ranch, Nebraska
2008: Kniebel Farms and Cattle Company, Kansas
2007: Broseco Ranch, Colorado
2006: Pitchfork Ranch, Illinois
2005: Prather Ranch, California
2004: Olsen Ranches, Inc., Nebraska
2003: Tailgate Ranch, Kansas
2002: Griffith Seedstock, Kansas
2001: Maxey Farms, Virginia
2000: Bill & Claudia Tucker, Virginia
1999: Mossy Creek Farm, Virginia
1999: Giles Family, Kansas
1998: Mike & Priscilla Kasten, Missouri
1998: Randy & Judy Mills, Kansas
1997: Merlin & Bonnie Anderson, Kansas
1996: Virgil & Mary Jo Huseman, Kansas
- 1995:** Joe & Susan Thielen, Kansas
1994: Fran & Beth Dobitz, South Dakota
1993: Jon Ferguson, Kansas
1992: Kopp Family, Oregon
1991: Dave & Sandy Umbarger, Oregon
1990: Mike & Diana Hopper, Oregon
1989: Jerry Adamson, Nebraska
1988: Gary Johnson, Kansas
1987: Rodney G. Oliphant, Kansas
1986: Charles Fariss, Virginia
1985: Glenn Harvey, Oregon
1984: Bob & Sharon Beck, Oregon
1983: Al Smith, Virginia
1982: Sam Hands, Kansas
1981: Henry Gardiner, Kansas
1980: Jess Kilgore, Montana
1979: Bert Hawkins, Oregon
1978: Mose Tucker, Alabama
1977: Mary & Stephen Garst, Iowa
1976: Ron Baker, Oregon
1975: Gene Gates, Kansas
1974: Lloyd Nygard, North Dakota
1973: Pat Wilson, Florida
1972: Chan Cooper, Montana

PAST BIF PIONEER AWARD RECIPIENTS

- 2017**
Harvey Lemmon (posthumously),
Lemmon Angus
Dorian Garrick, Iowa State University
- 2016**
Doug Hixon, University of Wyoming
Ronnie Green, University of
Nebraska
Bill Rishel, Rishel Angus
- 2015**
Paul Genho, Florida
Tom Woodward, Texas
- 2014**
Merlyn Nielsen, Nebraska
Gary Bennett, Nebraska
Steve Radakovich, Iowa
- 2013**
Keith Bertrand, Georgia
Ignacy Misztal, Georgia
Glenn Selk, Oklahoma
- 2012**
Sally Buxkemper, Texas
Donald Franke, Louisiana
Leo McDonnell, Montana
- 2011**
Mike Tess, Montana
Mike MacNeil, Montana
Jerry Lipsey, Montana
- 2010**
Richard McClung, Virginia
John and Bettie Rotert, Missouri
Daryl Strohbehn, Iowa
Glen Klippenstein, Missouri
- 2009**
Bruce Golden, California
Bruce Orvis, California
Roy McPhee (posthumously),
California
- 2008**
Donald Vaniman, Montana
Louis Latimer, Canada
Harry Haney, Canada
Bob Church, Canada
- 2007**
Rob Brown, Texas
David and Emma Danciger, Colorado
Jim Gosey, Nebraska
- 2006**
John Brethour, Kansas
Harlan & Dorotheann Rogers, Miss.
Dave Pingrey, Mississippi

PAST BIF PIONEER AWARD RECIPIENTS

2005

Jack and Gini Chase, Wyoming
Jack Cooper, Montana
Dale Davis, Montana
Les Holden, Montana
Don Kress, Montana

2004

Frank Felton, Missouri
Tom Jenkins, Nebraska
Joe Minyard, South Dakota

2003

George Chiga, Oklahoma
Burke Healey, Oklahoma
Keith Zoellner, Kansas

2002

H.H. "Hop" Dickenson, Kansas
Martin & Mary Jorgensen, South Dakota
L. Dale Van Vleck, Nebraska

2001

Larry Benyshek, Georgia
Minnie Lou Bradley, Texas
Tom Cartwright, Texas

2000

J. David Nichols, Iowa
Harlan Ritchie, Michigan
Robert R. Schalles, Kansas

1999

Joseph Graham, Virginia
John Pollak, New York
Richard Quaas, New York

1998

John Crouch, Missouri
Bob Dickinson, Kansas
Douglas MacKenzie Fraser, Canada

1997

Larry V. Cundiff, Nebraska
Henry Gardiner, Kansas
Jim Leachman, Montana

1996

A.L. "Ike" Eller, Virginia
Glynn Debter, Alabama

1995

James S. Brinks, Colorado
Robert E. Taylor, Colorado

1994

Tom Chrystal, Iowa
Robert C. DeBaca, Iowa
Roy A. Wallace, Ohio

1993

James D. Bennett, Virginia
M.K. "Curly" Cook, Georgia
O'Dell G. Daniel, Georgia
Hayes Gregory, North Carolina
Dixon Hubbard, Virginia
James W. "Pete" Patterson, North Dakota
Richard Willham, Iowa

1992

Frank Baker, Arkansas
Ron Baker, Oregon
Bill Borrer, California
Walter Rowden, Arkansas

1991

Robert A. "Bob" Long, Texas
Bill Turner, Texas

1990

Donn & Sylvia Mitchell, Canada
Hoon Song, Canada
Jim Wilton, Canada

1989

Roy Beeby, Oklahoma
Will Butts, Tennessee
John W. Massey, Missouri

1988

Christian A. Dinkle, South Dakota
George F. & Mattie Ellis, New Mexico
A.F. "Frankie" Flint, New Mexico

1987

Glenn Burrows, New Mexico
Carlton Corbin, Oklahoma
Murray Corbin, Oklahoma
Max Deets, Kansas

1986

Charles R. Henderson, New York
Everett J. Warwick, Maryland

1985

Mick Crandell, South Dakota
Mel Kirkiede, North Dakota

1984

Bill Graham, Georgia
Max Hammond, Florida
Thomas J. Marlowe, Virginia

1983

Jim Elings, California
W. Dean Frischknecht, Oregon
Ben Kettle, Colorado
Jim Sanders, Nevada
Carroll O. Schoonover, Wyoming

1982

Gordon Dickerson, Nebraska
Mr. & Mrs. Percy Powers, Texas

1981

F.R. "Ferry" Carpenter, Colorado
Otha Grimes, Oklahoma
Milton England, Texas
L.A. Maddox, Jr., Texas
Charles Pratt, Oklahoma
Clyde Reed, Oklahoma

1980

Richard T. "Scotty" Clark, Colorado
Bryon L. Southwell, Georgia

1979

Robert Koch, Nebraska
Mr. & Mrs. Carl Roubicek, Arizona
Joseph J. Urick, Montana

1978

James B. Lingle, Maryland
R. Henry Mathiessen, Virginia
Bob Priode, Virginia

1977

Ralph Bogart, Oregon
Henry Holsman, South Dakota
Marvin Koger, Florida
John Lasley, Missouri
W. L. McCormick, Georgia
Paul Orcutt, Montana
J.P. Smith, Missouri
H.H. Stonaker, Colorado

1976

Forrest Bassford, Colorado
Doyle Chambers, Louisiana
Mrs. Waldo Emerson Forbes, Wyoming
C. Curtis Mast, Virginia

1975

Glenn Butts, Missouri
Keith Gregory, Nebraska
Braford Knapp, Jr., Montana

1974

Reuben Albaugh, California
Charles E. Bell, Jr., Virginia
John H. Knox, New Mexico
Paul Pattengale, Colorado
Fred Wilson, Montana
Ray Woodward, Montana

1973

Jay L. Lush, Iowa

PAST BIF CONTINUING SERVICE AWARD RECIPIENTS

- 2017**
Michelle Elmore, Alabama BCIA
Shauna Hermel, Angus Journal
Matthew Spangler, University of
Nebraska - Lincoln
Kevin & Lydia Yon, South Carolina
- 2016**
John Pollak, U.S. Meat Animal
Research Center
Alison Van Eenennaam, University of
California, Davis
Alison Sunstrum, GrowSafe
Steve Kachman, University of
Nebraska-Lincoln
- 2015**
Joe Cassady, South Dakota State
University
Andy Boston, Indiana
Lois Schreiner, Kansas State
University
Chris Shivers, American Brahman
Breeders Association
- 2014**
Larry Kuehn, U.S. Meat Animal
Research Center
Wade Shafer, American Simmental
Association
Warren Snelling, U.S. Meat Animal
Research Center
Susan Willmon, American Gelbvieh
Association
- 2013**
Ben Eggers, Sydenstricker Genetics
Brian House, Select Sires
Lauren Hyde, American Simmental
Association
Jerry Taylor, University of Missouri
Jack Ward, American Hereford
Association
- 2012**
Tom Field, Nebraska
Stephen Hammack, Texas
Brian McCulloh, Wisconsin
Larry Olson, South Carolina
- 2011**
Tommy Brown, Alabama
Mark Enns, Colorado
Joe Paschal, Texas
Marty Ropp, Montana
Bob Weaber, Missouri
- 2010**
Bill Bowman, Missouri
Twig Marston, Nebraska
David Patterson, Missouri
Mike Tess, Montana
- 2009**
Darrh Bullock, Kentucky
Dave Daley, California
Renee Lloyd, Iowa
Mark Thallman, Nebraska
- 2008**
Doug Fee, Canada
Dale Kelly, Canada
Duncan Porteous, Canada
- 2007**
Craig Huffhines, Missouri
Sally Northcutt, Missouri
- 2006**
Jimmy Holliman, Alabama
Lisa Kriese-Anderson, Alabama
Dave Notter, Ohio
- 2005**
Jerry Lipsey, Montana
Micheal MacNeil, Montana
Terry O'Neill, Montana
Robert Williams, Missouri
- 2004**
Chris Christensen, South Dakota
Robert "Bob" Hough, Texas
Steven M. Kappes, Nebraska
Richard McClung, Virginia
- 2003**
Sherry Doubet, Colorado
Ronnie Green, Virginia
Connee Quinn, Nebraska
Ronnie Silcox, Georgia
- 2002**
S.R. Evans, Mississippi
Galen Fink, Kansas
Bill Hohenboken, Virginia
- 2001**
William Altenburg, Colorado
Kent Andersen, Colorado
Don Boggs, South Dakota
- 2000**
Ron Bolze, Kansas
Jed Dillard, Florida
- 1999**
Bruce Golden, Colorado
John Hough, Georgia
Gary Johnson, Kansas
Norman Vincil, Virginia
- 1998**
Keith Bertrand, Georgia
Richard Gilbert, Texas
Burke Healey, Oklahoma
- 1997**
Glenn Brinkman, Texas
Russell Danielson, North Dakota
Gene Rouse, Iowa
- 1996**
Doug L. Hixon, Wyoming
Harlan D. Ritchie, Michigan
- 1995**
Paul Bennett, Virginia
Pat Goggins, Montana
Brian Pogue, Canada
- 1994**
Bruce E. Cunningham, Montana
Loren Jackson, Texas
Marvin D. Nichols, Iowa
Steve Radakovich, Iowa
Doyle Wilson, Iowa
- 1993**
Robert McGuire, Alabama
Charles McPeake, Georgia
Henry W. Webster, South Carolina
- 1992**
Jack Chase, Wyoming
Leonard Wulf, Minnesota
- 1991**
John Crouch, Missouri
- 1990**
Robert Dickinson, Kansas
- 1989**
Roger McCraw, North Carolina
- 1988**
Bruce Howard, Canada
- 1987**
Bill Borrer, California
Jim Gibb, Missouri
Daryl Strohbehn, Iowa
- 1986**
Larry Benyshek, Georgia
Ken W. Ellis, California
Earl Peterson, Montana

PAST BIF CONTINUING SERVICE AWARD RECIPIENTS

- 1985**
Jim Glenn, IBIA
Dick Spader, Missouri
Roy Wallace, Ohio
- 1984**
James Bennett, Virginia
M.K. Cook, Georgia
Craig Ludwig, Missouri
- 1983**
Art Linton, Montana
- 1982**
J.D. Mankin, Idaho
- 1981**
Mark Keffeler, South Dakota
- 1980**
Glenn Butts, PRI
Jim Gosey, Nebraska
- 1979**
C.K. Allen, Missouri
William Durfey, NAAB
- 1978**
James S. Brinks, Colorado
Martin Jorgensen, South Dakota
Paul D. Miller, Wisconsin
- 1977**
Lloyd Schmitt, Montana
Don Vaniman, Montana
- 1976**
A.L. Eller, Jr., Virginia
Ray Meyer, South Dakota
- 1975**
Larry V. Cundiff, Nebraska
Dixon D. Hubbard, Washington, D.C.
J. David Nichols, Iowa
- 1974**
Frank H. Baker, Oklahoma
D.D. Bennett, Oregon
Richard Willham, Iowa
- 1973**
F. R. Carpenter, Colorado
Robert DeBaca, Iowa
E.J. Warwick, Washington, D.C.
- 1972**
Clarence Burch, Oklahoma

PAST BIF AMBASSADOR AWARD RECIPIENTS

- 2017:** Kevin Ochsner, Colorado • NCBA
Cattlemen to Cattlemen
- 2016:** Bob Hough, Colorado • Freelance writer
- 2015:** E. C. Larkin, Texas • *Gulf Coast Cattlemen*
- 2014:** John Maday, Colorado • Drovers CattleNetwork
- 2013:** A.J. Smith, Oklahoma • *Oklahoma Cowman Magazine*
- 2012:** Burt Rutherford, Texas • *BEEF Magazine*
- 2011:** Jay Carlson, Kansas • *BEEF Magazine*
- 2010:** Larry Atzenweiler and Andy Atzenweiler, Missouri •
Missouri Beef Cattlemen
- 2009:** Kelli Toldeo, California • Cornerpost Publications
- 2008:** Gren Winslow and Larry Thomas, Canada •
Canadian Cattleman Magazine
- 2007:** Angie Denton, Missouri • *Hereford World*
- 2006:** Belinda Ary, Alabama • *Cattle Today*
- 2005:** Steve Suther, Kansas • Certified Angus Beef LLC
- 2004:** Kindra Gordon, South Dakota • Freelance Writer
- 2003:** Troy Marshall, Missouri • *Seedstock Digest*
- 2002:** Joe Roybal, Minnesota • *BEEF Magazine*
- 2001:** Greg Hendersen, Kansas • *Drovers*
- 2000:** Wes Ishmael, Texas • Clear Point Communications
- 1999:** Shauna Rose Hermel, Missouri •
Angus Journal & BEEF Magazine
- 1998:** Keith Evans, Missouri •
American Angus Association
- 1997:** Bill Miller, Kansas • *Beef Today*
- 1996:** Ed Bible, Missouri • *Hereford World*
- 1995:** Nita Effertz, Idaho • *Beef Today*
- 1994:** Hayes Walker III, Kansas • *America's Beef Cattleman*
- 1993:** J.T. "Johnny" Jenkins, Georgia •
Livestock Breeder Journal
- 1991:** Dick Crow, Colorado • *Western Livestock Journal*
- 1990:** Robert C. DeBaca, Iowa • *The Ideal Beef Memo*
- 1989:** Forrest Bassford, Colorado •
Western Livestock Journal
- 1988:** Fred Knop, Kansas • *Drovers Journal*
- 1987:** Chester Peterson, Kansas • *Simmental Shield*
- 1986:** Warren Kester, Minnesota • *BEEF Magazine*

BIF BAKER/CUNDIFF AWARD



Frank H. Baker 1923-1993

(Photograph of portrait in Saddle and Sirloin Club Gallery; Everett Raymond Kinstler, artist)

Frank H. Baker, Ph.D., 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 two and a half 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 Nov. 16, 1986. His ability as a statesman and diplomat earned him 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 Feb. 15, 1993, in Little Rock, Arkansas.



Larry Cundiff

(Photograph taken at BIF 2014, by Angus Journal.)

Larry Cundiff, Ph.D., retired in January 2007 after 40 years of service as a research geneticist with the U.S. Department of Agriculture, Agricultural Research Service. He was research leader of the Genetics and Breeding Research Unit at the U.S. Meat Animal

Research Center from 1976 until 2005, when he accepted an interim eight-month appointment as acting center director.

Larry Cundiff was born in Kansas in 1939, received his B.S. from Kansas State University in 1961, and his M.S. and Ph.D. from Oklahoma State in 1964 and 1966. He married his wife, Laura, in 1960. They have three children. He was on the faculty at the University of Kentucky from 1965 to 1967, before working as a research geneticist in the USDA.

Cundiff has not only designed, conducted and published some of the most important beef breeding research of the 20th century, but also has led the transfer of new technology to the beef industry through his continued work in BIF and his presentations made across the nation and around the world.

Continued >

PAST BIF BAKER/CUNDIFF AWARD RECIPIENTS

2017

Cashley Ahlberg, Kansas State University
Lindsay Upperman, University of California-Davis

2016

Kathleen Ochsner, University of Nebraska-Lincoln
Kashly Schweer, University of Nebraska-Lincoln

(2015 and earlier. this was known as the Frank Baker Scholarship)

2015

Justin Buchanan, Oklahoma State University
Jamie Parham, South Dakota State University

2014

Heather Bradford, Kansas State University
Xi Zeng, Colorado State University

2013

Heather Bradford, Kansas State University
Erika Downey, Texas A&M University

2012

Jeremy Howard, University of Nebraska-Lincoln
Kristina Weber, University of California-Davis

2011

Brian Brigham, Colorado State University
Megan Rolf, University of Missouri

2010

Kent A. Gray, North Carolina State University

2009

Lance Leachman, Virginia Polytechnic Institute and State University
Scott Speidel, Colorado State University

2008

Devori W. Beckman, Iowa State University
Kasey L. DeAtley, New Mexico State University

2007

Gabriela C. Márquez Betz, Colorado State University
Yuri Regis Montanholi, University of Guelph

2006

Amy Kelley, Montana State University
Jamie L. Williams, Colorado State University

2005

Matthew A. Cleveland, Colorado State University
David P. Kirschten, Cornell University

2004

Reynold Bergen, University of Guelph
Angel Rios-Utrera, University of Nebraska

2003

Fernando F. Cardoso, Michigan State University
Charles Andrew McPeake, Michigan State University

2002

Katherina A. Donoghue, University of Georgia
Khathutshelo A. Nephawe, University of Nebraska

2001

Khathutshelo A. Nephawe, University of Nebraska
Janice M. Rumph, University of Nebraska

2000

Paul L. Charteris, Colorado State University
Katherine A. Donoghue, University of Georgia

1999

Janice M. Rumph, University of Nebraska
Bruce C. Shanks, Montana State University

1998

Patrick Doyle, Colorado State University
Shannon M. Schafer, Cornell University

1997

Rebecca K. Splan, University of Nebraska
Robert Williams, University of Georgia

1996

D. H. "Denny" Crews, Jr., Louisiana State University
Lowell S. Gould, University of Nebraska

1995

D. H. "Denny" Crews, Jr., Louisiana State University
Dan Moser, University of Georgia

1994

Kelly W. Bruns, Michigan State University
William Herring, University of Georgia

His research efforts have involved evaluation and utilization of diverse breeds, effects and utilization of heterosis through alternative crossbreeding systems, and evaluation and effectiveness of selection for traits of economic importance in beef production. Since his retirement, he has continued service as a collaborator at the U.S. Meat Animal Research Center, assisting with preparation of research reports and speaking at beef industry meetings

and conferences. Cundiff has served as chairman of the Beef Improvement Federation (BIF) Committee on Genetic Prediction from 1973 until 2007, and as the Agricultural Research Service, USDA representative on the BIF Board of Directors from 1981 until 2007. He has served as editor of the Beef Improvement Federation's 9th Edition of Guidelines for Uniform Beef Improvement Programs.

ROY A. WALLACE MEMORIAL SCHOLARSHIP



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.

Roy 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 \$1,250 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.

PAST ROY A. WALLACE SCHOLARSHIP RECIPIENTS

2017

Dustin Aherin (graduate), Kansas State University
Tanner Aherin (undergraduate), Kansas State University

2016

Will Shaffer (graduate), Oklahoma State University
Ryan Boldt (undergraduate), Colorado State University



2015

Joshua Hasty (graduate), Colorado State University
Matthew McIntosh (undergraduate), University of Connecticut

2014

Heather Bradford (graduate), Kansas State University
Maci Lienemann (undergraduate), University of Nebraska-Lincoln

2013

Loni Woolley (graduate), Texas Tech
Tyler Schultz (undergraduate), Kansas State University

2012

Ky Polher (graduate), University of Missouri
Natalie Laubner (undergraduate), Kansas State University

2011

Jessica Bussard (graduate), University of Kentucky
Cassandra Kniebel (undergraduate), Kansas State University

2010

Paige Johnson (graduate), Texas Tech University
Sally Ruth Yon (undergraduate), Clemson University

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Focus on Efficient Red Meat Production

Michael Genho, Director, Feedyard Business, Elanco Animal Health

Utilizing Elanco's Benchmark Feedyard Performance database, 24,427 steer and heifer lots (4,056,148 head) closed between May 2016 and April 2018 were evaluated to determine key drivers of cash-to-cash Profit and Loss (P&L) basis. For this analysis, P&L basis is defined as the difference between each lot P&L and the mean weekly P&L for the region in which the lot closed. Utilizing a basis value in lieu of the nominal P&L removed the effect of macro swings in feedyard profitability from this analysis. The relative contribution of differing variables to P&L basis were determined utilizing forward stepwise regression (Prob to enter = 0.25 and Prob to leave = 0.10) of lot level P&L basis on performance and market data variables. The final model $R^2 = 0.763$ with the three leading variables (purchase price, sales price and Average Feed Conversion (AFC)) explaining 59% of P&L basis variation. Lot level AFC explained approximately 10.6% of P&L basis variation making it the single most economically relevant feedyard production metric.

Despite the economic contribution of feed efficiency to overall feedyard profitability and a focus on genetic selection metrics such as residual feed intake, lot level AFC across the industry has either increased (heifers) or improved very modestly (steers) over the past 17 years. Between 2000 and 2017, AFC conversion among feedyards participating in Elanco's Benchmark Feedyard Performance Database increased 0.044lbs and decreased 0.011lbs in heifers and steers, respectively. However, it is important to consider AFC in the context of dynamic industry days on feed (DOF) given that AFC increases as cattle are on feed longer. Over the past 17 years DOF has increased 29.3 days in steers and 13.4 days in heifers.

A better approach to evaluating efficiency would be to control for endpoint using a metric such as Empty Body Fat (EBF). Guiroy et al. 2001¹ published the following EBF equation using commercially available carcass data:

$$EBF = 17.76207 + [4.68142 * BF (cm)] + [0.1945 * HCW (kg)] + [0.81855 * QG Adjusted] - [0.6754 * REA (cm)]$$

BF = Back fat, HCW = Hot Carcass Weight, REA = Ribeye Area and QG Adjusted = Avg. Marbling Score/100 + 1

Applying this formula to the 4,056,148 individual carcasses closed in Elanco's Benchmark database over the past two years resulted in a mean lot-level average EBF of 30.3 with the 25th and 75th percentile equal to 29.8 and 31.0, respectively. In addition the mean within lot standard deviation of EBF values was equal to 1.35 indicating a high degree of within lot variation in degree of carcass finish. Cattle were then further stratified at the lot level by sex, placement weight (100lb weight group) and EBF index (in 1 whole unit increments) to determine the mean AFC and range of AFC within each group. Despite this level of segmentation, the interquartile range (difference between 25th and 75th percentile) of lot level AFC was over 0.50lbs even when controlling for in wt, sex and degree of end point finish (i.e. EBF). Obviously, variation in individual animal AFC within these cohort groups would be even greater. These data suggest that ample opportunity exists to make significant genetic progress in efficiency.

In addition, consideration should be taken in driving genetic improvement in efficiency relative to the targeted carcass to produce. Empty body fat targets would provide such guidance. While commonly used, residual feed intake fails to consider the "widget" the commercial cattle feeder is incented to produce. New selection criteria that measure efficiency relative to end point targets should be considered.

Guiry et. al. 2001, Predicting individual feed requirements of cattle fed in groups. J. Animal Science

Positioning for the Future of Beef Production – Focus on Quality

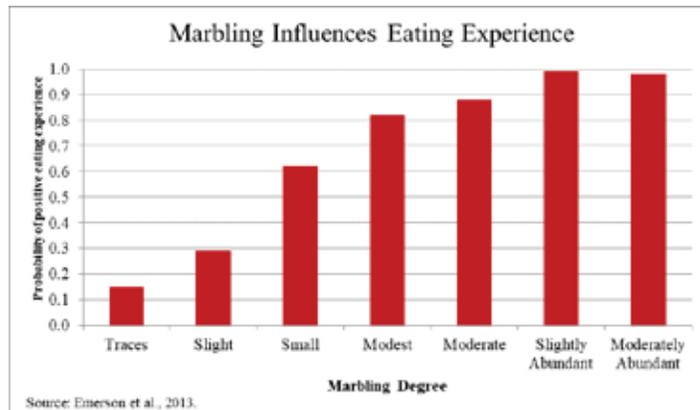
Mark McCully, Certified Angus Beef LLC

Background

While the term “quality” can refer to many beef attributes including freshness and color, references to “quality” in this paper will be synonymous to “quality grade.”

The US government established the beef quality grading system in the early 1900s to predict eating satisfaction and provide marketplace standardization. The USDA Quality Grades as we know them today are based on an assessment of the amount of marbling (intramuscular fat) and maturity (both skeletal and lean), but the primary determinant of quality grades in fed beef production is marbling.

Beef sensory attributes and consumer eating satisfaction are highly correlated with quality grade, as marbling positively influences tenderness, juiciness and flavor.

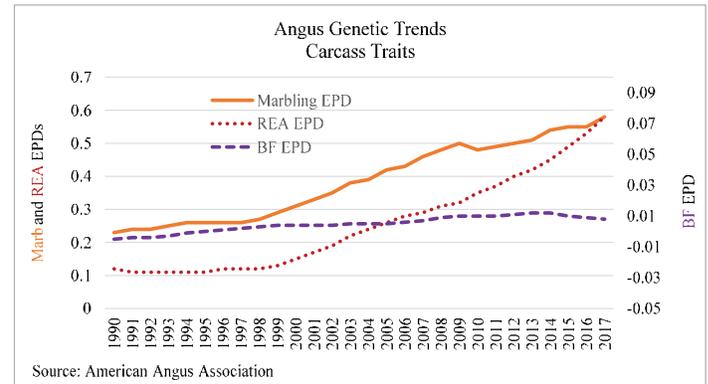


Of note, with numerous industry innovations and the corresponding improvement in tenderness (National Beef Tenderness Survey), flavor and juiciness have become far more important palatability factors and have a more significant influence in consumer satisfaction.

Measured against industry targets and going back as far as 1991, quality grade has been identified as the number one, lost economic opportunity in every National Beef Quality Audit (NBQA, 2016). In addition, improving quality has been identified as a top strategy to improve overall beef demand (Beef Demand Determinant Study).

The genetics of marbling are well-understood. Marbling is a highly heritable trait and significant differences exist between and within breeds (Herring, 2009.) Nearly all breed associations publish an EPD for marbling and the genetic trend within most breeds is positive. With the use of EPDs,

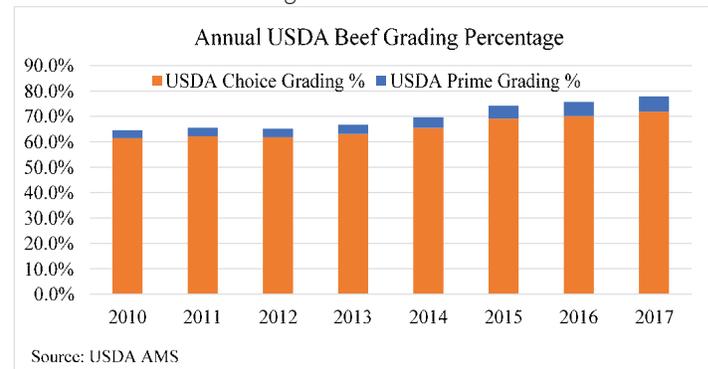
breeders have been able to make progress for quality while concurrently improving ribeye area and managing external fat.



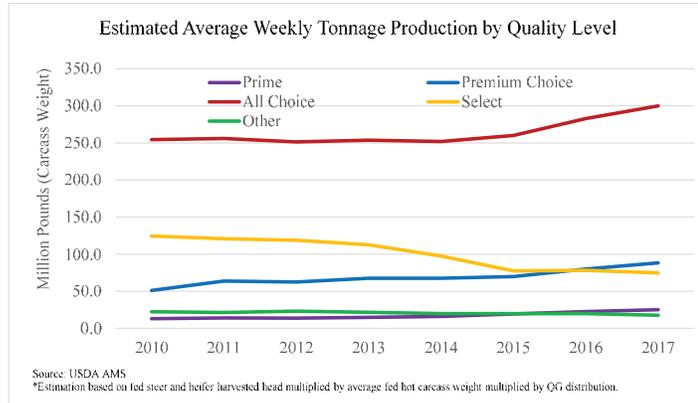
The Certified Angus Beef program was established in 1978 by the American Angus Association and is generally recognized as the original and largest fresh beef brand in the world. To qualify for the brand, cattle must be processed at a CAB-licensed packing plant, be of Angus phenotype (predominantly solid black, no white behind the shoulders or above the flanks) and pass 10 carcass specifications, which include Modest or higher marbling, or Average Choice and above. Of Angus-type cattle not qualifying for the brand, more than 90% fail due to insufficient marbling.

The Marketplace for Quality

It is no industry secret that beef quality grades have risen dramatically in recent years. Much publicity has been given to the continued record grading levels with the percent of fed cattle grading USDA Choice and Prime rising from 65% in 2010 to 78% in 2017. The percent of cattle grading USDA Prime was 3.2% in 2010 but averaged 6% in 2017, with some weeks in 2018 exceeding 8%.



Grading percentages are informative but actual production levels (quantities) are potentially more insightful. When put on a carcass weight basis, the weekly production of USDA Prime, Premium Choice and all Choice has increased 12.1 M lbs (93%), 37.2 M lbs (73%), and 45.6 M lbs (18%), respectively, comparing 2017 to 2010. In this same time frame, the average weekly production of USDA Select has decreased 49.7 M lbs (40%).

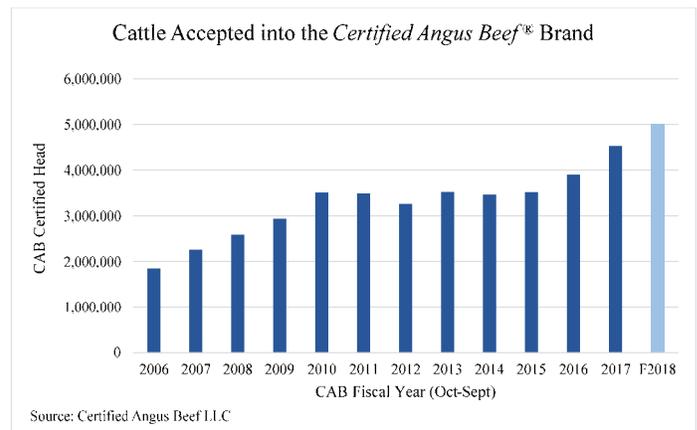


	USDA Prime	Premium Choice	All Choice	Select
2011	+6.9%	+24.6%	+0.6%	-3.0%
2012	-1.6%	-1.9%	-1.8%	-1.6%
2013	+7.5%	+8.1%	+1.0%	-5.1%
2014	+9.4%	-0.1%	-0.7%	-13.6%
2015	+20.3%	+3.5%	+3.2%	-20.4%
2016	+16.7%	+14.5%	+8.7%	+0.9%
2017	+11.1%	+10.4%	+6.1%	-4.4%
2017 vs 2010	+92.8%	+72.8%	+17.9%	-40.0%

Source: USDA AMS
*Estimation based on fed steer and heifer harvested head multiplied by average fed hot carcass weight multiplied by QG distribution.

Supplies for the Certified Angus Beef® brand have also increased significantly. With approximately 85% of the fed cattle packing capacity licensed for brand production, an increasing percentage of cattle meeting the Angus phenotype requirements, and a growing percentage of those Angus-type cattle meeting the 10 carcass specifications, the number of carcasses certified into CAB exceeded 4.5 million head in 2017 (CAB fiscal year of October to September) and is projected to exceed 5 million head in 2018.

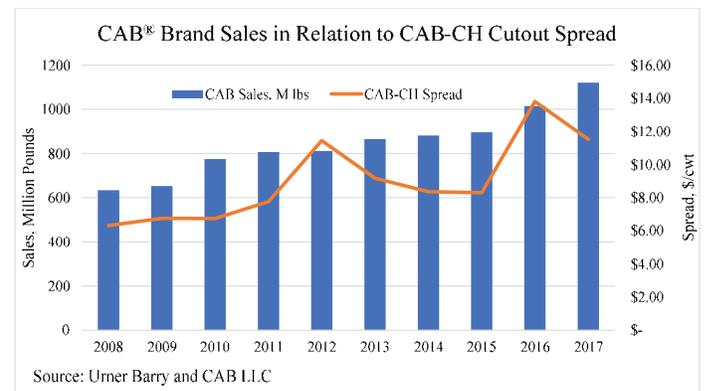
The rise in quality grades across the industry has been very intentional, and the factors behind this improvement have been well-documented (Dykstra, 2016). Improvements in cattle genetics and management, supportive feeding economics and grading technology enhancements have all contributed to the trend, but ultimately the industry has responded to the market signals calling for more high-quality beef.



Understanding these market signals starts with deciphering wholesale beef values and the trends in the spreads between quality levels. The “cutout” is simply the assimilation of prices for the individual cuts along with values for trim, fat and bone, all weighted back to a carcass value. The difference between the Choice and Select cutouts, typically referred to as the “Choice-Select spread,” has historically been recognized as the indicator of high quality beef demand. While still important in today’s market, other spreads like the CAB-Choice and Prime-Choice have become increasingly more significant in the wholesale beef trade and relevant to the value of finished cattle sold on a value-based system.

The spreads in relation to the production levels of each quality grade provide direction and insight for cattlemen. Spreads have continued to grow, or at least maintain, as the industry has produced substantially larger supplies of Choice, CAB/Premium Choice and Prime.

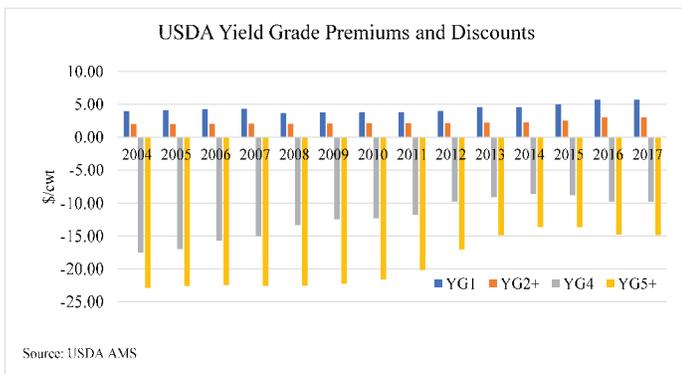
For CAB, the number of cattle qualifying for the brand has risen from 2.6 million head in 2008 to 4.5 million in 2017. The resulting product sales for the brand have increased 77%, from 634 million pounds in 2008 to 1.121 billion pounds in 2017. And in that same timeframe, the CAB-Choice spread has grown to \$11.52/cwt, an increase of 82%.



The wholesale cutout spreads experienced by the packer are translated into premiums and discounts on value-based

grids. These grid premiums and discounts are ultimately the quality signals received by producers when selling finished cattle. In 2017 the average grid premium per hundred weight for Prime (over Choice), CAB (over Choice) and Choice (over Select) was \$15.94, \$4.33 and \$11.82, respectively (USDA AMS). Put on a dollars-per-head basis, there was a \$250 gap between the value of a 900-lb. Select and a Prime carcass. If a carcass failed to reach Select, the discount for USDA Standard was \$25.59/cwt.

Also noteworthy are the discounts for YG 4 and 5 carcasses. Not only have the discounts decreased in recent years but many packers also offer thresholds whereby a producer is allowed a certain number of YG 4s before discounts are applied. These reduced discounts should be considered a “quality signal” as they are largely driven by the packers’ need to be competitive in procuring high grading cattle.



Additionally, some feeders seek out high grading cattle for risk management and market flexibility benefits often not considered. Reducing days on feed can be economically beneficial by allowing a feeder to take advantage of a market opportunity (e.g. declining market price or seasonal CH-SE spread) or mitigate high feed costs without incurring severe QG discounts.

Market dysfunctions do exist, as industry segments rarely align and share data. The quality signal has been strong at the feeder level but much less distinct for cow-calf producers not retaining ownership. While there are exceptions, feeders have historically used hide color as a proxy for breed description and an estimate for high grading potential. Black-hided feeder cattle generally bring premiums for their perceived ability to grade better and qualify for CAB premiums. New, value-added programs quantifying genetic merit on feeder cattle are emerging. These will likely change the marketplace and more accurately assign quality premiums and discounts to feeder cattle thus creating a more direct incentive for commercial cow-calf producers to emphasize quality grading potential in genetic selection.

The Cost of Quality

The market premiums for quality grade are well-documented but the associated costs are less understood and more ambiguous. Fortunately for the beef industry, performance and efficiency in the finishing phase are not antagonistic to quality grade.

In a recent analysis by Five Rivers Cattle Feeding, high grading (Avg 10.3% Prime, 44.7% CAB) pens were compared to their low grading (Avg 0.6% Prime, 12.7% CAB) counterparts. The high grading pens had comparable ADG, F:G, and COG, longer DOF and heavier out weights.

Analysis of High and Low Grading Pens of Cattle

	Low Grade	High Grade	All
# of Pens	296	150	616
Head	62,774	33,345	136,016
%PR/CH	60.6	89.8	72.9
% PR	0.6	10.3	3.8
% CAB	12.7	44.7	25.2
% YG1-3	95.2	85.5	91.2
Dress %	63.6	64.2	64.1
Finish Weight, lbs	1354	1398	1369
DOF	152	166	158
ADG	3.58	3.53	3.55
F:G (DM)	5.85	5.94	5.90
COG, \$	0.72	0.70	0.71

Source: Five Rivers Cattle Feeding. Steers only, Conventional production, Beef-type, 750-850-lb. placement weight, June-Oct 2017 closeout.

Less understood than feedyard performance is the relationship of marbling and cowherd function. Work done at Colorado State University concluded that selection for marbling was not antagonistic to fertility in Red Angus cattle (McAllister et al., 2011). Others have recognized a positive correlation between marbling and milking ability (Smith and Greiner, 2013) and suggested care must be taken in environments where feed resources are limited and high levels of milk production are detrimental.

It would appear that few if any maternal antagonisms exist with marbling selection, and today’s selection tools allow cattlemen to make improvement in cow herd function while also making genetic progress in carcass quality.

The Future of Quality

With the great increase in the amount of Low Choice, Premium Choice and Prime beef produced in the past decade, the sustainability of this demand needs to be explored. Beyond the simple fact that improved quality leads to improved demand, there are a number of additional factors and trends in place that suggest a strong marketplace exists in the future for high quality beef.

1. Increased supplies allow for new customers. Many retailers and foodservice operators desire to offer higher quality beef, like USDA Prime or CAB, but have been faced with limited supplies. Record grading levels and availability have allowed new businesses to consistently access the level

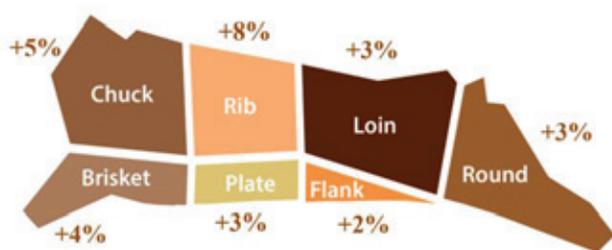
of quality that they and their customers desire. In recent years, Costco has begun selling Prime beef, and Walmart has a substantial section of its beef case dedicated to a Premium Choice, Angus program.

2. The value and importance of marbling has typically been thought of as isolated to middle meats (rib and loin). While the spreads across quality levels of middle meats are substantial, spreads on the end and thin meats (chuck, round, brisket, plate and flank) are increasing due to changing demand.

Consumers today prefer quicker preparation items like steaks for grilling, and are far less interested in roasting. Extensive research and effort have gone into identifying great new items like the flat iron, Denver steak and Vegas steak to meet this demand. These steak items perform better with higher levels of marbling. The wholesale value of Choice flat irons is \$0.16/lb more than Select and a CAB flat iron brings \$0.24/lb more than Choice (Urner Barry Yellow Sheet, 2017). Marbling was once thought to be unimportant for items cooked “low and slow” but as direct heat preparation is utilized on more cuts across the carcass, the value of marbling increases.

For CAB, the premium over Choice is growing on all primals. Increased demand for end cuts, thin meats and grinds has driven significant carcass utilization and value.

CAB® Brand Premium Over Choice



Source: 2017 Urner Barry

3. Ground beef is no longer quality grade neutral. Ground beef has been one of the fastest growing categories for the CAB brand, and USDA Prime hamburgers are now in the marketplace. The incredible growth in the premium grinds category by companies like Five Guys, Smashburger and Shake Shack has redefined “hamburgers” and premium, high-quality raw material is in high demand and necessary to differentiate in this crowded and competitive marketplace.

4. Some of the largest growth-opportunity export markets for US beef are countries that value high quality. Due to their traditional cookery methods and consumer preference, countries like Japan, Korea and China prefer highly marbled beef.

Industry Targets for Quality

The 2016 National Beef Quality Audit identified the ideal quality grade consist as 5% Prime, 35% Upper 2/3 Choice (CAB), 35% Low Choice, and 25% Select. The continued growth in Prime, CAB and other premium programs – all with premiums steady to growing – suggests those goals may be too conservative. Is 60% Prime and Upper 2/3 Choice a better goal?

	NBQA 2016 Targets	Maybe?
%Prime	5	15
%Upper 2/3 Choice	35	45
%CH-	35	30
%SE	25	10
%YG1	10	10
%YG2	45	45
%YG3	40	40
%YG4	5	5
%YG5	0	0

Conclusion

The beef industry is more economically viable and sustainable today as a result of cattlemen intentionally improving eating satisfaction and growing demand through a focus on quality. Consumers have responded to higher quality options in the marketplace, and beef continues to enjoy a significant price premium to the competing pork and chicken options. The US beef industry’s competitive advantage in the global marketplace is to produce highly marbled, grain-fed beef. Giving up this advantage and attempting to compete with a leaner beef product seems irrational given the drastic differences in cost structure of our global competitors.

That all said, single trait selection for marbling is obviously ill advised. Cattlemen should focus on improving the quality grading potential of their cattle while also being mindful of the other economically relevant traits in their operation. Fortunately, this is not an “either/or” situation, and the ability to improve quality while also making progress in fertility, maternal function, performance and red meat yield is very achievable with today’s selection tools.

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NOTES

Positioning for the Future of Beef Production: Focus on Sustainability

Sara Place, Ph.D., Senior Director, Sustainable Beef Production Research,
National Cattlemen's Beef Association, a contractor with the Beef Checkoff

Introduction

Sustainability is about balancing economic, social, and environmental concerns and positive attributes (i.e., the triple bottom line) and having a long-term focus (i.e., meeting the needs of the present without sacrificing the ability of future generations to meet their own needs; UN, 1987). Much of the focus in recent years on beef and sustainability has been on environmental impacts, and in particular, beef's higher environmental footprints (e.g., carbon, water, and land) relative to other foods when expressed per pound or per unit of crude protein (Poore and Nemecek, 2018).

The relative differences in environmental footprints of foods has led to recommendations to consume more plant-based foods, or switch to pork, poultry, and fish over beef. Additionally, the environmental footprints of beef and other animal proteins has been a key focus of so-called "plant-based meats" and is a driving force behind the development of cell culture-derived muscle tissues that are yet to come to market. Ultimately, a prevailing narrative in food-informed and environmentally-concerned consumer, media, and investment circles has been "eat less meat for better human and planetary health" or "less meat, less heat" referring to curbing climate change by consuming fewer animal-derived foods, with a focus on beef.

Context on meat and heat

Broad consensus exists regarding the underlying climate science that increasing concentrations of greenhouse gases in the atmosphere, driven by human activity, are affecting the global climate system. Numerous gases, including water vapor, can trap heat in the earth's atmosphere. This heat-trapping effect, or greenhouse effect, is responsible for keeping the global average temperature at a hospitable level for life on earth. Without the greenhouse effect the global average temperature would be 0°F compared to 59°F with the effect (Ma, 1998). However, recent changes in greenhouse gas concentrations (Table 1) have led to concerns that the global climate will change at a pace that will negatively affect human livelihoods, and the natural ecosystems and agroecosystems that we depend upon.

Most of the observed warming due to increasing greenhouse gas concentrations has come from carbon dioxide (72% of global human-caused greenhouse gas emissions in 2010), with the majority of the concentration increase due to the combustion of fossil fuels and land use changes that have released biogenic carbon (i.e., carbon from soils, plant biomass) and reduced the capacity of atmospheric carbon dioxide to be sequestered via plant biomass (i.e., reduction in photosynthetic capacity of rainforests due to deforestation; IPCC, 2014). The second and third most important human-derived greenhouse gases are methane and nitrous oxide, representing 20% and 5% of human-caused greenhouse gas emissions globally in 2010, respectively. Both gases are primarily derived from microbial processes, with fossil fuel sources playing a more minor role. Agriculture is an important source for both methane and nitrous oxide, with ruminant animal agriculture being a considerable source of methane naturally-derived from ruminant digestive systems (IPCC, 2014).

Discussions of greenhouse gas emissions from beef production often conflate global statistics for U.S.-specific estimates and total livestock emissions with emissions from beef production. The U.N. FAO's latest estimate of global livestock emissions using life cycle assessment (i.e., feed production and deforestation included) was 7.1 Gt of carbon dioxide equivalents or 14.5% of global greenhouse gas emissions. The reference year for the report was 2005 and global human-caused emissions were assumed to be 49 Gt of carbon dioxide equivalents. The FAO's estimate for global beef production was 2.9 Gt of carbon dioxide equivalents or 6% of global emissions. In the United States, direct emissions from beef cattle enteric fermentation and manure represent 0.132 Gt of carbon dioxide equivalents or 2% of U.S. greenhouse gas emissions (0.27% of global emissions), with all direct emissions from livestock, including beef, representing 3.9% of U.S. emissions in 2016. However, for context, within the United States, agricultural emissions of greenhouse gases are completely offset by annual carbon sequestration from land use, land use change, and forestry. Thus, U.S. agriculture and forestry combined in 2016 represented a net sink of carbon emissions (-0.154 Gt of carbon dioxide equivalents; EPA, 2018).

Table 1. Changes in greenhouse gas concentrations in the atmosphere and 100 yr. global warming potentials of each gas. Data from EPA Greenhouse Gas Emissions Inventory 1990-2016 and IPCC, 2014.

Gas	Pre-Industrial concentration, parts/million	Current concentration, parts/million	Global Warming Potential 100 yr. ¹
Carbon dioxide	280	401	1
Methane	0.700	1.823	28
Nitrous oxide	0.270	0.327	265

¹Greenhouse gases have different potentials to trap heat in the atmosphere and different atmospheric lifetimes, thus a system of global warming potentials (GWP) have been developed to compare across gases on a similar time-scale, expressed in carbon dioxide equivalents. The Intergovernmental Panel on Climate Change (IPCC)'s latest assessment uses the 100-yr. GWP of 1 for carbon dioxide, 28 for methane, and 265 for nitrous oxide.

While reports regarding global food demand relative to the year 2050 often highlight how meat demand will increase per capita, these assessments often mask longer-term trends in animal-derived food consumption by species. Specifically, over the past 5 decades within the United States (Figure 1) and globally, there has been a pronounced shift in increasing consumption of monogastric animal protein foods (pork, poultry) and flat or even declining consumption of ruminant meats. For example, the relative change in per capita consumption from 1961 to 2013 was a decline of 1% for bovine meat, a 100% increase for pig meat, and a 420% increase in poultry meat globally (UN FAO, 2018).

Of course, per capita availability or consumption is not demand, but it seems unlikely that these longer-term trends will shift in a pronounced way in the next 32 years as the global population reaches 9.8 billion persons. If current trends of per capita consumption, population growth, and beef productivity trends continue, the global cattle herd will likely grow by approximately 7% from today's herd of 1.5 billion to 1.6 billion in 2050. Improving the productivity of beef production above current rates could potentially even reduce the size of the global cattle herd by 2050, while still meeting bovine meat demand for 9.8 billion consumers.

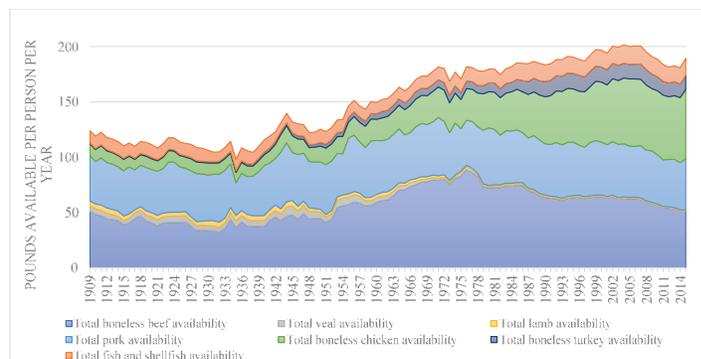


Figure 1. Long-term meat availability trends per capita in the United States from the USDA Economic Research Service Food Availability system for the years 1909 through 2015. These data are before accounting for consumer, retail, and food service losses. Relative to 1909 annual per capita availability, beef was 0.6% higher, red meat (beef, lamb, veal, and pork combined) was 3% lower, and meat overall was 53% higher in 2015.

Cattle herd size relative to beef produced is a critical component that determines the total resource use of beef production within the United States and globally. Per capita beef consumption is sometimes used as a proxy for estimating impacts from beef production, and recent reductions in per capita consumption within the United States have been highlighted as a reason for reduced greenhouse gas emissions. However, this is incorrect. Emissions from U.S. beef production have declined because the U.S. cattle herd has declined, and more beef has been produced per live animal (considering all supporting herd cows, bulls, replacement heifers, and cattle bound for finishing). The same amount of beef produced spread out over a growing population will result in lower per capita consumption, but will not result in a decline in total environmental impacts unless fewer environmental impacts are generated from each pound of beef produced. As Table 2 illustrates the relationship between per capita meat consumption, total direct greenhouse gas emissions from cattle production, and emissions intensity is not clear cut.

Table 2. Total live cattle and buffalo stocks, per capita bovine meat availability, cattle meat emissions intensity, and total emissions from cattle and buffalo meat production for selected countries. All data from UN FAO's FAOSTAT database and relevant to the year 2013. Relationship between per capita bovine meat consumption and total emissions from cattle and buffalo are not clearly positive – Spearman rank correlation coefficient for these selected countries is -0.26.

	Total cattle beef and dairy and buffaloes	Per capita bovine ¹ meat availability kg/yr.	Emissions intensity for cattle meat, CO ₂ -eq/kg	Total emissions ² from cattle and buffalo, Gt CO ₂ -eq.
Argentina	50,996,397	55.48	28.9	0.081
Ethiopia	55,027,080	3.61	146.6	0.050
India	298,400,000	0.81	106.4	0.210
Niger	10,733,314	8.97	71.3	0.010
United States	90,095,200	36.24	11.5	0.136
China	103,582,286	5.23	16.3	0.135

¹Includes cattle and buffalo meat. Carcass weight basis and before losses.

²Includes methane and nitrous oxide emissions from manure management, manure applied to soils, manure left on pastures, and methane gas from enteric fermentation. Only non-dairy cattle emissions included.

Why have ruminants like beef cattle in a food system?

While environmental footprints, such as carbon footprints, are useful tools to benchmark the sustainability of an individual food industry or commodity, like beef, they are also unable to capture all the relevant components of a sustainable food system. Relatively higher environmental footprints for beef compared to other protein-source foods are used by some to advocate for dramatically reduced beef consumption and production within the United States and globally. Essentially, the argument of some against beef is that the social costs of beef production outweigh the benefits, or alternatives to beef would provide greater social benefit. However, a full accounting of the social costs of beef production (e.g., carbon emissions) vs. the social benefits (e.g., human nourishment, ecological benefits, wealth) has not been completely assessed to this author's knowledge.

Multiple factors important to a sustainable food system that are not captured in environmental footprints include:

1. Cattle can convert human-inedible feedstuffs into high quality human-edible protein.

Collection of management and feeding information from over 2,200 beef producers across the United States has been used to generate environmental footprints and estimate feed consumption and conversion (Rotz et al., submitted). From a full life cycle perspective, 1 kg of beef carcass weight produced in the United States requires 13.2 kg dry matter of grazed forage, 5.1 kg dry matter of harvested forage (e.g., hay), 2.6 kg dry matter of grain concentrate (mostly, corn grain), and 1.5 kg dry matter of other feeds that mostly includes

human-inedible byproduct feeds from human food, fiber, and biofuels production. Thus, 89% of the 22.3 kg dry matter feed required per kg of grain-finished beef carcass weight produced in the United States is human inedible plant matter.

Because the majority of the feed resources used to generate grain-finished beef in the United States are not in competition with the human food supply, and the protein value of beef to humans is 2.63 times greater than corn grain, our current grain-finished beef system is generating more high-quality protein for the human populace than it is using. However, slight reductions in the corn grain required per kg of beef carcass weight produced can further enhance the protein upcycling value of U.S. beef production (Table 3). Recent research at the global scale observed similar results. For every 1 kg of human edible protein generated from beef production, only 0.6 kg of human edible feed were required; thus, global beef production provides 66% more human edible protein to the human food system than beef cattle themselves consume (Mottet et al., 2017).

Table 3. Human edible energy returns, human edible protein returns, and net protein contribution estimates for grain-finished beef cattle fed varying amounts of corn grain per kg of beef carcass weight produced. In all scenarios, the protein amount and quality (considering amino acid composition and digestibility) of the grain-finished beef produced exceeds the corn grain fed to cattle. This means more human nutritional value is generated by feeding corn grain to cattle and consuming the resulting beef as compared to humans eating the corn grain directly.

Corn grain consumed (kg DM) per kg of grain-finished beef produced (carcass weight basis)	Human-edible energy return ¹	Human-edible protein return ²	Net protein contribution ³
2.6	0.48	0.96	2.53
2.4	0.52	1.04	2.74
2.2	0.57	1.14	2.99
2.0	0.63	1.25	3.29
1.8	0.69	1.39	3.66
1.6	0.78	1.56	4.12

¹Human edible energy return = MJ energy in kg of beef carcass weight/MJ energy in corn consumed per kg of beef. Assumed 80% of corn grain is human edible and corn metabolizable energy content is 13.78 MJ/kg of DM, and beef (choice grade) metabolizable energy content is 12.81 MJ/kg of carcass weight.

²Human edible protein return = kg edible protein (crude protein) in kg of beef carcass weight/kg of edible protein in corn consumed per kg of beef. Assumed 80% of corn grain is human edible and crude protein content of corn is 8.65% per kg of DM, and beef crude protein content (choice grade) is 173.2 g per kg of beef carcass weight.

³Net protein contribution is human edible protein return * protein quality ratio. Protein quality ratio is the digestible indispensable amino acid score (DIAAS) of beef (111.6)/DIAAS of corn (42.2). Net protein contribution values greater than 1 indicate more high-quality protein generated in the form of beef than the cattle consume (i.e., adding to the human food protein supply; Ertl et al., 2016).

2. Cattle consume forages/roughages that are grown on lands unsuitable for cultivation, thereby expanding the land base available for food production.

As outlined above, the majority of the feed resources used by the U.S. beef industry are human inedible forages. Most of these forages are produced on lands unsuitable for cultivation, or from lands that if cultivated, would be highly erodible. In the United States, there are approximately 800 million acres of land that are considered range and pasture lands (USDA-ERS, 2018). Currently, the only way to generate human food from this land area that represents 35% of the United States is to convert the biomass to human edible products with ruminant livestock – cattle, sheep, and goats. U.S. cattle producers provide land management services and help preserve habitats on hundreds of millions of acres across the nation.

3. Cattle consume byproduct feeds from the food, fiber, and biofuels industries.

Considering human food alone, Fadel (1999) estimated that for every 100 kg of human food produced from crops, 37 kg of byproducts were produced. Using the 1.5 kg dry matter of byproduct feeds fed to cattle from above (Rotz et al., submitted) and assuming 11.8 billion kg of beef production, U.S. beef cattle consume and value-add approximately 18 million metric tons of byproducts annually. While it could be argued these byproducts could be disposed of or used to create compost as a soil amendment, feeding human food byproducts to cattle generates multiple benefits. Byproduct feeds fed to cattle generate human nourishment, wealth, and manure which is a high-quality organic fertilizer. In this way, as with integrated crop-cattle production systems, cattle act as a component of the circular bio-economy, cycling and upcycling nutrients and energy through the integrated food, fiber, and biofuels system.

4. Integrating cattle into row-crop plant agriculture systems can have environmental and socioeconomic sustainability benefits.

Cattle can be and are integrated into crop production systems either at the farm-scale on the same land base or are integrated from a regional perspective to capture synergies between cropping and cattle farming systems. Benefits of integration depend on the production system, soils, and climate, but can include improved nutrient cycling, added farm enterprise diversity (a form of risk management), and the generation of multiple human usable products (i.e., both plant and animal products) from a given land area (Sulc and Franzluebbers, 2014). Examples include crop residue grazing, such as using corn stalks remaining after harvesting corn grain (which can be used for human food, biofuels, animal feed, or other industrial purposes) for cattle feed. Approximately, 70% of surveyed cow-calf

producers in the Midwest and Northern Plains of the United States were using crop residue grazing in their production systems, whether owned land or leased (Asem-Hiablie et al., 2016). Another example is grazing winter wheat with stocker cattle in the Southern Great Plains. Approximately, 2 million cattle graze winter wheat pasture each year (USDA-NASS, 2018), which can be subsequently harvested for human-use and milled into flour. One of the byproducts of the wheat milling process, wheat middlings, can then be fed back to cattle – again, this highlights the upcycling role that cattle play in our bio-economy.

5. Beef cattle operations represent over one third of the farms in the United States, and thus beef cattle producers play an important role in the agricultural economy and the social fabric of rural America.

In 2012, there were 2.1 million farms in the United States and 913 thousand were cattle operations (beef and dairy combined). Beef cow-calf operations were estimated at 727 thousand (USDA-NASS, 2012). The cattle industries are responsible for approximately 2.1 million jobs and \$165 billion in added value to the U.S. economy (Thoma et al., 2017). Because cattle operations are often located in regions unsuitable for significant cultivated agriculture, they can serve as economic hubs to rural economies supporting other businesses and local services. Additionally, well-managed cattle grazing operations are generating wealth and nutrition from landscapes in a manner than can be highly resilient and viable for the long-term (Heitschmidt et al., 1996), in contrast to the boom-and-bust cycle of some natural resource development. Thirty-nine percent of cattlemen and women donate their time to a civic organization compared to the national average of 7% (Cattlemen's Stewardship Review, 2017).

6. Cattle produce more than edible beef – they are also a source of a variety of ancillary products from leather to pharmaceuticals.

Edible beef sold as muscle meat cuts and ground beef is approximately 42% of the animal's live weight, whereas 44% is available for byproduct production. Byproducts include hides, inedible offal, and edible offal (which includes variety meats). Byproducts from cattle are used for a variety of purposes including in the manufacture of adhesives, ceramics, cosmetics, fertilizers, glues, pet food, chewing gum, photographic films, and leather products. Additionally, glands and tissues from cattle can be sources of epinephrine, insulin, serums, vaccines, and antigens (Marti et al., 2011). To this author's knowledge, no life cycle assessment has examined the economic, social, or environmental consequences if these byproducts derived from cattle were severally limited or eliminated from a food system without cattle production.

What can we do to improve beef's sustainability?

While U.S. beef has made impressive productivity gains in the past 4 decades that have translated into reductions in environmental impacts per unit of beef, opportunities remain to further improve. One way to frame these opportunities is to think about the value proposition beef brings to the food system. Compared to other meats, beef production excels at transforming lower value resources, such as human inedible plants and uncultivable lands, into a high-quality and desirable protein product, essential micronutrients, and other key ancillary products, such as leather and pharmaceuticals. Our collective challenge is optimizing this upcycling service against potential negative environmental outcomes, and enhancing the social acceptability of beef production.

Key to optimizing the upcycling service of beef production is feed conversion efficiency. Feed conversion efficiency can be approached in multiple ways – dry matter conversion into gain, human edible feed conversion into beef, human edible protein conversion into human edible protein in beef, etc. Reducing human edible feed requirements per unit of beef while still maintaining a highly desirable, marbled product would improve the food system value of beef. From a whole industry perspective, optimizing maintenance energy costs against total beef production, particularly from the cow herd, can potentially improve upcycling and increase beef produced per acre from grazing lands. As Figure 2 demonstrates, the cow maintenance energy costs per kg of beef produced have remained relatively flat for the past two decades. Optimizing cow size to the operation's natural resources and environment has the potential to improve both individual cow-calf enterprise's profitability and whole industry efficiency (Lalman et al., 2018).

Another potential avenue of enhancing beef's upcycling value proposition is finding viable and cost-effective solutions to reduce enteric methane production, or more specifically, decrease the loss of potential metabolizable energy as methane gas. According to the latest EPA greenhouse gas emissions inventory, enteric methane emissions from beef cattle were 4,853 kt in 2016, which is 6.44×10^{10} Mcal of energy. Fractional improvements in redirecting methane energy losses to animal metabolism could improve the efficiency of the entire U.S. beef industry.

Finally, beef producers do affect a large percentage of the land area of the United States for a relatively small number of individuals. Any improvements in grazing management practices and wider adoption of adaptive management techniques would likely enhance the long-term viability of individual operations, enhance ecosystems, and maintain or improve the health of soils.

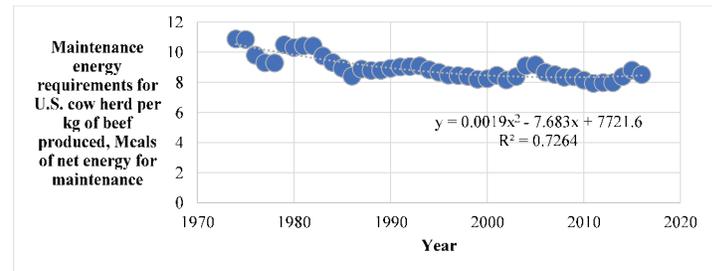


Figure 2. U.S. average cow maintenance energy costs (Mcal of NEm) per kg of beef carcass weight produced. In the past 20 years, cow maintenance energy costs per kg of beef produced have remained relatively flat. Using USDA-NASS cow slaughter weights and annual beef production data, and maintenance energy requirement equation from NASEM, 2016.

Conclusion

Sustainability has been an issue at the forefront of the beef industry for most of the past decade. Given current marketing trends and the real pressures on our food and earth system as the global population grows by 2 billion additional people in the next two decades, sustainability will not be going away as an issue. Increased interest from consumers in where and how their food was produced presents an excellent opportunity for the beef community to show the passion and care that is involved in producing beef. Doing more with less and doing the right thing because it's the right thing to do are central to sustainability. However, with increased interest comes increased scrutiny, thus, the beef community also needs to address misinformation and make changes when needed to maintain social acceptability. At times, this may mean simply presenting what the beef community does daily in an innovative way.

Food for thought: The beef community uses a technology that produces high-quality protein from solar energy locked within human inedible plants. The technology produces a natural organic fertilizer, and is mobile without using fossil fuels. The technology self-replicates.

The technology is cattle. Beef is the original, sustainable plant-based meat.

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NOTES

Focus on Traits Not Considered

Dorian Garrick • D.Garrick@massey.ac.nz

Chief Scientist, AL Rae Centre of Genetics and Breeding, Massey University, NZ

Introduction

Phenotypes are observable and typically measurable characteristics or traits, such as birth weight, coat color, stature, reproductive status, behavior etc. Improvement programs typically focus on a relatively small subset of all the possible traits, most commonly those that are associated with growth, calving ease, and ultrasound measures of carcass characteristics. It is well known that selection will be much more effective when the measured performance of the selection candidate and its relatives is adjusted for non-genetic effects, summarised in terms of the estimated breeding value (EBV) or expected progeny difference (EPD) of the animal for each trait of interest, then weighted by its economic value in an economic index. The purpose of this paper is to consider EPDs for those traits that might be important but are not currently attracting much focus in national improvement programs, and to discuss the manner in which there might be improved emphasis on those traits.

There are several different approaches in which the various stakeholders in beef improvement might consider EPDs they believe should receive focus. These include the data driven approach used by cattlemen and others directly involved in the supply chain, the bio economics driven approach used by animal breeders, and the gene driven approach used by molecular geneticists. However, despite positive industry-wide value propositions for some traits not typically considered, market failure at the level of the bull breeder commonly contributes to valuable traits having inadequate focus.

The data driven approach used in the supply chain

Bull breeders directly control the nature and rate of genetic improvement as it is the bull breeders that choose the sires they will use to produce sons for sale, the sires they will use to produce daughters to retain as replacements, and the sires of the bulls they will market to bull buyers. Further, bull breeders choose the traits to invest in measuring, in order to generate EPDs for immediate use in selection, or for inclusion in economic indexes to use for selection.

Bull buyers indirectly influence the nature and rate of genetic improvement by rewarding some bull breeders with increased demand and higher prices for sale bulls. For every bull breeder, buyers send market signals when they invest more in the purchase of the bulls they like. Bull breeders

respond by attempting to produce more such bulls in the future.

Bull breeders and bull buyers tend to focus more on attributes that they can easily visualize or measure, such as growth rate or calving ease, and less on attributes that are less visible in their production systems, such as feed intake during grazing, eating quality of the final product, and disease resistance. Further, they tend to focus more on traits with moderate to high rather than low heritability, and those measured early rather than late in life, as they can easily validate the effects of their selection choices within their own production systems.

Sadly, the current status of most national and international beef cattle evaluation systems reflects a narrow data driven approach to choosing traits on which to focus selection.

The bio economics driven approach used by animal breeders

There is a logical approach to developing a breeding program that includes thorough biological and economic considerations of the traits to consider. The first step is the formulation of the goal of the breeding program. That would normally reflect some measure of increasing satisfaction – and in an agricultural context profitability is usually a major determinant of satisfaction. A goal would often be more finely tuned, for example by expressing it per unit of limiting resource – such as profit per unit of land, or profit per cow place.

The second step in developing a breeding program is to define the breeding objective. This involves two components – the list of traits that influence the goal, and the relative emphasis to be placed on each of those traits. A profit-based goal should consider every trait that influences any component of whole system income, or any component of whole system cost. Given such a list of traits, determination of the relative emphasis of each trait in the list is an economics problem. It can be solved by calculating the partial derivative of the profit function of the production system if that can be specified, or it may be computed more simply by partial budgeting. Traits can vary in their number of expressions over the lifetime of the animal, and in the timing of those expressions, and these factors should be considered to determine the economic values. This approach

will implicitly consider every economically-relevant trait if the methodology is thoroughly applied.

An ideal selection index from the perspective of the breeding objective would require that a discriminating EPD be obtained by the time of selection for every selection candidate for each and every trait in the breeding objective. However, that requires that discriminating phenotypes be collected, perhaps on the trait directly corresponding to the desired EPD, but more commonly on some other so-called indicator trait or traits that are correlated with the breeding objective trait. Using an indicator trait, such as age at puberty to predict lifetime reproductive performance can sometimes be more effective than directly measuring the ERT phenotype, because it might have a higher heritability, and is often measurable at a younger age. In other cases, an indicator trait is used because the ERT phenotype cannot be collected on the live animal, such as when ultrasound measures are used as predictors of carcass characteristics or eating quality. Another example that relies on an indicator trait would include the direct measurement of a disease phenotype that requires the animal be exposed to a pathogen that would be undesirable to introduce to a breeding animal.

Other considerations in the logical design of a breeding program would include: 1) the design of a breeding scheme, such as determining whether selection candidates should be individually measured or progeny tested, and how many times they should be measured; 2) the design of a dissemination system, determining what should be done with the selected individuals, such as distributing them by natural mating, or by artificial insemination or embryo transfer, or perhaps cloning; 3) the mating plan, which determines the manner in which mates of selected individuals are chosen, including alternative plans such as inbreeding or outcrossing; and 4) a full economic analysis of the costs and benefits of the entire improvement system. This is the most critical aspect, and it needs to be re-evaluated as often as there are significant changes to production circumstances, to costs or prices, to measurement technologies etc. This aspect also needs to consider who must pay for the improvement costs, and who benefits from the improvement. Typically, there are several alternative scenarios for the design and implementation of a breeding program, and all must be considered if stakeholders want to be sure they adopt one of the better options.

A proper analysis of a breeding industry would therefore consider all possible traits that might be economically-relevant and would consider all possible traits that might be useful indicators for routine recording to rank the ERT. However, such an analysis would require an exhaustive set of trait measurements to characterize the predictive

ability of various indicator traits, and such an exhaustive dataset is never available. Instead, research and/or academic institutions need to conduct experiments to collect potentially interesting data and determine its usefulness – and these experiments often must be done on rather small scales, and in fewer environments than would be ideal, in order to screen options for adoption by industry.

A review of those activities, in comparison with the current levels of industry adoption would suggest that the traits not being adequately considered probably includes everything other than growth and calving ease. Namely, there is inadequate consideration of reproduction, inadequate consideration of eating quality, inadequate consideration of the human healthfulness of the beef, inadequate consideration of disease resistance, inadequate consideration of feed intake and feed efficiency, inadequate consideration of lifetime performance, inadequate consideration of welfare traits such as horns, and inadequate consideration of environmental attributes such as water use, greenhouse gas emissions, or levels of effluent particularly Nitrogen outputs. All these characteristics exhibit phenotypic variation, and all are heritable, so could be included in breeding programs.

There are many reasons for the inadequate consideration of these traits not currently considered in a particular breeding program – some political, some structural, some economic and some biological.

The gene driven approach used by molecular geneticists

The genomics era has led a major revisit of the design and implementation of breeding schemes, more so in some species than in others. It has provided several mechanisms for increasing the focus on traits not previously adequately considered in our national and international pedigree-based breeding programs. These mechanisms are genomic prediction, depletion of homozygous haplotypes, and exome analysis.

Genomic prediction

Conventional pedigree-based prediction results in the merit of every new-born individual being assessed at its parent average (PA), until the breeder “purchases” additional information on that selection candidate by measuring some phenotype on the individual, or that of a descendant. In contrast, genomic prediction characterizes the EPD of every chromosome fragment using historical information and predicts the EPDs of selection candidates by summing up the EPD values of all the chromosome fragments each candidate appears to have inherited. This means that EPDs on selection candidates can be more discriminating than PA without having to measure the phenotype on the

selection candidate or a descendant. The positive aspect of this approach is that measurement and selection activities can be undertaken on conceptually distinct populations. This opens the door to ranking animals for disease resistance, eating quality, and some other ERTs that are difficult to measure. A negative aspect of this approach is that it can stifle innovation – a breeder that invests in feed intake measurement equipment to provide a competitive advantage at his or her bull sale might find that as a result every genotyped bull in the nation has a genomic predicted EPD for feed intake regardless of whether or not the other breeders made any investment in trait measurement.

Depletion of homozygous haplotypes

Marker panels such as the commonly-used 50k chips, allow chromosome fragments known as haplotypes to be identified and their inheritance to be traced. Deleterious recessive mutations are often underrepresented in breeding populations in their homozygous form or may be completely absent if they cause embryonic lethality. Haplotypes that carry such a mutation will not be present in homozygous form, even though there may have been large numbers of matings between sires and dams that each carry that haplotype allele containing the recessive mutation. Identification of these haplotypes, or the causal mutations themselves, allows matings between carriers to be avoided, and this can markedly affect trait performance, in fertility and in any other affected traits.

Exome analysis

Next-generation sequence analysis allows virtually all the mutations present in an animal to be detected. However, less than 2% of the genome is expressed as gene products, and it is only those mutations that influence exon expression whose effects can be predicted. Mutations that prematurely terminate a gene product, or those that alter the amino acid sequence in the gene product are likely candidates to cause variation in performance. Comparative analysis from other species including humans and mice can predict the traits that might be affected by such a mutation, allowing focus on traits that are not otherwise being measured. For instance, mutations that cause ataxia, rickets, chondrodysplasia, blindness and other immune system defects have been identified and used in selection. In future, knowledge of pathogenic mutations will increase, and sequencing costs will erode. Accordingly, it is likely that all widely-used sires will be individually sequenced and their variants annotated, allowing an increased genome-driven focus on some traits.

Market Failure

The bull breeding sector typically bears the costs of recording, including trait measurement, database

development, genetic evaluation and reporting. Bull breeders invest in selection to improve successive crops of sale bulls, and reasonably expect a financial reward for these activities. However, increasing their investment in recording, such as taking additional effort to record traits not previously considered, is often not rewarded by an increase in sale revenue. Bull buyers can easily see the effects of bulls that are superior for growth rate, or for calving ease, but cannot easily see differences in lifetime fertility, feed intake, eating quality and many other traits that are currently inadequately considered.

In vertically-integrated production systems, it is much easier to invest in new traits, with the knowledge that the system will capture the resultant extra reward. The beef cattle industry is not vertically integrated, and the bull breeding sector is much bigger than it needs to be, increasing immediate competition in bull sales, and reducing the rewards that are available for innovation. Further, elite sires are typically made available to the entire industry, allowing every breeder to market bulls from the same widely-used sires. Collectively, these factors contribute to market failure

In plant-breeding industries there are plant variety rights which allow a breeder to obtain royalties on the use of their products, and those royalties can fund ongoing innovation. This allows the number of plant breeders working directly on corn improvement for example, to greatly exceed the number of animal breeders working on beef cattle improvement.

One approach to provide greater focus on traits not considered is to subsidize the costs that would be incurred by the bull breeders. The two obvious sources of such subsidies are from industry levy funds, or from consumers via government investment from tax revenues. Unfortunately, in the US the National Cattlemen's Beef Association (NCBA) has not seen fit to invest in these activities, unlike its counterparts in other countries. Government funds are widely used, most notably through the activities of land-grant universities and by USDA funding of their own research centres or through their competitive grants programs. Some other countries, most notably Australia and Canada, have enjoyed much greater investments in these activities in their beef cattle sectors than has occurred in the US.

Conclusion

Investment in data collection and subsequent selection activities typically occurs in the bull breeding sector. The bull breeder and the bull buyer have traditionally focussed on those traits that influence productivity that are most easily measured, and mostly easily validated by measuring or observing resultant offspring.

Animal breeders tend to have a much wider focus on traits, and include research on traits not currently considered, but their activities rely on investment by government or by organisations that collect production levies. Those investments often now include outreach but seldom include the implementation phase.

Genomic technologies provide some new options for studying phenotypes and are leading to increased emphasis on traits that have not been adequately considered in the past.

But ultimately, it is innovative bull breeders such as those that were involved in the foundation of the Beef Improvement Federation that drive adoption of new traits. After 50 years of this organisation, we need to ensure that the annual symposium and conference continues to motivate new generations of those leading breeders, and to lobby funds to allow us to move forward and continuously reconsider trait opportunities.

NOTES

Positioning for the Future of Beef Production: Bringing It All Together

John Pollak, Emeritus Professor, Cornell University

Introduction

The Beef Improvement Federation (BIF) is an organization established fifty years ago by forward thinking industry leaders to provide a platform for discussion of topics related to genetic improvement. Those topics include appropriate methods of data collection, methods of analyzing those data in genetic evaluations, selection and mating strategies and the development and implementation of new technologies. An integral part of the success of sustaining beef production has been the commitment and efforts of beef producers to improve the genetic capability of cattle following many guidelines established by BIF. It is appropriate to reflect on the accomplishments of the past 50 years, but we can also use this opportunity to question how to do even better going forward in meeting challenges of the future. In celebration of the 50th anniversary of BIF, this symposium focuses on “Positioning for the Future of Beef Production.”

Contributions by Mark McCully and Michael Genho address quality of beef products and efficiency in producing beef, respectively. These are examples of traits important to the industry. I emphasize these being examples as the portfolio of economically relevant traits (ERTs) in beef production is much more diverse and complex. Sara Place discusses sustainability and the need to address three components defining sustainability; economic viability, environmental footprint and social concerns. Dorian Garrick examines traits currently not considered in the scheme of beef selection.

Over the past 50 years the beef industry has witnessed tremendous growth in the amount and type of data collected. Over that same period the industry experienced numerous advances in technology for managing cattle, capturing data and in computing genetic evaluations. Most recently, DNA technology adoption has reached a level at which that technology is making a significant contribution to genetic evaluations for traits in the EPD portfolio. It is against this backdrop that we look to future opportunities for selection.

Selection is a process used to make genetic improvement towards a desired goal. The process includes creating a well-defined breeding objective and gathering data on traits included in that breeding objective either directly on the trait and/or through genetic indicators for those traits. These data are used in the assessment of genetic merit

of individuals. Selection among candidates to be parents is done by ranking animals on specific traits or indices and keeping the requisite number of animals needed to meet the size requirement of the population. In thinking of selection in this light, there really are no alternatives to the process. Rather our focus should be on alternatives to the components within the process to better reflect the industry needs (the goal and breeding objective) or enhance the response to selection (e.g., more or better data, better assessment strategies). The objective of this paper is to further examine some concepts, challenges and opportunities presented in the symposium presentations and discuss them in terms of impact on strategies for the future selection of beef cattle.

The Goal of the Breeding Program

Garrick states:

“There is a logical approach to developing a breeding program that includes thorough biological and economic considerations of the traits to consider. The first step is the formulation of the goal of the breeding program. That would normally reflect some measure of increasing satisfaction....”

What should the goal of the breeding program for the beef industry be moving forward into the next half century? I am not aware of a well-articulated and universally accepted statement of the goal for beef production that provided the motivation for our historical selection program. However, even if one did exist it certainly needs to be refreshed given current economic trends in the industry, environmental concerns on production footprint and consumer demands. Perhaps the first step moving forward into the future is to establish a modernized statement of the goal for beef production and *BIF is the perfect venue to have this discussion.*

The Breeding Objective

The breeding objective provides a basis for the overall value of an individual's potential contribution to the goal. The seedstock segment of the beef industry is the engine that drives genetic progress throughout the industry. The ambassadors of the seedstock genetic enterprise are the yearling bulls produced by the selection program. Ideally the selection program would address the needs of the commercial, feedlot, processing and marketing segments of the industry as well as expectations of consumers. If

we make an honest assessment of the current selection program, we will likely find that there are areas of weaknesses in doing so. So, if we step away from the current situation in the industry and take the utopian approach of defining a breeding objective that meets all challenges of a segmented industry and consumer demand, we can identify those weaknesses. Once identified, we can then design strategies to overcome them. In addressing this concept Garrick points out several shortcomings in the current selection strategy:

“Namely, there is inadequate consideration of reproduction, inadequate consideration of eating quality, inadequate consideration of the human healthfulness of the beef, inadequate consideration of disease resistance, inadequate consideration of feed intake and feed efficiency, inadequate consideration of lifetime performance, inadequate consideration of welfare traits such as horns, and inadequate consideration of environmental attributes such as water use, greenhouse gas emissions, or levels of effluent particularly Nitrogen outputs. All of these characteristics exhibit phenotypic variation, and all are heritable, so could be included in breeding programs.”

One motivation for this exercise is simply to ensure the economic viability of beef production. There are still ERTs for profitable beef production that we do not adequately address such as health. A second motivation is to systematically address other components of sustainability. Sustainability encompasses not just economic viability but also environmental issues and consumer concerns. Sara Place cautions us that:

“Sustainability has been an issue at the forefront of the beef industry for most of the past decade. Given current marketing trends and the real pressures on our food and earth system as the global population grows by 2 billion additional people in the next two decades, sustainability will not be going away as an issue.”

In preparing for the future, two significant challenges in implementing a better industry breeding program are to create incentives to broaden the scope of traits included in the breeding objective and to establish the infrastructure to capture data to support that objective. Sustainability is an excellent starting point in the planning for an alternative breeding objective for the future and *BIF is the perfect venue to have this discussion.*

I discussed a breeding objective as if there should be one for entire industry. The beef industry is not one large integrated operation but rather is comprised of a multitude of independent businesses. There will naturally be variation in the emphasis of traits under selection. It is also recognized that, given most seedstock are sold to commercial operations within a limited radius of the seedstock operation, certain traits will be more important

in some geographical regions than others. Fescue tolerance, heat or cold stress tolerance, and high-altitude tolerance are some examples of traits that would need to be emphasized differently in their respected regions. This does not distract from having a comprehensive breeding objective with a more complete portfolio of traits but rather place emphasis on the economic values of those traits when being selected within individual programs. Decision support tools can be useful in addressing regional or local economic values.

Phenotypic Data

Much of the selection that has occurred over the past 50 years has been driven by traits for which data collection was relatively easy. This does not diminish the importance of those traits but does constrain the selection program. Dorian Garrick refers to this as being “Data Driven Selection”:

“Bull breeders and bull buyers tend to focus more on attributes that they can easily visualize or measure, such as growth rate or calving ease...”

A more sustainable breeding objective as discussed above, requires reaching for “higher hanging fruit” which by its very nature will be more difficult and perhaps more expensive to collect. We must keep in mind that conceiving of what new traits to include in a breeding objective is easy. Building the infrastructure to collect, store and process data once those traits are identified is more difficult. Understanding that there can be significant differences in the investment needed for including new traits means prioritizing traits based on some long-term cost/benefit analysis as investment funding within the industry is limited. *This is another area for fruitful discussion within BIF.*

One certainty going forward is that the capability to gather phenotypic data will continue to evolve as it has in the past. Over the past 50 years we have seen the development of technology such as ultrasound for measuring carcass characteristics on live animals, technology for obtaining individual feed and water intake and technology for instrument grading. There is a growing emphasis in research in precision management which has a focus on improving capability for data collection on individuals within a group through enhanced instrumentation. Much of the effort is focused on developing technology to capture data in existing production systems.

We also know that there are valuable databases in segments of the industry that do not contribute to the national breeding program. An excellent example is the massive amounts of health data collected in feedlots. That data may not currently be able to be connected to databases for genetic evaluations due to animal ID issues or knowledge of parentage but at least the infrastructure for data collection exists. Strategies to circumvent issues in connecting that data can be establish given the right

incentives and *BIF is the perfect venue to have discussions on how to do so.*

Another issue for discussion is whether the trait, as measured and evaluated, is consistent with industry needs. As a positive example, McCully discusses the improvement in carcass quality grades that has occurred over the years because of a consistent market signal:

“The rise in quality grades across the industry has been very intentional, and the factors behind this improvement have been well-documented (Dykstra, 2016). Improvements in cattle genetics and management, supportive feeding economics and grading technology enhancements have all contributed to the trend, but ultimately the industry has responded to the market signals calling for more high-quality beef.”

Genho, however, discusses efficiency of gain in the Elanco’s Benchmark Feedyard Performance database which shows that actual average feed conversion for lots has increased in heifers and only slightly decreased in steers. This result is attributed in large part to the industry trend in increasing days on feed. Genho argues for an alternative efficiency measure:

“A better approach to evaluating efficiency would be to control for endpoint using a metric such as Empty Body Fat (EBF).”

The premise for this argument is to define a trait that more closely aligns with a measure of success which in this case is lot average feed conversion. This idea raises the larger issue as to whether we are doing an appropriate job in evolving our methods of data collection to accommodate trends in the industry. Are we adequately monitoring our data collection protocols such that we are sensitive to any trend in the industry that might negatively impact the value of phenotypes currently being collected? *BIF is the perfect venue to have this discussion.*

One final area of discussion relative to phenotypic data is to examine if are we fully capitalizing on existing data in our programs to evaluate traits. In some cases, the existing data might be useful in providing an EPD for an ERT for which data does not exist. An example is the use of information on mature size and milk yield EPDs to estimate Cow Maintenance Energy requirements. Advantages in using functions of existing information to create EPDs on any new trait is 1) leveraging existing information increasing its value, 2) doing so provides information on historic animals and 3) starting with the use of existing data could provide an impetus to develop programs to capture actual measures of the new trait if the value proposition for doing so exists. *BIF is the perfect venue to have this discussion.*

DNA Genotypic Data

The most significant change in the selection program for beef in the last decade has come from DNA technology. The current level of adoption has provided for an impactful infusion of new information into genetic improvement programs. As previously stated, the seedstock industry is where most of the investment in the genetic enterprise for the beef industry occurs. Bulls produced in the seedstock sector and transferred to the commercial industry traditionally had low accuracy EPDs, several based only on pedigree information. Incorporation of DNA marker information into the genetic evaluation programs has greatly enhanced the accuracy of evaluating these bulls.

DNA technology also provides for a way to obtain genetic evaluations on animals for the “novel” traits. Several large USDA grants addressing novel traits have been issued. USDA has also invested in the extensive GPE project at USMARC which now supports genomic investigation. All the requirements of discovery populations and ongoing assessment of marker value, issues of using results across breeds or in crossbred populations have been ongoing topics of conversation. These are challenges that will ultimately be resolved, and the technology will provide for inclusion of new traits into the breeding objective. Are we prepared to appropriately align the economic value of these traits in our multiple trait indices? *BIF is the perfect venue to have discussions on the economic weights for these new traits.*

One area of potential great significance in using marker information is the identification of deleterious alleles such as embryonic lethal variants. Garrick points out:

“Marker panels such as the commonly-used 50k chips, allow chromosome fragments known as haplotypes to be identified and their inheritance to be traced. Deleterious recessive mutations are often underrepresented in breeding populations in their homozygous form, or may be completely absent if they cause embryonic lethality. Identification of these haplotypes, or the causal mutations themselves, allows matings between carriers to be avoided, and this can markedly affect trait performance, in fertility and in any other affected traits.”

Opportunities provided by this technology bring promise to addressing the desire for a more comprehensive breeding objective.

Determining How to Measure Success

Data collected on animals are utilized to evaluate genetic merit on the individual and relatives. Change occurring from selection is derived from yearly averages of EPDs over some span of time. The historic breed trends show selection has changed numerous traits. However, the question remains as to whether these changes represent

progress towards reaching industry objectives. Are there alternatives to defining success? An example is the issue of greenhouse gas emissions in the cattle industry. Concern over the contribution of cattle to the greenhouse gas issue has led researchers to investigate methane production and the microbiome of individual animals. There is the opportunity to define metrics that might be useful for genetic assessment and subsequent selection towards reduced emission if they are heritable. If these metrics are included in the breeding objective, then over time we can evaluate success in response to selection by the change in the average emission per animal per year as we do when looking at trends in weight or any other trait.

However, an alternative measure of success and perhaps one that resonates more closely to public concern is to estimate the yearly production of greenhouse gases by beef cattle based on animal numbers and total beef produced. Sara Place commented:

“Cattle herd size relative to beef produced is a critical component that determines the total resource use of beef production within the United States and globally. Per capita beef consumption is sometimes used as a proxy for estimating impacts from beef production, and recent reductions in per capita consumption within the United States have been highlighted as a reason for reduced greenhouse gas emissions. However, this is incorrect. Emissions from U.S. beef production have declined because the U.S. cattle herd has declined, and more beef has been produced per live animal (considering all supporting herd cows, bulls, replacement heifers, and cattle bound for finishing).”

In doing so, the emphasis changes from how well we are progressing with selection for the new metrics used to evaluate emissions to how well the entire selection portfolio is impacting success. For example, new strategies for selecting or mating cattle for improved fertility utilizing knowledge of variants causing early embryonic death will result in a change in the ratio of gas emission per pound of beef produced either by increasing the number of calves harvested or decreasing the size of the national cow herd.

There are other scenarios where we can alter our approach to measuring success that appropriately examine the impact of the breeding program, such as production per acre rather than individual animal performance. *BIF is the perfect venue to have this discussion.*

Summary

It is suggested that as we look to the future as an industry, we establish a statement of our goal for beef production. Based on this goal we should establish a breeding objective that ensures economic viability but also focuses on the needs of the industry to respond to today's social climate. The portfolio of traits will surely contain those for which we currently have genetic evaluations. We need to make sure our current approach to collecting existing data and the evaluations produced from those data are consistent with the needs of the industry. The portfolio will also include new traits for which we will need to develop strategies of collection and use. We will need to understand the cost/benefit ratio of developing new datasets and prioritize our approach to inclusion as investment resources are limited. There will be the need to incentivize this entire process. *BIF is the perfect venue to have these discussions.*

NOTES

Ultrasound Guidelines Council Update: Systems Review Committee

J R Tait, Ph.D, Ultrasound Guidelines Council, System Review Committee Chair

The Systems Review Committee (SRC) of the Ultrasound Guidelines Council (UGC) is comprised of the three academic members of the UGC board of directors and one at-large appointed person.

The SRC approves ultrasound systems for intramuscular fat estimation where the data will be used in genetic evaluations of U.S. beef breed associations. An ultrasound system is a combination of: ultrasound scanning machine, ultrasound machine settings, frame grabber, and interpretation software.

Systems Review Committee has established the protocol for new ultrasound system approval by the UGC. Highlights of this protocol include:

1. Notice to SRC of intention to approve a new system with development data provided.
2. Entity proposing new system will pay for all expenses of system approval.
3. Minimum of 70 animals with both ultrasound data and chemical extracted fat data.

4. Chemical extracted fat is the reference phenotype to compare ultrasound data to.
5. A currently UGC approved reference ultrasound system must also scan the same group of animals.

Statistical measures used to evaluate the accuracy of the proposed ultrasound systems include:

1. Bias
2. Correlation
3. Standard error of prediction
4. Slope of ultrasound trait on carcass trait

Recently, the following systems were approved by the Ultrasound Guidelines Council System Review Committee:

Items in bold are recently approved components and/or software algorithms.

The Ultrasound Guidelines Council is glad to see a continued investment in identifying new ultrasound hardware and supporting technologies to enhance the characterization of body composition traits in seedstock beef cattle for selection purposes.

Test participant	Ultrasound machine	Frame grabber board	Intramuscular fat prediction model
Ultrasound	New Aloka 500	Avermedia frame grabber	Ultrasound New Aloka Intramuscular Fat model
Ultrasound	E. I. Medical - EVO	Onboard digital image storage	Ultrasound EVO Intramuscular Fat model
CUP Lab	New Aloka 500	Elgato frame grabber	CUP Lab New Aloka Intramuscular Fat model
CUP Lab	Aquila	Elgato frame grabber	CUP Lab Aquila Intramuscular Fat model
CUP Lab	ECM Exago 16 cm magnification	Digital Image Transfer	CUP Lab Exago 16 cm Intramuscular Fat model
CUP Lab	ECM Exago 20 cm magnification	Digital Image Transfer	CUP Lab Exago 20 cm Intramuscular Fat model
CUP Lab	E. I. Medical - EVO	Onboard digital image storage	CUP Lab EVO Intramuscular Fat model
CUP Lab	E. I. Medical - Ibex Elgato	Elgato frame grabber	CUP Lab Ibex Elgato Intramuscular Fat model

Ultrasound Guidelines Council Update: Field and Lab Certification Review

Patrick Wall, Ultrasound Guidelines Council Executive Director

The Ultrasound Guidelines Council (UGC) serves as the seedstock industry standard for establishing proficiency testing guidelines for collecting, interpreting, and submitting carcass data records via live animal ultrasound to participating beef breed associations in the United States. Since 2003, these standards have been reviewed, upheld, or even strengthened as the technology has progressed. Field technicians must “certify” that they are proficient at scanning cattle by collected good quality images that are easy to interpret in the lab. These technicians must certify **in person** at least twice before they are eligible for **in absentia** certification, a process that reviews image quality on the body of work submitted by the technician over the previous two years. Lab technicians, or those that interpret images submitted from the field, must also certify every two years with no eligibility for **in absentia**. Lab certifications are tied to a specific technology, or type of ultrasound machine.

The Certification Process (Proficiency Testing)

To become UGC Field Certified, ultrasound technicians must pass proficiency testing (often referred to as UGC Field Certification). Proficiency testing includes a written exam, and the collection of ultrasound images of the rump, rib, and intramuscular fat. Twenty animals, varying in age, gender, and condition are scanned representing breeding cattle as well as harvest cattle. Each technician collects images on every animal twice (i.e., in two sessions). Animals are renumbered between sessions. Technicians should be prepared to spend no more than three minutes collecting images from a single animal. All animals will be clipped in advance by the host institution.

UGC Reference Field Technicians collect images on the same animals. The images collected are interpreted by UGC Reference Lab Technicians to yield estimates of ribeye area, rib fat, rump fat, and intramuscular fat. The Reference Lab Technicians also score every image for image quality. Measurements from images collected by the Reference Field Technicians are used as the standards for each trait. Technicians are evaluated based on several statistics including image quality, correlation, bias, standard error of prediction, repeatability, and standard error of repeatability. The UGC website contains study materials and explanations of the statistics used to evaluate technician proficiency.

Statistics for all technicians are evaluated by members of the UGC Board of Directors which makes all pass/fail decisions. Technicians are notified of the results within about six weeks of the certification program.

Standards for **in person** UGC certification of field technicians

An **in person** demonstration of proficiency will consist of an official UGC proctored event at which 20 animals will be scanned twice by the individual seeking certification. The animals used at this event will be of a weight representative of well managed yearling age purebred beef cattle of breeds that are commonly used in commercial beef production.

These same cattle will be scanned immediately prior to the certification event by three UGC certified technicians (reference technicians) who have previously met the criteria for in absentia certification in the immediately preceding two certification cycles (i.e., four years). Subject to quality control, the data produced by the reference technicians, when averaged, will serve as the standard for the certification event.

Images collected during the certification event will be analyzed independently by a minimum of two experienced and UGC certified image interpretation technicians. Average results of these analyses (again subject to quality control) will be the data used to assess the proficiency of each individual.

Any individual seeking in person certification of their proficiency in ultrasonic imaging of phenotypes that are indicative of carcass merit in beef cattle must successfully meet all of the following criteria.

1. Achieve a score of 70% or greater on a 25 question open book examination of the individual's general knowledge of UGC, use of ultrasound by the beef industry, and applicable ultrasound technologies.
2. Produce a minimum of 15 pairs of images that can be interpreted for depth of fat at the 12th-13th rib interface FAT, depth of fat over the rump (RMP), area or the longissimus dorsi muscle at the 12th-13th rib interface (REA), and intramuscular fat within the longissimus dorsi (IMF). Failure to produce 16 pairs of interpretable images for any of the anatomical locations shall result in the individual not being certified by UGC.

3. Achieve minimum average image quality scores of 0.70, 0.65, and 0.88 for RMP, RIB, and IMF, respectively.
 4. For those animals with repeated measures of each trait, achieve correlations among those measures of 0.90, 0.80, 0.80, and 0.80 for RIB, REA, RMP, and IMF.
 5. The standard deviations of differences between the repeated measures of RIB, REA, RMP, and IMF shall not exceed 0.06, 0.05, 1.10, and 0.75, respectively.
 6. Achieve product-moment correlations for RMP, RIB, REA, and IMF between reference and candidate technician produced values greater than 0.90, 0.90, 0.85, and 0.85, respectively.
 7. The standard deviation of the differences between reference and candidate predictions of RMP, RIB, REA, and IMF shall not exceed 0.05, 0.05, 1.00, and 0.70, respectively.
 8. The Student's t-test for the paired differences between reference and candidate generated values will not be highly significant ($P < 0.01$) for any of the measured traits.
2. Have image quality scores for a minimum of 3000 head scanned.
 3. Have image quality scores for a minimum of 250 head scanned annually in the preceding two years.
 4. For RIB images: Have no more than 0.6% of images submitted scored as "reject"; and at least 93.4% of all RIB images scored as "acceptable" over the preceding two years.
 5. For IMF images: Have no more than 0.5% of images submitted scored as "reject"; and at least 94.5% of all IMF images scored as "acceptable" over the preceding two years.
 6. For RUMP images: Have no more than 0.1% of images submitted scored as "reject"; and at least 98.9% of all RUMP images scored as "acceptable" over the preceding two years.

Standards for *in absentia* UGC certification of field technicians

A field technician seeking *in absentia* certification of their proficiency in ultrasonic imaging of phenotypes that are indicative of carcass merit in beef cattle must successfully meet all of the following criteria. Failure to meet any of these 6 criteria will result in the field technician being required to demonstrate their proficiency in person.

1. Have successfully demonstrated their proficiency ***in person*** at least once, and have not failed a more recent in person evaluation of their proficiency.

Lab Certification Policies

Beginning in 2003, Lab certifications included 40 images per technology (Examples: Aloka, Classic, etc.). Since each technology portrays the image differently (i.e. brightness, contrast, grayscale, etc.) and uses different scaling or magnification, lab technicians must be proficient on each ultrasound technology, and thus are tested accordingly. As you might imagine, several lab technicians are certified on multiple technologies.

UGC administers lab certifications with all tracing images linked to carcass data, and with both tracing and image quality images set up to measure technician repeatability. UGC also can conduct lab certifications for technicians in other countries by using a paid independent third-party proctor.

A 3-point scale (1=Acceptable, 2=Marginal, 3=Rejected) for Image Quality replaced the 7-point scale used in field and lab certifications in 2012.

NOTES

Geometric Biometrics as a Robust Approach to Quantification of Livestock Phenotypes

Catherine McVey, Pablo Pinedo, Department of Animal Sciences, Colorado State University

Introduction

In most standard linear models, model specification includes the simplifying assumption that covariates are known without error (Kutner et al 2005). For some simple categorical variables, like gender or herd of origin, this is perhaps true, excluding errors in data entry (Meyer 1997). Measurements that seek to capture more complex and dynamic sources of information, however, can seldom be represented without error. In this case, a thorough understanding of the nature of the error associated with a measurement system is necessary to fully evaluate the appropriateness of such simplifying assumptions, and where necessary, make accommodations and adjustments in the development of a robust model. At the outset of a chapter focused entirely on metric validation and characterization of error, it therefore seems prudent to briefly reflect more abstractly on the process of measurement of complex features.

When approaching the task of extracting anatomical information from a digital image, it is essential that one not conceptualize a cow simply as a solid object of finite dimensions existing in three-dimensional space. Instead, conceive of an image of a cow as existing in a high dimensional space, sometimes colloquially referred to in the natural sciences as a hyperspace, built from a composite of information of numerous types (Hurlbert 1981; Ojiem et al 2006; Van Heel 1984). Part of the high dimensional space in which such an image lives will capture information about the physical attributes of an animal, but many other dimensions will capture extraneous information classified in this application as noise - age, coat length, coat color, cleanliness, emotional state, position, light exposure, shadow exposure, background, etc. In developing a novel measurement system, the goal is to extract the maximum amount of information of a desired type, the signal, from information deemed extraneous, the noise (Measurement Systems Analysis Work Group 2010). This is effectively done through a series of data compressions steps. Careful consideration must be given to the assumptions made at each stage of dimensionality reduction to account for potential sources of error introduced by the compression technique selected (Kirby 2001). Finally, full characterization of a measurement system requires a thorough characterization of the resulting metrics to ensure

they demonstrate traits amenable to standard methods of statistical inference and predictive modeling (Kutner et al 2005).

Dimension Reduction

The first major compression of information utilized by this measurement system occurred in reducing the temporal dimension down to a single time point. It was assumed that boney structural features of a mature cow's head would not change significantly over a time window spanning only two weeks, excluding any obvious physical injuries. It should be stated that this is fully an assumption, as it does not appear that this issue has been addressed in the existing body of published research, and validation through an extended longitudinal study of the boney structures of the bovine face has been left to future research. In the process of obtaining facial photos, it was observed that this assumption may have been violated for select boney and cartilaginous structures obscured by a significant amount of soft tissue, as variations in facial expressions might obscure measurement of facial structure on a much finer time scale. This observation was explored indirectly as part of the larger metric validation procedure.

The second and perhaps most significant compression of information utilized by this measurement system was exclusion of pixel exposure information so that facial structures were represented only by the distances between landmark structural points. An image is typically represented by an $m \times n \times 3$ matrix, where each pixel index contains, depending on the format, a real number value reflecting the exposure level or hue intensity at that position in the captured scene. Even for a camera with moderate pixel resolution, this represents a massive amount of information contained in many thousand pixel values. Photos are often compressed to a grayscale $m \times n \times 3$ matrix for image analysis purposes, but even for modestly large image databases, standard pixel-based analysis techniques, like eigenface analysis, can quickly become computationally intractable (Kirby 2010). This would impose computational constraints that could limit the applicability of such a system, particularly if it were to be implemented at a breed-level.

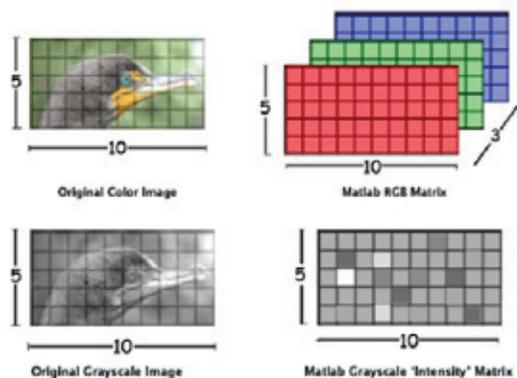


Figure 1: Basic Anatomy of a Digital Image (Singh 2012)

Perhaps of greater concern, however, is the susceptibility of pixel-based image analysis techniques to extraneous noise. At its core, eigen face analysis is just a form of principal components analysis, where in this case each pixel index represents a variable. Given a large number of images captured under very controlled conditions, eigen face analysis can be an effective means of dimension reduction, eliminating noise and redundancy in a set of training images to yield a much smaller set of basis images that concentrate the information of the signal. Like standard principal components analysis, however, eigen face algorithms are greedy algorithms, creating at each step a basis image which captures the maximum amount of variation found in the original training set possible. Subsequently, eigen face algorithms offer very little control with regards to how information is partitioned within basis images (Kirby 2001). This makes them a poor choice for isolating a specific class of features, such as facial anatomy, when conditions do not allow for tight control of other factors influencing image quality. Fluctuations in image exposure alone, with all other factors held constant, typically account for at least 10 dimensions in the resulting image space (Beveridge et al 2009). They also cannot discern between changes in the intended subject of the image (foreground) and random artifacts in the background, which can be difficult to control in a field setting. Additionally, in animals, eigen face algorithms seem more influenced by changes in coat pattern than overall facial morphology, a major concern for application to Holstein populations (Caiafa et al 2005). Neural network-based image analysis techniques, which can be thought of as a non-linear extension of principal components based eigen-techniques, are a newer approach, and subsequently not as well defined (Kirby 2001). However, deep learning algorithms, likely by virtue of their multiple differentiable layers, seem more adept at paring complex components of images down into their simpler components, making them perhaps a better algorithmic candidate for extraction of facial phenotypes from farm quality images (RSPI Vision 2017). Unfortunately,

robust networks require large and diverse image data sets to train, making them difficult to implement for applications without existing databases.

Given these constraints, it was determined that a face mesh approach was more appropriate for this domain of application. With this approach, key anatomical landmarks of the face are determined a priori. All images in a database are subsequently annotated with these landmark points, and their coordinate location within the pixel matrix of each image recorded and used in subsequent analyses. Large image databases have been used to train fully automated algorithms for landmark point extraction for applications in humans, but such work has not been pursued for animal populations, which again imposes practical constraints on the scale at which this technique can be imposed. Here again, however, deep learning algorithms have shown promise in this area, and new research indicates that learning algorithms for landmark point extraction trained on larger human databases may be effectively adapted to livestock features with much smaller reference data bases when strategic constraints are applied (Rashid 2017). For the purposes of this largely exploratory study, it was deemed sufficient to simply extract landmark points manually. By using MatLab's GINPUT tool to interactively select a predetermined series of key anatomical reference points on the face, and storing their coordinate locations within the pixel matrix, extraneous information related coat pattern and features of the farm environment, like variable lighting exposure and changing background content, were effectively excluded. It should be noted, however, that in applying this compression, a significant amount of structural information was inevitably lost as well, with only structural points that had been identified as descriptive a priori being retained for further analysis. This could serve as a source of bias, if certain regions of the face or types of structural variations were not adequately described by the landmark points defined. Additionally, physical selection of these anatomical points within the image was not without error, requiring targeted analysis to determine the magnitude and systematic nature of this source of measurement error.

The third major compression of information came from reducing facial structures from 3 to 2 physical dimensions. It would be possible to represent structural features of the face via a 3-dimensional image, and thereby capture all dimensions of facial shape, up to the resolution of the camera and accuracy of the stitching algorithm (Aldridge et al 2011; Obafemi-Ajayi et al 2014). To do so, however, would be an expensive and time-consuming endeavor, requiring specialized equipment and greater restraint of the animal. Thus, this compression decision was driven predominantly by practical concerns, as it was deemed that loss of information was outweighed by gains in accessibility realized by developing this measurement system around

the specifications of any standard quality digital camera. In projecting a 3D object onto a 2D plane, however, several sources of error are introduced. The first and most important is angle of the object relative the plane of the camera. Significant variations in angle related to depth can effectively distort the resulting image as it is projected onto the plane, effectively warping the relative distances between facial structures. This is a major concern, as it not only distorts the perceptions of facial shape, but because of the underlying geometry, tends to do so in a systematic way. In other words, errors from this source are not necessarily random, and tend to be correlated, which breaks the assumptions of many statistical models (Kutner et al 2005). This source of error was addressed in two ways. The first approach was procedural, attempting to reduce variation in camera angle as much as is possible on a farm working with large and at times disagreeable animals. Side profile images were obtained parallel to the surface of the cheek. This was partially achieved by attempting to center the image on the eye, and then aligning as closely as possible the ridges of the eye orbitals on either side of the forehead. Front profile images were obtained parallel to plane of the forehead. This was achieved by attempting to equalize the distance between either eye and the center of the forehead on either side of the face, and then seeking to obtain an image where the nose appeared as long as possible.

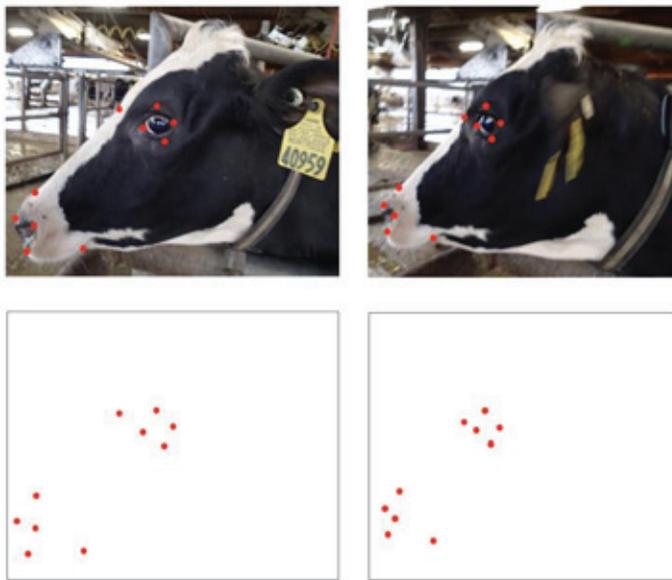


Figure 2: Impact of Out-of-Plane Variations in Face Angle on Coordinate Locations

The second major source of error introduced by this compression came from variations in relative position of the camera to the cow. Varying distances between the camera and object changes the proportion of the frame dedicated to the cow's face. This in turn changes the number of pixels

dedicated to capturing structural features of the cow's face (i.e. image resolution). If raw pixel distances between anatomical points were used, changes in image resolution would become a major source of error due to differences in scaling. This issue is often addressed by scaling the image to a known reference length of an object with the frame of the image, but this solution was deemed impractical on a working farm environment. Attempting to place a reference object in the frame near the cow so that it would be in a plane equidistant to the camera with the cow would not only significantly increase the amount of time required to obtain an image, but also increase stress experienced by the animal and put the handlers in a more exposed position. Instead this issue was addressed by developing biometrics that either reported angles or distances as proportions. Computation of angles between traits are of course geometrically dependent only on their relative, not absolute, distances. Similarly, by using proportions to report relative distance measures, the scaling factor of the image was effectively "divided out". Thus, this measurement system should be inherently robust to changes in image resolution that result from variable distances between camera and cow, as well as any variations in specs of the camera used or degree of zoom applied. Practically speaking, this greatly simplified the process of acquiring images of the cows and allowed greater focus to be placed on reducing variations in image angle.



Figure 3: Illustration of Elimination of Scale Effect by Division Op

One exception to this assumption of distance invariance was that, when the photograph was taken extremely close to the cow's face, as frequently happened when photos were acquired in the feed bunk, there seemed to be a significant interaction between position and angle. Put simply, when quite close to the cow, aligning the camera using the eye structural reference point created the correct

90-degree angle for the central part of the face, but still left a significant angle between the camera and distal parts of the face, namely the nose. Auxiliary image measurements were used in an attempt to correct for this potential source of error in such images.

The fourth and final source of compression comes from converting the 2D coordinate vectors representing the locations of key structural points into 1D descriptive measures that could be used as covariates in predictive models. Previous studies have frequently accomplished this by simply taking the Euclidean distance between all pairwise combinations of anatomical points, globally normalizing by the sum of all lengths to correct for differences in image resolution, and then reducing the number of candidate variables by using a multivariate compression technique such as principal components (Cole et al 2016; Aldrige et al 2001), or else using data clustering techniques designed for high dimensional input (Obafemi-Ajayi et al 2014). While this procedure is quite simple to apply, it has two key drawbacks. The first and most significant is that the resulting distance measures are directly geometrically related, resulting in complex correlations structures. A slight change in the relative position of one anatomical point would be reflected in slight changes in all pairwise distances of which that point is a member. When points change their relative positions due to underlying face shape, associated Euclidean distance terms will change as well, but so many of these points would change simultaneously that it becomes difficult, if not impossible, to discern the nature of this geometric shift just from direct appraisal of the data.

Algorithmic Solutions

Principal component analysis is a means to concentrate this redundant information, but in doing so assumptions of linearity are necessary. When a number of facial features shift simultaneously, their cumulative effects on individual pairwise distances may not necessarily be additive, which could potentially lead to inflation of the parameter space or misleading reparameterizations (Kirby 2001; Johnson & Richard 2007). When the relative position of points changes due to error in point selection, as opposed actual changes in facial shape, this error is also subject to geometric constraints between pairwise combinations of points, potentially leading to correlation in the error structures. Most correlation-based multivariate techniques, including principal component analysis, require the assumption that error terms are uncorrelated. When this is not in fact true, correlation in error is mathematically interpreted as correlation in the signal. As a result, application of these dimension reduction techniques lead to concentration of both signal and error simultaneously (Johnson & Richard 2007), which is at best inefficient but also a potential source of bias in downstream analysis.

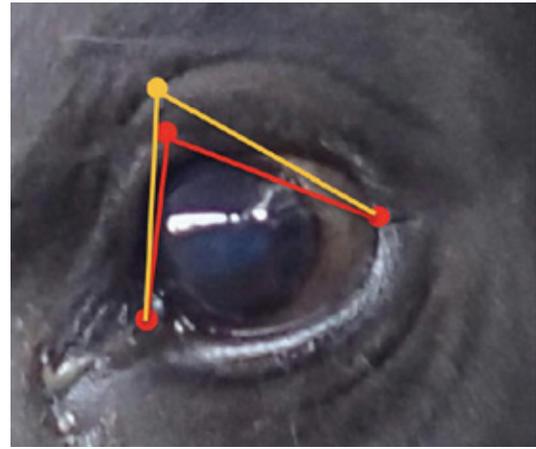


Figure 4: When horizontal eye landmarks are constant, error in point selection leads to triangular relationship between edges

The second drawback of this technique is that principal component analysis, while an effective means of dimension reduction, is limited in terms of its descriptive ability. For exceedingly high dimensional input, it is difficult to determine from the orthogonal bases vectors what information is captured in each new transformed variable. In other words, it might be possible to determine from the relative scale of orthogonal basis values that a given dimension is dedicated largely to describing variations in eye structure, but it would be difficult if not impossible to determine what this would relate to in terms of the underlying structural variability without a means of effectively regenerating the face (Nielson et al 2011). This makes any subsequent models built using reparameterized variables difficult to interpret. While this is perhaps sufficient for purely predictive models, it makes it difficult if not impossible to assess the biological appropriateness of such results. Further, as principal component analysis is not a model-based technique, it is not generally considered readily extrapolatable to novel data sets, which makes it more appropriate for descriptive studies as opposed to predictive modeling (Johnson & Richard 2007).

In an effort to overcome these drawbacks, a geometric approach to biometric extraction was developed. This approach had two key goals. The first was to minimize correlation between resulting biometrics, attempting to isolate specific changes in shape using targeted geometric relationships on the front end of the algorithm to create independence between measurements, as opposed to applying an indiscriminate orthogonalization technique like PCA on the back-end. This was done in two ways. The first was that, as opposed to normalizing pixel distances between points using the sum of all pairwise distances, it divided by distances between nearby points that were selected to produce more intuitive interpretations of shape. For example, instead of describing the height of the eye as

a proportion of overall face size using the sum of distances, which would in turn be influenced by many other unrelated anatomical factors like jowl depth or nose length, it was compared directly to the length of the eye, or to the depth. The second means of achieving this goal was to make use of projection lengths over simple Euclidean distances. The coordinate locations of many key anatomical points were frequently observed to be influenced by multiple independent variations in facial shape. By projecting such a point onto a number of carefully selected reference slopes from nearby facial features, the effects of these independent shape variants could be more effectively broken up into distinct distance measures to isolate their independent effects. For example, the location of the highest point of the eye is influenced by two variants in eye shape: how tall the eye is, and how angular the top of the eye is (i.e. how far forward is the highest point). Simple Euclidean distances would capture both effects at the same time. By instead relying on projections, the angularity of the eye is captured by projecting the highest point of the eye onto the horizontal plane of the eye (Eye Height Point Proportion - EHPP), and the height of the eye is captured by projecting the highest point of the eye onto the plane perpendicular to the horizontal reference plane of the eye (Eye Height Proportion - EHP).

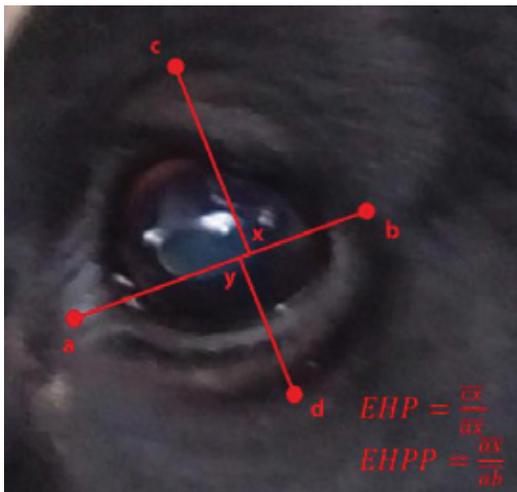


Figure 5: Example of Geometric Biometric using Orthogonal Projects

The second goal pursued with a geometric approach to biometric extractions was to reduce the impact of errors in point selection. This was done in several ways. First, by attempting to define facial shapes using targeted comparisons of length measures, as opposed to Euclidean distances between all pairwise combinations of anatomical reference points, and by relying on a local as opposed to global normalization scheme, any error incurred in the selection of the coordinate location of a given anatomical reference point was effectively isolated to only a targeted

handful of metrics, and not amplified across the broader set of metrics. Put more simply, if the coordinate location of the highest point of the eye was selected poorly in a given picture, that error was only seen in a subset of the eye biometrics and had no impact on biometrics extracted from the nose, topline, or forehead. This characteristic was enhanced by relying predominantly on projection lengths. Just as the projections were used to break down distances into the distinct influences of shape, they also effectively orthogonalized the components of error. This was particularly helpful for traits where coordinate selection was perhaps clear in one direction but less easy to distinguish for another. For example, take highest point of the eye. For very rounded eyes, multiple coordinate selections might return points with very similar vertical distances horizontal plane of the eye, but a great deal of variability in the horizontal distance. This error in point selection would in turn be isolated only to metrics that relied on the horizontal component of this point location and have virtually no influence on metrics that rely only on the vertical distance, whereas for simple Euclidean distance this error would influence any pairwise combination that involved this point.

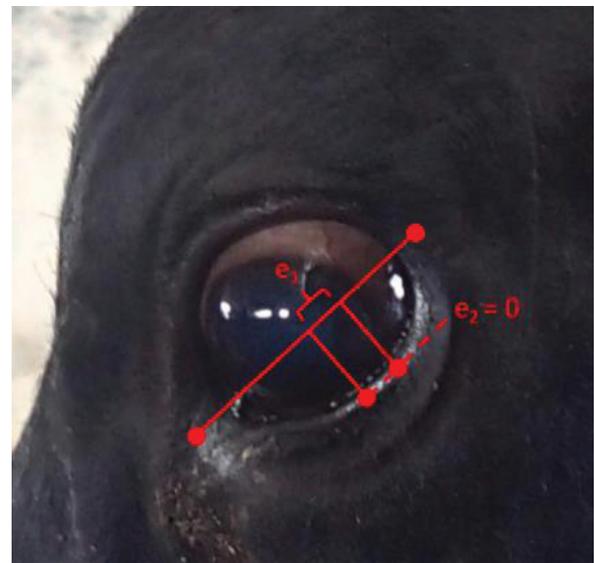


Figure 6: Orthogonalization of Error Component

Finally, measurement error due to error in point selection was also reduced with the strategic use of interpolated points, defined as the intersection point of two extrapolated lines formed by anatomical points from other regions of the face. Efficiently calculated using a solution to standard cross-product formula, such points were frequently used to infer the location of an anatomical structure that could not be reliably identified by eye. This frequently happened for traits obscured by a significant amount of flesh or muscle. The location of the back of the jaw is an example of an interpolated point. Often difficult to identify visually for cows with significant amounts of skin and fat deposits

around the jowl, this point was interpolated by projecting a line from the bottom of the chin along the jaw bone and then finding its perpendicular intersect with the back of the poll.



Figure 7: Example of an Interpolated Landmark Point (red)

A total of 104 candidate geometric biometrics was developed to fully describe the shape of the bovine face. To assess the efficacy of this novel approach to biometric extraction from digital images, geometric biometrics will be compared to standard normalized length measures within each region of the face to determine which strategy demonstrates more robustness to measurement error while minimizing correlations between metrics without use of dimension reduction techniques. Final estimates of repeatability will then be used to select which candidate biometrics demonstrate sufficient robustness to warrant farther study in predictive models of dairy productivity and longevity.

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NOTES

Value Driven by Information

Wade Small, President, Livestock Division, Agri Beef Co.

Agri Beef Co. is a vertically integrated branded beef company that has utilized information and technology to drive its production system and improve the quality of beef produced. The progress that has been made in the company related to the quality of beef produced is apparent in the increased volume of sales of upper Choice and Prime product. This trend is not unique to Agri Beef.

As an industry we have added value to the industry at an accelerated rate over the last 10 years. We have seen an increase in total pounds as well as an increase in Choice + pounds per head across the industry. This is very apparent when you look at genetic trends across multiple breed associations as well as feedlot and packing plant benchmark data.

This is true value that has been created in the industry. With the historically segmented nature of the business identifying where the value is captured is often difficult to do, and depending on market conditions, the segment gaining the greatest benefit may shift from year to year. The longer the ownership resides with one party throughout the production system the greater the opportunity to capture a larger percentage of the value.

As an industry we spend a lot of time and money to capture a tremendous amount of data in all segments. How we analyze and utilize the data is what creates value in the production system.

Value over the last ten years has been driven by improvements in daily gain and marbling. These have been the two factors that have also been the focus of the industry.

Daily gain and carcass weight are the main driver behind profitability and marbling is the main factor increasing carcass value and improving beef demand. It is also phenotypic data that is easy to capture, analyze, and ratio.

Identifying the areas in the industry where we need to focus to continue to meet consumer demand and improve profitability will require innovative ways to capture and analyze economically important traits that have been historically hard to track. Capturing this data requires increased cooperation across segments of the industry, that has historically been difficult to track.

With the importance of animal welfare, increased scrutiny of antibiotic use, and the increased growth of antibiotic free programs, animal health has an increasing impact on profitability as time goes on. This is an example of data that is difficult to capture do to the lack of a standardized data collection platform and management practices.

As topics like these move more to the forefront of the cattle feeding and packing industry, and begin to have a greater financial impact there will be more collaboration on identifying ways to capture animal health data and make selection decisions that increase value throughout the industry.

We have proved as an industry that we can make dramatic improvements in traits that we can measure and select for. Identifying ways for the industry to collaborate to collect data on traits that will add the greatest value over the next ten years will be the greatest challenge to continue to build upon the progress made in the last ten years.

What I Learned from Pigs

Marty Ropp, Allied Genetic Resources

This presentation is part of an on-going BIF educational initiative to “look over the fence” at competing meat production chains and perhaps learn from the changes in their industries and genetic improvement programs. Though our paths are not perfectly parallel nor are we destined for exactly the same paradigm changes, we are each charged with genetic improvement for all segments including product quality and acceptability as our competitors. By learning from the experiences of others with whom we share similar protein businesses, we should be able to make our own changes with greater security and with plans that make for a smoother transition to the future. Coincidentally, my experience and stories begin in 1973, just a few years after the creation of BIF.

I was fortunate to grow up in the Purebred swine seedstock business in central Illinois during a time of significant success and prosperity for that industry. Unfortunately, for most of the producers with whom I shared the success of the day, the good times were fleeting and few predicted the magnitude of the changes to come. With immense structural changes in the larger swine industry that included a move to large systems-based models of production and accountability at all levels, most independent seedstock producers were unable and or unwilling to make the changes necessary to service a changing industry and a changing customer. The resulting

failure of thousands of independent seedstock businesses was difficult to watch as a young person who saw many of those producers as both mentors and friends.

Beginning with timelines, industry details and voices from the past, I hope to show patterns of opportunities and missed opportunities which plagued the independent seedstock production model that dominated the swine industry of the past. My hope is to show pattern similarities to the changing beef genetics business. Though there may be no perfect model for genetic improvement and seedstock production that doesn't require more change to tradition than is palatable to some, by doing a better job of predicting change, all of us have a better chance to be successful in the future.

Paradigm changes in the beef business will surely be unique and are much slower to manifest than those in the swine, poultry or even dairy industries, but change is happening. The beef genetics business absolutely has the opportunity today to help lead the way to a more profitable future for the entire industry should we choose to. The second and more painful option is for the seedstock industry to simply follow along reacting to adjustments it could have predicted and repeat the failure cycle of other businesses. Working with and supporting the Beef Improvement Federation is a great place to start.

ABS: Using Data to Maximize Profit from Genetic Progress

Matthew A. Cleveland, Ph.D.

Director, Global Beef Product Development, Genus ABS, De Forest, WI 53532

Who is ABS?

ABS Global is the world leading provider of bovine genetics, reproduction services, artificial insemination technologies, and udder care products. The company, founded in 1941, markets in more than 70 countries around the globe and currently supports more than 50,000 customers with more than 17 million inseminations and embryo transfers annually.

ABS is focused on the continuous development of better genetics to help our customers produce better quality beef more efficiently and sustainably. With a long history of innovation, ABS is at the forefront of delivering new genetic solutions to make our customers more profitable.

Brief history of data collection efforts

ABS has been collecting data for genetic improvement of beef cattle for more than 50 years and was involved in the early years of BIF and development of the BIF guidelines. A large-scale multi-herd progeny test program was initiated by ABS in the early 1960s, followed by the first published EPDs from that program, adhering to BIF standards, in 1973. The collection of Real World Data continued to be an integral part of the beef program, leading ABS in 1996 to partner with the Angus Sire Alliance formed by Circle A Ranch, which became an exclusive ABS test program in 2007. The Angus Sire Alliance has tested thousands of commercial progeny from more than 100 bulls, for traits directly related to whole-herd customer profitability. All the data collected through various testing programs has contributed to the improvement of the major beef breeds in the US.

How ABS operates today

ABS continues to collect data in the US through the Angus Sire Alliance and breed association carcass merit programs, and is growing testing capacity through partnerships with progressive herds throughout the country. We have focused on collecting phenotypes for traits that are relevant to our customers and have made efforts to collect data for traits that are economically relevant but have historically not been routinely recorded, such as individual feed intake. ABS has been one of the largest individual contributors of carcass and feed intake data to the American Angus Association database. In addition, we are collecting phenotypes and genotypes to feed internal evaluations.

Outside of the US, ABS has made significant efforts to work with producer-partners to collect data that enables a greater understanding of the impact of our genetics in different environments and how this impacts customer profitability. Specifically, in the UK/Europe and in Latin America, we have developed commercially relevant data pipelines to measure the full animal life cycle, including feed intake and several novel traits. Much of the data we collect in these systems is for commercial crossbred animals and so all data, including genomic information, are fed into our internal database system that we use to create customer solutions.

The data challenge

The largest data challenge that ABS faces is the same challenge the global industry is faced with – collecting data and making genetic improvement for economically relevant traits in a targeted and sustained manner. Genetic improvement that leads to a differentiated product drives profit maximization in a system, and the engine that drives this improvement is robust and relevant data. The value of a sire or dam to create more profitable progeny can only be effectively determined by collecting data in the system or environment in which they will be used. In addition, as we make progress for traits that are today routinely recorded, we open up the opportunity to target other factors that impact animal performance which until now have seemed to be too difficult or complex to measure.

One solution to this challenge is to reduce the emphasis on developing somewhat compromised solutions that will work across the whole industry and instead focus on improving individual systems where targeted genetic improvement can have a more rapid impact, and where there is a clear incentive to collect data. ABS is working with customer systems and customer data, inside and outside the US, to develop programs targeted to customer systems, which in most cases include traits and animals not routinely recorded elsewhere. The outcome of these programs is identification of improved genetics that have demonstrated added value to the customer. When genetic decisions become more “local,” the economic relevance of certain traits is more obvious leading to more robust datasets and ultimately improved profitability.

American Angus Association Data Access Policies and Procedures

Dan W. Moser, Stephen P. Miller and Kelli J. Retallick
Angus Genetics Inc.

Since its formation, the primary mission of the American Angus Association (AAA) included recording of information for the benefit of its membership. Initially, pedigree information was of primary interest, but over time, phenotypic measurements and genomic information became equally important. Today, the Angus database includes 22 million animals in the extended pedigree, nearly nine million weaning weights and a half-million genotypes. The investment in genotyping by members of the American Angus Association exceeds \$25 million. A primary responsibility of the organization is to maximize the return on members' investment in pedigree recording, phenotypic data collection and genomic testing.

As the size and complexity of the Angus database has grown over the years, Angus staff and elected leadership have developed policies designed to protect that investment while maximizing its benefit. In 2007, the association formed a wholly-owned subsidiary, Angus Genetics, Inc. (AGI), to provide services to the beef industry that assist in the genetic evaluation of economically important traits. Toward that mission, AGI develops and promotes technology for use by the beef industry, including DNA technology.

Genomic testing of seedstock and commercial Angus cattle is conducted by ordering tests from and submitting samples to AGI. AGI then contracts with genomics laboratories to provide genotyping services. Ownership of samples is transferred from customers to AGI upon submission, and sample identity is recoded before forwarding to labs for genotyping. Genotype result files are re-matched with original animal identities at AGI, and that information is added to the genetic evaluation weekly. The unused portion of each sample is returned to AGI for long term storage and potential research use. The sample resource at AGI is currently close to 1 million samples.

With a staff of four in-house geneticists and extensive research partnerships, AGI conducts internal research with phenotypes and genotypes to develop better selection tools for members. Both AAA and AGI share information for research purposes with outside entities under the terms of data transfer agreements. Examples of recent research efforts include implementation of Single Step genomic evaluation, validation of genetic condition tests, investigations of genetic factors involved in heat and altitude tolerance, identification of sequencing candidates, and development of the Angus GSTM genomic profile test.

Big Data

John Genho, Livestock Genetic Services

We live in the era of big data. Every click of a mouse or swipe on a smartphone creates data that is tied to you as the user. A glance through recent events (Mark Zuckerberg's discussions on Capitol Hill and the serial killer case cracked with the use of 23 And Me to cite a couple) have shown that the ownership and use of that data is not always clear or as we expect it should be. This extends into the cattle industry. If there is no clear agreement, who owns a genotype sent to

a breed association? What of commercial entities that are building large databases and doing analysis independent of breed associations? Breeders and associations should be aware now more than ever of who owns data collected on their animals, and how that data will be used. In addition, they should create clear policies spelling this out to avoid problems in the future.

Panel Discussion: Who Owns the Data and Where Is It?

Larry Benyshek, Benyshek and Hough Consulting Services, Inc., Manhattan, Kansas

Historically, the beef industry has had significant debates concerning performance data after scientific investigation revealed the benefits of selection based on objective measurements. These debates took place at various venues; however, none more significant than those at the annual Beef Improvement Conferences. Breed associations, at first, debated the usefulness of collecting objective data since it was so different from the subjective evaluation used in the show ring and practiced by purebred cattle breeders. It was impossible for the subjective evaluation of cattle to stand up to the research results showing genetic change via selection based on objective performance records.

Once performance testing became conventional wisdom there were still issues of whether associations could use a breeder's data for the benefit of all association members and/or the cattle industry. The development of EPDs moved the industry into a new era of cattle breeding. The breed associations moved from protectors of the herd book of pedigrees to the major archives of objective cattle data for creating genetic values on which to base selection decisions.

Early on, some objected to the use of the data they personally collected being used for the common good of the breed. Association by-laws were amended to allow the use of recorded performance data to benefit all members and the cattle industry in general. The competitiveness of the industry prevailed, and every breed resolved to create the best genetic values possible for their breeders. This philosophy is embraced by today's registered cattle industry.

While the breed associations became the archives for performance data, early on they were not prepared to handle the complicated computations leading to EPDs. Several universities stepped up to help with the move to selection based on EPDs. This required a research effort which meant that the archived data of the associations was placed in the hands of another entity. This again sparked a good bit of discussion and debate at association board meeting. Universities were called on to explain the technology. Once the technology was in place university personnel were called on to explain changes in the evaluation from one year to

the next. Changes occurred since the data was accumulating at a fast pace and the analysis technics improved even faster. Of course, universities were never the owners of the data and it was fortunate that the industry had access to these arm's length entities which could objectively develop genetic evaluation.

Today, huge amounts of data are being collected throughout the industry. These data reside in a variety of databases held by private entities. These data can improve the competitiveness of entities in a segmented beef industry. Private concerns are now available to analyze data with sophisticated technology. These analyses are focused on more than just genetic improvement. The cattle industry has moved from a way of life to a business. A successful business cannot be sustained without data on which to make decisions.

In addition, the mapping of the bovine genome has resulted in the next generation of genetic evaluation procedures. Genomic testing results in large amounts of data which must be archived and brought into the evaluation process. Combining genomic data and performance data to compute genetic values is a milestone for the cattle industry. There may be questions of who owns the data; however, it is unquestionable as to the impact of these new technologies. Each improvement brings change, which requires explanation. Universities, breed associations and genomic testing companies all have major responsibilities to make sure the best analyses are available to the industry.

As genomic testing improves, it is possible that some entities will not share those values for the common good of the industry. Again, this is a competitive industry, and everyone is entitled to pursue ways to be competitive. Ownership of data may change in the future with private entities holding large amounts of data supporting their business decisions. It may become more difficult to access data necessary to promote the common good of the beef industry. Therefore, it is imperative that public sector research entities be adequately funded so research can be conducted that will make the general segmented industry competitive.

Genetic Improvement of Feed Efficiency in Beef Cattle

Miranda Culbertson, Department of Animal Sciences, Colorado State University

~ 2018 Baker/Cundiff Award Recipient ~

Introduction

In economic environments of rising feed costs, producers have become increasingly aware of the need to improve feed utilization in beef cattle. Traditionally, the beef industry had placed emphasis on improving output traits, such as fertility and live weight, to increase production profitability (Arthur et al., 2001; Hill, 2012) but the profitability of any agricultural production system is dependent on both output and inputs. As output traits (i.e. weight traits) are increased, there is a corresponding increase in input traits, such as feed (Meyer et al., 2008).

Feed costs are reported as the largest expense to producers in the beef industry accounting for 50 to 70% of total production costs (Anderson et al., 2005). It has been estimated that increasing performance (i.e. gain) by 10% would increase profits by 18%, this is compared to a 10% improvement of feed efficiency which has been estimated to increase profits by 43% (www.beefeconomy.org). The Alberta Agriculture and Rural Development (2006) reported that a 5% improvement in feed efficiency would have 4 times the economic effect of a 5% improvement in average daily gain. Therefore, decreasing feed costs without sacrificing animal performance could have a large impact on the profitability of a beef operation.

Due to the large influence of feed costs on production profits, interest in selecting for cattle that are more feed efficient has increased. However, there is a debate as to what is the best phenotype for feed efficiency in cattle, how to incorporate it into a breeding program or genetic evaluation, and what impacts selection on feed intake or efficiency would have on other performance traits (Berry and Pryce, 2013). This essay will evaluate and contrast the various measures of feed efficiency, as well as the incorporation of these phenotypes into breeding programs and genetic evaluations.

Literature Review

1. Measuring Feed Intake

The ability to measure feed efficiency in cattle is dependent on the capability to measure individual feed intake and the integrity of the individual dry matter intake (DMI) records (Hill, 2012). Traditional methods of measuring intake involved housing animals individually. The collection

of DMI on individually housed animals severely limited the number of animals that could be observed and thus limited the ability for estimation of reliable genetic parameters of DMI (Hill, 2012). Since the mid-1990's there have been advancements in technology that has led to a large increase in the measurement of DMI for group housed animals (Cruz et al., 2011; Hill, 2012, Arthur et al., 2014). Research facilities and performance-testing centers have been equipped with technology for the capability to measure individual feed intake on group housed animals (Hill, 2012). The technology to measure feed intake must be capable of identifying individual animals, weighing rations fed to the individual animal, associate the measured feed consumed to the appropriate animal and compile the data into a useable format (Dahlke et al., 2008). Measuring feed intake is expensive, time consuming and testing facilities have a limited capacity for the measurement of individual feed intake (Wang et al., 2006; Nielsen et al., 2013). These limitations restrict the number of animals that can be measured within a year and therefore limit the amount of data generated for genetic evaluations.

Currently, individual feed intake measurements are collected in feedlot environments and have a direct application to feedlot cattle. The translation of these feedlot-measured intakes to the cowherd grazing on rangeland is unknown. Approximately 50% of feed costs in the beef industry are attributed to the mature cow herd (Whisnant, USDA-NIFA-CRIS). To select for a cowherd that is more efficient in forage utilization, individual grazing intake needs to be measured. Currently there is no technology to effectively measure feed intake on a population of grazing cattle. Methods used for estimation of DMI for grazing animals lack precision and are often tedious, expensive and time-consuming (Undi et al., 2008). Current techniques for measuring grazing DMI typically involve digestive markers, group housed animals that measure herbage disappearance, or equations predicting DMI based on net energy requirements (NRC 2000; Meyer et al., 2008; Undi et al., 2008).

2. Phenotypic measurements of feed intake and efficiency

Efficiency is defined as a level of performance that uses the lowest amount of input to obtain the greatest level of

output. Efficiency can be described at a production level as the saleable output per unit input, weighted according to their relative economic importance (Berry and Crowley, 2013). Feed intake and feed efficiency are significant, contributing factors to the economic weights for production efficiency (Berry and Crowley, 2013; Hill 2012). Given that feed costs are the largest expense to producers, feed intake and efficiency have a direct economic relevance and are therefore an economically relevant trait (Nielsen et al., 2013). However, there is no definitive definition of feed efficiency in beef cattle and several alternative definitions and calculations for feed efficiency exist. Feed efficiency in beef cattle are typically described as either a ratio or residual trait (Berry and Crowley, 2013). In the context of genetic improvement, there is often a debate as to what is the best measure for feed efficiency, how to incorporate feed efficiency into a breeding program and what the impact of selection would do to other performance traits (Berry and Pryce, 2013; Nielsen et al., 2013).

2.2. Feed Intake

Dry matter feed intake (DMI) is the amount of feed an individual animal ingests on a dry matter basis. Since it is a direct measure of an animal's actual feed intake, it is easily accepted and understood by producers. Dry matter intake only measures the amount of feed consumed by an animal and gives no indication of the animal's performance for other production traits, such as average daily gain or body weight. As a result, DMI is not a measure of feed efficiency but is significant in the calculations of feed efficiency measurements (Berry and Pryce, 2013).

Dry matter intake is influenced by physiological factors such as body composition, frame score, physiological state and age. The extent of the influence of these factors on DMI in cattle are complex and not fully understood (NRC, 2000). As a result of the effect of physiological factors on DMI, DMI is correlated with performance traits (i.e. average daily gain) and increases as an animal's body size increases (NRC, 2000).

2.3. Feed Conversion Ratios

Traditional measures of feed efficiency in the beef industry are ratios of intake to production such as feed conversion ratio (FCR) and are commonly represented as:

$$FCR = \frac{\text{(Average Daily Gain)}}{\text{(Feed Intake)}}$$

Feed conversion ratios are the most commonly used measures for feed efficiency (Berry and Pryce, 2013) and are often referred to as gain to feed (G:F) or it's reciprocal feed to gain (F:G). These measures are widely used in production settings (Nielsen et al., 2013) where feedlots use pen averages for ADG and feed intake. Animals with higher

values for FCR are considered to be more efficient, but FCR do not account for the differences in maintenance efficiency among individual animals (Berry and Crowley, 2013).

Direct selection of ratios is difficult for genetic improvement (Gunsett, 1986; Berry and Crowley, 2013). Gunsett (1986) argued that "prediction of response to selection practiced to change a trait such as feed conversion assume that the trait has a normal distribution with some mean and variance. The fact that feed conversion is a ratio of two traits has made the ability to predict the change of the trait in future generations difficult." He contended that placing selection on the components that comprised the ratio would be more effective for improved feed efficiency. Using a simulated dataset, Gunsett (1986) was able to show that selection on the components of the trait (included in an index) led to more genetic change than direct selection on the ratio.

Although FCR are easy to calculate and easy for producers to understand, it is not an ideal measure of feed efficiency for the purposes of genetic improvement given the inherent problems with selection on ratios as the phenotype. This has led to the proposal of other traits for genetic improvement on feed efficiency, such as residual feed intake.

2.4. Residual Feed Intake

Koch et al. (1963) introduced the use of residual feed intake (RFI) as a measure of feed efficiency. The authors proposed that feed efficiency was not a directly measurable trait but must be calculated as a function of feed intake, an increase in body weight, and time. They concluded that efficiency expressed as gain adjusted for differences in feed consumption, or the deviation from the regression of gain on feed intake, was considered the most accurate mathematical description for feed efficiency. Since that body of work, the general definition of RFI has developed into the difference between the actual feed intake and the estimated feed intake adjusted for the requirements of production (Kennedy et al., 1993). A typical RFI equation for beef cattle would be:

$$RFI = DMI - (\beta_1 ADG + \beta_2 Fat + \beta_3 WT^{0.75})$$

where DMI is the individual animal's dry matter intake, ADG is an animal's average daily gain, Fat is the animal's ultrasound measurement for back fat, $WT^{0.75}$ is the metabolic mid-weight for an animal, and β_i is the regression coefficient for the corresponding trait. Metabolic mid-weight is estimated by taking the animal's weight at the midpoint of the test and raising it to the $\frac{3}{4}$ power and accounts for energy sinks when included in the model (Berry and Crowley, 2013).

Animals with positive RFI values would be considered inefficient as their feed intake was more than what was

expected given their level of performance. Negative RFI values would indicate animals that are deemed more efficient as their feed intake was less than what was expected given their level of performance. A property of RFI is its independence from the variables (i.e. ADG) included in the multiple regression model on a phenotypic level. This is an assumption for a multiple regression model and is therefore theoretical. Given that RFI are residual terms of the model, they are dependent on the variables included in the model. As more variables are included in the regression model, the risk of over parameterizing the model increases (Koch et al., 1963; Berry and Pryce, 2013).

An advantage to RFI is that it is a measure of feed efficiency since it accounts for the animal's level of production (Berry and Pryce, 2013). This is compared to DMI which only measures the amount of feed ingested by cattle and doesn't account for the animal's performance. An animal's intake will depend on the its level of performance, age and size (NRC, 2000). Larger cattle will have a higher DMI while DMI for smaller cattle will be lower. Selecting for cattle with lower DMI may inadvertently select for smaller cattle (Nielsen et al., 2013). Therefore, a measure of feed efficiency, such as RFI, would have to reduce DMI without sacrificing gain in body weight. The inclusion of ADG in the calculation of RFI accounts for an animal's performance in body weight gain and therefore, animals with negative RFI are maintaining a level of performance on less than expected feed.

There are several disadvantages to RFI for application in the beef industry. One disadvantage is that it can be conceptually difficult to explain to producers (Berry and Pryce, 2013). From a technical standpoint, the calculations for RFI would seem complex and difficult for some producers to understand. In addition, RFI can be counter intuitive. Negative RFI would be more desirable which may be problematic for producers to understand. An additional disadvantage is that RFI is susceptible to genetic by environment interactions and since RFI is a residual from a regression model, its actual value can only be compared to other animals that were included within the regression model (Berry and Crowley, 2013). In other words, a direct comparison of RFI values cannot be made across different tests or locations.

These disadvantages of RFI become problematic when trying to incorporate into a genetic evaluation. Contemporary grouping (CG) may be problematic due to varying conditions, such as differences in the equipment measuring feed intake or how the test was conducted resulting in differences in the reporting of DMI used for the calculation of RFI (Nielsen et al., 2013).

3. Genetic parameters of feed efficiency and intake

3.1. Heritability

Heritability is defined as the measure of strength of the relationship between breeding values (genetics) and performance and is an indication of the proportion of the differences observed for a trait in a population due to inheritance (Bourdon, 1997). Heritability is expressed as a ratio of variances:

$$h^2 = \frac{\sigma_{BV}^2}{\sigma_P^2}$$

where σ_{BV}^2 is the variance of breeding values and σ_P^2 is the phenotypic variance. For selection and genetic improvement, heritability is crucial for polygenetic traits, such as feed efficiency, since it is an indication of the relative importance of the combination of multiple genes contributing to the phenotype. Therefore, increases in heritability lead to an increase in response to selection.

Numerous studies have estimated heritabilities for feed efficiency (RFI and FCR) and DMI to quantify the genetic influence on these traits. A large range of heritabilities have been reported for all three traits. In growing cattle, the heritability estimates reported for DMI ranged from 0.06 ± 0.12 (Bishop et al., 1992) to 0.70 ± 0.11 (Inoue et al., 2001). Minimum heritability estimates for RFI and FCR in growing cattle were 0.07 ± 0.13 (Fan et al., 1995) and 0.06 ± 0.04 (Robinson and Oddy, 2004), respectively, with maximum estimates of 0.62 ± 0.14 for RFI (Archer et al., 1997) and 0.46 ± 0.04 for FCR (Bishop et al., 1992; Arthur et al., 2001). Heritability estimates on mature cows ranged from 0.02 ± 0.02 to 0.60 ± 0.14 for DMI (Fan et al., 1996a; Spurlock et al., 2012), 0.01 ± 0.05 to 0.38 for RFI (Vallimont et al., 1995; Veerkamp et al 1995), and 0.05 ± 0.01 to 0.32 ± 0.13 for FCR (Fan et al., 1996b; Spurlock et al., 2012).

Heritability estimates for mature cows were lower than estimates for growing animals, however, the number of studies are considerably smaller and indicative of the lack of knowledge for mature cattle (Berry and Crowley, 2013). The large range of heritabilities reported for feed efficiency (RFI and FCR) and DMI is not surprising considering the differences in RFI calculations and analyses that estimated the heritability. The majority of studies that presented heritabilities for both DMI and RFI, the heritabilities for DMI were higher than RFI. This would indicate that faster genetic improvement for DMI could be achieved when compared to RFI.

3.2. Genetic Correlations

Genetic correlation is defined as the relationship between breeding values of one trait and the breeding values of another trait (Bourdon, 1997). When traits are genetically

correlated, selection on one trait results in genetic change in another. The performance of one trait can be used to predict the performance of a genetically correlated trait.

In the context of feed efficiency and intake, understanding the relationship between genetically correlated traits is crucial for two primary reasons. First, there is a lack of knowledge on the effect of selection for feed efficiency on other performance traits, especially survival traits (i.e. health and reproduction). Second, measuring feed intake is expensive and time consuming in addition to a limitation to the availability of facilities to measure intake. The use of an indicator trait could help to mitigate the expense of measurement and enable the ability to measure a greater number of animals.

The opportunity to improve production efficiency is dependent on the magnitude of genetic correlations between DMI or feed efficiency to other production traits (Herd et al., 2003). In general, estimation of precise genetic correlations between feed efficiency or intake to production traits are generally not achievable due to relatively small datasets. This problem is exacerbated for genetic correlations between lowly heritable traits and feed efficiency or intake (Berry and Crowley, 2013; Berry and Pryce, 2013). Tables 1, 2, and 3 present genetic correlations of feed efficiency and feed intake to performance, carcass, mature cow and reproductive traits.

Genetic correlations between RFI and postweaning traits indicate that selection for lower RFI has the potential to reduce feed intake without a reduction in cattle size, therefore improving the efficiency of cattle (Herd et al., 2003). The association between RFI and reproduction traits are in general unfavorable. Crowley et al. (2011) found unfavorable genetic correlations with large standard errors for feed efficiency measures with age at first calving (-0.55 ± 0.14 for FCR and -0.29 ± 0.14 for RFI) but non-significant correlations for calving interval and calving to first service. Basarab et al. (2011) showed that the exclusion of ultrasound back fat when modeling RFI resulted in a significant difference in calving rates, but when ultrasound back fat was included in the model, there was no difference in the calving rates. Arthur et al. (2005) reported from a divergent selection of RFI experiment, a 5-d later calving date in cows with low RFI compared to high RFI cows. The effect of selection on feed efficiency and the correlated response to fertility and survival traits merit further research (Berry and Crowley, 2013). Additionally, the association of selection for reduced RFI and forage intake for mature, grazing cattle is unknown (Herd et al., 2003).

Genetic correlations between RFI and carcass traits lacked in consistency across studies and resulted in large standard errors. In general, animals with higher RFI values had improved carcass conformation (Berry and Crowley, 2013).

There is a tendency for RFI to be negatively correlated with carcass traits in beef cattle, indicating that as RFI decreases (improves), carcass merit also improves. There was a tendency for RFI and FCR to be positively correlated with fat in beef cattle, 0.08 ± 0.05 and 0.20 ± 0.04 respectively (Berry and Crowley, 2013). Few studies who have examined the genetic correlation between feed efficiency and meat quality. Genetic correlations between both RFI and FCR and meat fatty acid composition have been examined in Japanese Black steers. The correlations with RFI were zero and with FCR was -0.38 (C18:0 and C18:1) to 0.43 (C14:1) with standard errors of approximately 0.20 (Inoue et al., 2011; Berry and Crowley, 2013).

4. Genetic Improvement of Feed Efficiency and Intake

There is an ongoing debate on whether to include feed intake or RFI in a breeding objective (Berry and Pryce, 2013). However, reducing feed intake only should not be the goal of the breeding objective. Selection pressure should be placed on not reducing production or output traits while attempting to reduce feed intake (Nielsen et al., 2013). From the perspective of genetic improvement for feed efficiency, selection for feed efficiency can be accomplished through selection on a selection index including the traits for output (i.e. body weight) and input traits (i.e. DMI). Appropriately weighting the index traits for output as positive and input traits as negative, feed efficiency would not have to be explicitly be calculated (MacNeil et al, 2013; Nielsen et al., 2013). Berry and Crowley (2013) stated that genetic selection for improved efficiency of production could be achieved through a breeding goal of simultaneous selection for all traits that influence profitability rather than individual trait selection.

Efficiency measures, such as RFI, that are calculated from feed intake and performance traits, provide no additional information beyond the traits used to calculate the efficiency measures (Kennedy et al., 1993). Van der Werf (2004) stated that in growing animals, including all components of traits of RFI in a breeding objective or selection index is mathematically equivalent to including RFI assuming no fixed effects are included in the genetic evaluation model. Therefore, there was no additional benefit of including RFI (or any feed efficiency measure) in a breeding goal or selection index that already included the individual feed and production traits. In the context of national cattle evaluation (NCE), it was recommended to analyze feed intake. In order to increase accuracy of feed intake, known genetically correlated traits that were more easily obtained (i.e. post weaning weight) were suggested to be included in models for feed intake (Nielsen et al., 2013). Selection decisions for genetic improvement of feed efficiency should be based on genetic prediction from multi-trait genetic evaluations of feed intake (MacNeil et al., 2013; Nielsen et al., 2013).

Table 1. Genetic correlations between feed efficiency traits.

Traits ¹	DMI ²	FCR	Source
FCR	0.31 (0.07)		Arthur et al. (2001a)
FCR	-0.49 (0.22)		Robinson and Oddy (2004)
FCR	0.64 (0.07)		Arthur et al. (2001b)
FCR	-0.60 (0.18)		Rolfe et al. (2011)
RFI	0.69 (0.03)	0.66 (0.05)	Arthur et al. (2001a)
RFI	0.64 (0.16)	0.70 (0.22)	Herd and Bishop (2000)
RFI	0.43 (0.15)	0.41 (0.32)	Robinson and Oddy (2004)
RFI	0.79 (0.04)	0.85 (0.05)	Arthur et al. (2001b)
RFI	0.66 (0.12)		Rolfe et al. (2011)

¹FCR = Feed conversion ratio; RFI = Residual feed intake

²DMI = Dry Matter Feed intake

Table 2. Genetic correlations (S.E.) between feed efficiency and postweaning traits.

Trait ¹	DMI ²	FCR ³	RFI ⁴	Source
ADG	0.54 (0.06)	-0.62 (0.06)	-0.04 (0.08)	Arthur et al. (2001a)
ADG			0.09 (0.29)	Herd and Bishop (2000)
ADG	0.87 (0.05)	-0.86 (0.10)	0.09 (0.20)	Robinson and Oddy (2004)
ADG	0.39 (0.08)	-0.46 (0.08)	0.32 (0.10)	Arthur et al. (2001b)
ADG	0.56 (0.16)			Rolfe et al. (2011)
MMWT	0.65 (0.03)	-0.01 (0.07)	-0.06 (0.06)	Arthur et al. (2001a)
MMWT			0.22 (0.29)	Herd and Bishop (2000)
MMWT	0.76 (0.07)	-0.62 (0.18)	-0.20 (0.16)	Robinson and Oddy (2004)
MMWT	0.71 (0.11)			Rolfe et al. (2011)
LWT	0.83 (0.04)	0.24 (0.09)	-0.10 (0.13)	Arthur et al. (2001b)
200d WT	0.28 (0.15)	-0.21 (0.20)	-0.45 (0.17)	Arthur et al. (2001a)
200d WT			0.34 (0.34)	Herd and Bishop (2000)
400d WT	0.56 (0.09)	-0.09 (0.15)	-0.26 (0.13)	Arthur et al. (2001a)
400d WT			0.15 (0.28)	Herd and Bishop (2000)

¹ WT = weight; ADG = Average daily gain; MMWT = metabolic midweight (WT0.75); LWT = Live weight;

²DMI = Dry matter intake

³FCR = Feed conversion ratio of feed to gain

⁴RFI = Residual feed intake

Table 3. Genetic correlations between feed efficiency and carcass traits.

Trait ¹	DMI ²	FCR ³	RFI ⁴	Source
RIB	0.27 (0.05)	0.03 (0.06)	0.17 (0.05)	Arthur et al. (2001a)
RIB	0.61 (0.11)	0.38 (0.32)	0.48 (0.12)	Robinson and Oddy (2004)
P8	0.14 (0.05)	-0.04 (0.07)	0.06 (0.06)	Arthur et al. (2001a)
P8	0.59 (0.10)	0.40 (0.33)	0.72 (0.17)	Robinson and Oddy (2004)
LMA	0.43 (0.07)	-0.12 (0.11)	0.09 (0.09)	Arthur et al. (2001a)
LMA	0.23 (0.16)	0.20 (0.42)	-0.24 (0.26)	Robinson and Oddy (2004)
IMF%	0.39 (0.14)	0.08 (0.28)	0.22 (0.17)	Robinson and Oddy (2004)
LCC			-0.43 (0.23)	Herd and Bishop (2000)
CC	-0.07 (0.16)	0.12 (0.19)	-0.06 (0.17)	Crowley et al. (2011)
CF	0.02 (0.21)	0.15 (0.23)	0.19 (0.21)	Crowley et al. (2011)
CWT	0.16 (0.17)	0.29 (0.19)	-0.01 (0.17)	Crowley et al. (2011)

¹RIB = 12/13th rib fat depth; P8 = rump P8 fat depth; LMA = longissimus muscle area; LCC = lean carcass content; IMF% = intramuscular fat; CC = carcass conformation; CF = carcass confirmation; CWT = carcass weight.

²DMI = Dry matter intake

³FCR = Feed conversion ratio

⁴RFI = Residual feed intake

Estimating higher accuracies for selection of feed efficiency and intake has been the main obstacles for the implementation of feed efficiencies in breeding objectives (Berry and Pryce, 2013). The existing databases are generally too small for national genetic evaluations with the added problem of selection bias. Given the expense of measuring feed intake on cattle, producers tend to test their more elite animals. As a result, databases of recorded DMI may not be truly representative of the cattle population.

Conclusion

Feed intake and feed efficiency traits are important and economically relevant traits. Heritability estimates for DMI, RFI and FCR indicate that genetic improvement on these traits is possible. The incorporation of feed intake or efficiency into a breeding program should be considered to improve efficiency and profitability of an operation. However, the reduction of feed intake alone should not be the ultimate breeding objective. Simultaneous selection for all traits that influence profitability of an operation would improve efficiency.

There is a large body of research on the subject of feed intake and feed efficiency, however there are still gaps in knowledge. Few studies have examined feed efficiency and its correlation to cow performance or health traits. There is also a lack of knowledge on the robustness of feed reduction and how it affects feed efficient animals. Arguably, the largest gap in knowledge for feed intake is grazing intake on the mature cow herd. Considering that approximately 50% of feed costs in the beef industry are associated with the mature cow herd, for a beef operation to truly be efficient, selection for a cowherd that is more efficient for forage utilization must be accomplished. Continued research is needed to develop the technology to measure grazing intake and the explore the relationship between intake from grazing cattle and feed intake measured in a feedlot.

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Parent-of-origin Effects on Growth Related Traits in *Bos taurus indicus* x *Bos taurus taurus* Reciprocal Crosses

Jose S. Delgadillo Liberona

~ 2018 Baker/Cundiff Award Recipient ~

Introduction

The constant increase in the world's population goes by hand-in-hand with a sustainable increase in the global demand for quality food. Additionally, the increase in human population from developed countries has been historically associated with increases in food consumption per capita, and increased amounts of livestock products in the diet. This scenario holds true for developing countries today, and leads to the need for increased production and/or efficiency from livestock systems.

In the United States, the most important livestock industries correspond to cattle production, with large national economic impacts. Furthermore, the United States is the largest producer of beef products in the world, supplying a variety of products for domestic and external markets. Considering the expected increases of global demand for livestock products, beef production in the United States is under constant need for increasing production system efficiency.

Among the options to increase the efficiency of beef production systems is crossbreeding between *Bos taurus indicus* (Bi) and *Bos taurus taurus* (Bt) breeds. This type of cross makes it possible to utilize greater heterosis for economically relevant traits in beef cattle, in addition to advantages provided by Bi breeds, such as higher resistance to disease and parasites, and greater adaptation to tropical and subtropical climates. As a consequence, use of Brahman (Bi breed) and Brahman x Bt crosses has been key for cattle operations in the southern and southeastern regions of the United States, where the predominant subtropical climate could lead to the reduction in efficiency of purebred Bt or crosses between two or more Bt breeds.

However, several authors have reported differences in growth-related traits between Bi x Bt F1 reciprocal crosses, particularly where Bi-sired calves express higher birth weights, and a tendency to have higher weaning weights and yearling weights. Moreover, this pattern has also been observed among other Bi-Bt crosses when the sire had a higher amount of Bi influence in comparison to the amount of Bi in dam.

Additionally, sexual dimorphism has also been reported between the reciprocal F1 and backcrosses, where the difference in weights between male and female calves is

much greater in Bi-sired calves, as well as when the sire has a higher contribution of Bi to its genetic composition in relation to the dam.

Parent-of-origin effects, through genomic imprinting, have been proposed as a potential mechanism that could be explaining this peculiar phenomenon. However, further research is needed to fully uncover the genomic and molecular bases behind these reciprocal crosses differences.

Review of literature

World demand for livestock products

World population is under constant growth, as is world food demand and production. So far the growth rate of global food production has been faster than the rate of population growth, which should make possible to satisfy the food consumption needs of nearly everyone. However this has not being a reality because of many different factors, with poverty probably the most important cause. The Food and Agriculture Organization of the United Nations (FAO) has estimated that the human population could reach 9.15 billion by the year 2050 (Alexandratos and Bruinsma, 2012). This implies a challenge for agriculture in order to keep growing food production at rates that could satisfy the global increases in food demand.

Additionally, the increase in population and wealth in developed countries has been associated with increases in per capita food consumption and increased consumption of livestock products. This pattern can also be observed in developing countries, but the increase in consumption of livestock products will probably not be as strong as what occurred in western developed countries (Alexandratos and Bruinsma, 2012). Nevertheless, the estimated increase in population and in global demand for livestock products will produce a major impact in agriculture world-wide.

Cattle production in the United States

Among livestock products, cattle production represents one of the most important industries in the United States, ranking first in forecasted total cash receipts (USDA, 2016). Moreover, the United States' cattle industries correspond to the largest producer of beef in the world, with a variety of products for both domestic and external markets (USDA, 2018).

The beef industry in the United States can be divided into two major production sectors, cow-calf operations and cattle feeding. On one hand, cow-calf operations are present across the United States, taking advantage of land not suitable or needed for crop production. Furthermore, the efficiency of beef cattle in these operations is highly influenced by the pasture and climatic conditions. On the other hand, cattle feedlots are mostly located in the Great Plains, having also an important role in parts of the Corn Belt, Southwest, and Pacific Northwest. Beef cattle in these operations are developed with the final goal of producing high quality beef. For this reason, these operations make use of grain-based diets and other concentrates for about 140 days (USDA, 2018). As a consequence, this sector can be highly influenced by fluctuations in grain and livestock prices and supply.

Despite this division into sectors, currently the beef industry have shown a marked shift into vertical integration of cow-calf operations, specialized feedlots and processing sectors in order to secure the production of high quality beef (USDA, 2018).

Genotype-environment interactions

The efficiency and profitability of a beef cattle operation are under the control of several factors, such as feeding strategies, supply prices, environmental conditions, and cattle breed(s) used. The last two factors are directly related through genotype-environment interactions, where animals from a same breed raised under different environments could experiment a differential expression of their genetic potential, leading to differences in their phenotypic performance (Butts et al., 1971; Souza et al., 2005). Therefore, to select an adequate breed or animal type to be used in a specific environment is key to increase the efficiency of the system.

Classification of cattle breeds

Overall, cattle breeds used in productive systems belong to the *Bos* genus, either to the *Bos taurus taurus* (Bt) or *Bos taurus indicus* (Bi) sub-species. Breeds from these two sub-species present particular characteristics that make them more or less efficient depending on the environment where they will be raised, in addition to the market to which the final products are targeted. On one hand, Bt breeds correspond to non-humped breeds originated from Middle East domestication events (Herring, 2014). Breeds from this group are characterized by favorable carcass attributes such as marbling, tenderness and yield, in addition to improved production in temperate climates (Prado et al., 2008). On the other hand, Bi breeds had their origin in Asia and Africa, and its members present a characteristic hump in the shoulder or neck regions. Furthermore, members of the Bi group share an increased parasite and disease resistance, as

well as higher tolerance to heat, improving their productive performance in tropical and subtropical climates (Whipple et al., 1990; Jonsson, 2006; Amen et al., 2007; Prado et al., 2008; Herring, 2014).

Influence of *Bos taurus indicus* breeds in the United States

Breeds from both cattle sub-species are currently used in the United States, with Brahman the main Bi breed used in beef operations. The American Brahman breed has its origin in Zebu cattle from four Asian cattle breeds (Sanders, 1980) widely used in Brazil as well as in other tropical and subtropical countries due to a better adaptation to those climates (Whipple et al., 1990; Jenkins and Ferrell, 2004; Calegare et al., 2009). For this reason, the inclusion of Brahman and Brahman-influenced crossbreds have had a major impact in the breeding systems of Southern and Southeastern regions of the United States, where the predominant climate correspond to subtropical (Dillon et al., 2015). Moreover, crossbreeding between Brahman and Bt breeds has also allowed to harvest the benefits of parasite resistance, and increase female fertility and longevity (Cartwright, 1980; Franke, 1980; Turner, 1980; Olson et al., 1990; Riley et al., 2001).

Heterosis benefits and concerns

Due to the different domestications events that lead to the formation of the Bi and Bt breeds, crossbreeding between breeds from these two groups have been widely used to harvest a greater heterosis effect over economically relevant traits for the beef industry (Riley et al., 2007), with female fertility and longevity among the most important traits favored by heterosis in Bi-Bt crossbred dams (Koger, 1980; Olson et al., 1990; Riley et al., 2001).

However, the effects of heterosis are not equally beneficial for all traits, and for some of them can have detrimental effects. This can be observed for traits such as birth weight, where higher weights due to heterosis are associated to higher incidence of dystocia, which have a negative impact over dam and calf's health, or even risking the survival of both (Dillon et al., 2015).

Reciprocal crosses differences for growth and carcass related traits

The increase in birth weight due to heterosis has shown to be unequal depending on the type of cross between Bi and Bt breeds, specifically depending on which breed is utilized as the sire or as the dam. Ellis et al. (1965) reported that F₁ Brahman (Bi) x Hereford (Bt) calves (sire x dam) expressed birth weights 8.9 kg greater than the calves out of the reciprocal cross (Hereford sires x Brahman dams). Additionally, F₁ Bi x Bt calves have shown to be heavier at birth than calves produced by the cross between two

Bt breeds. This has been observed between calves out of Brahman x Angus (Bt) and Senepol (Bt) x Angus crosses, where in average F₁ Brahman x Angus calves were 3 kg heavier at birth than F₁ Senepol x Angus calves (Chase et al., 2000). These results are similar to those of Holloway et al. (2002), where F₁ Brahman x Angus calves had an average birth weight 4.7 kg heavier than F₁ Senepol x Angus calves. Following the same trend, Paschal et al. (1991) found that birth weights of F₁ Gray Brahman (Bi) x Hereford calves, F₁ Red Brahman (Bi) x Hereford calves, and F₁ Nellore (Bi) x Hereford calves were higher than birth weights of F₁ Angus x Hereford calves by 5.3 kg, 5.6 kg, and 4.9 kg, respectively. Moreover, this pattern has also been reported in studies evaluating other Bi-Bt crossbred animals where the sire had a higher influence of Bi in its genetic composition in relation to the amount of Bi in the dam (Amen et al., 2007).

Additionally, a peculiarity has been observed regarding sexual dimorphism of calves out of the Bi x Bt cross, where this cross has much larger birth weight of male calves than female calves; this sex difference is much greater than what is observed for calves out of the reciprocal cross (Bt x Bi), and either Bt x Bt or Bi x Bi crosses (Long and Gregory, 1974; Holloway et al., 2002; Riley et al., 2007; Bazzi, 2011; Fuad et al., 2014; Dillon et al., 2015). Riley et al. (2007) reported birth weight differences for males and female calves out of crosses involving Angus, Romosinuano (tropically adapted Bt), or Brahman, with Brahman x Angus calves expressing the greatest sexual dimorphism (5.7 kg) in comparison to Brahman x Brahman calves (2.5 kg), Angus x Angus calves (1.8 kg), Angus x Brahman calves (-0.8 kg, females heavier than males), Romosinuano x Angus calves (2.2 kg), and Angus x Romosinuano calves (1.7 kg). The same pattern can be seen in results reported by Dillon et al. (2015), where male calves out of the Brahman x Simmental cross were 5 kg heavier at birth in comparison to female calves; however, within the reciprocal cross the sexual dimorphism was much lower, being the females calves slightly heavier than male calves at birth (0.7 kg). In addition, the difference in birth weight between male and female Bi x Bt calves is much higher than the one reported for some Bi breeds, such as Sistani (1.9 kg; Bazzi, 2011), and Kedah-Kelantan (0.77 kg; Fuad et al., 2014).

Besides birth weight, additional traits have shown a trend to present differences when evaluated in calves out of Bi x Bt reciprocal backcrosses. This has been reported by Amen et al. (2007), who used information from the backcross between F₁ Angus x Bi (Brahman or Nellore) sires and dams to Angus, and Bi animals, in order to assess the reciprocal backcross effects over weaning weight, carcass weight, longissimus muscle area, fat thickness, intramuscular fat, and tenderness. This experiment concluded that backcross animals whose sire had a greater percentage of Bi in comparison to the dam (F₁-Angus and Bi-F₁ animals),

tend to be heavier at weaning, as well as present heavier carcasses than the reciprocal crosses (Angus-F₁ and F₁-Bi animals), however these differences were not statistically significant. Moreover, no trend was observed between reciprocal crosses for longissimus muscle area, intramuscular fat, and tenderness.

The trend described for weaning weight has also been reported by other authors, finding significant differences between reciprocal crosses. Among these authors, Thallman et al. (1993) found that Brahman x Simmental calves are heavier at weaning than Simmental x Brahman calves. Furthermore, this pattern also could be observed for yearling weight. Moreover, the difference found for yearling weight is consistent with results of previous studies that evaluated Brahman x Angus reciprocal crosses with a difference of 18.7 kg (Brown et al., 1993).

In addition, studies performed in Brahman x Romosinuano, and Brahman x Angus reciprocal crosses indicated that weaning weight differences between male and female calves result higher for the Brahman-sired calves. On one hand, the difference for Brahman x Romosinuano calves corresponded to 17.3 kg, and for Romosinuano x Brahman calves corresponded just to 6.3 kg. On the other hand, for Brahman x Angus calves the difference was 17.4 kg, and for Angus x Brahman calves 11.2 kg (Riley et al., 2007).

Gestation length also has shown to be longer for calves out of crosses between Bi sires and Bt dams, in comparison to the one observed for calves out of Bt x Bi crosses (Paschal et al., 1991; Thallman et al., 1993). Gestation length seems to follow the same pattern observed for other traits, increasing according to the higher percentage of Bi in the sire breed in comparison to the dam (Amen et al., 2007).

Potential parent-of-origin effects over reciprocal crosses differences

At the beginning, all the differences observed between Bi x Bt reciprocal crosses were thought to be a consequence of maternal effects over calf growth, or at least being highly influenced by them; however, additional research using embryo transfer calves out of recipient dams with an equal genetic composition have shown that the differences between the reciprocal crosses are consistent with what has been reported previously (Amen et al., 2007; Dillon et al., 2015).

Clearly, the behavior of some growth-related traits and gestation length in Bi x Bt reciprocal crosses does not follow the classical Mendelian inheritance pattern associated to quantitative genetics (Thallman et al., 2014), where the expectation would be to have a similar phenotypic expression for these traits in animals sharing the same genetic composition and subjected to similar environmental effects. Among the possible explanations to the phenotypic

differences observed between these heterozygotes with an equal genetic contribution from both paternal breeds, there is the hypothesis of a differential expression of some alleles depending if they have been inherited from the male or female parent, phenomenon known as parent-of-origin effect (Loschiavo et al., 2007; Vrana, 2007). As a consequence, this phenomenon generates a deviation from the expected expression patterns under the classical Mendelian inheritance model (Vrana, 2007). Furthermore, this type of differential allele expression is under genomic imprinting control, where epigenetic modifications in the DNA can trigger the complete or partial silencing of specific alleles. The main type of epigenetic modifications influencing gene expression correspond to DNA methylation and Histone acetylation and methylation (Reik and Walter, 2001; Li, 2002; Vrana, 2007; Shorter et al., 2012). Among them, the modification that has proved to have a major impact over gene expression corresponds to DNA methylations, specifically methylation of cytosine residues in gene promotor regions, reducing or preventing the coupling of transcription factors to those promotor regions (Vrana, 2007; Shorter et al., 2012).

Moreover, it has been observed in different livestock species that the main traits under parent-of-origin control, through genomic imprinting, are those associated to growth, development and behavior (Reik et al., 2003; Kim et al., 2007; Vrana, 2007; Imumorin et al., 2011), which results consistent with the observed differences in growth related traits and gestation length between Bi x Bt reciprocal crosses.

Genomic findings associated to parent-of-origin effects in cattle

In dairy cattle, studies performed with German Holstein detected the presence of dominance and parent-of-origin effects in a QTL associated to the bovine acylCoA-diacylglycerol-acyltransferase I (DGAT I) gene, where haplotypes involving the presence of the VNTR polymorphism in the promotor region and the non-conservative mutation K232A in DGAT I were associated to a significant higher milk yield and lower milk fat content, with a non-significant trend to higher protein yield when the haplotype was inherited paternally (Kuehn et al., 2007).

In beef cattle, Imumorin et al. (2011) found QTL under parent-of-origin control for different growth and carcass traits in an Angus-Brahman crossbred population. To assess the genomic location of QTL a total of 257 genetic markers, mainly microsatellites, were used. Eleven QTL under parent-of-origin control were detected to influence growth related traits, and 6 for carcass traits, where paternal, maternal or partial expression was concluded. However, the use alternative genomic markers such as single nucleotide polymorphisms (SNP), would provide a wider representation

of the genome and, as a consequence, a more precise detection of QTL influencing these traits.

Genomic findings associated to parent-of-origin effects in non-cattle livestock species

In swine, Kim et al. (2007) detected QTL under parent-of-origin control and under Mendelian expression in a cross between Korean native pig and Landrace. Among the detected QTL under parent-of-origin control at 5% genome-wide level, one QTL was only paternally expressed and associated to birth weight, two QTL were only maternally expressed and associated to leather weight and front leg weight, and three QTL were partially expressed for hot carcass weight, rear leg weight and bone weight.

Studies in reciprocal crosses between two chicken lines have found 4 significant and 3 highly suggestive parent-of-origin specific QTL affecting age at first egg, egg weight, number of eggs, body weight, feed intake and egg white quantity, where one significant QTL and one highly suggestive were only expressed when inherited from the father, and the rest when inherited from the female parent (Tuiskula-Haavisto et al., 2004). Rowe et al. (2009) also investigated the presence of parent-of-origin QTL and dominant QTL within a commercial Broiler line in 3 candidate regions in chromosome 1, 4 and 5. Their analyses provided suggestive evidence for a QTL under maternal expression associated with bodyweight and conformation score. Moreover, these results present evidence against the previous paradigm indicating that imprinting and, therefore, parent-of-origin effects correspond to phenomena present only in mammalian species (McGrath and Solter, 1984; Khatib, 2007).

Additional questions to answer

Is well known that growth-related traits in beef cattle are genetically correlated, where genetic correlations between birth weight and weaning weight, birth weight and yearling weight, and between weaning weight and yearling weight range from 0.37 to 0.71, 0.48 to 0.69, and 0.88 to 0.97, respectively (Bourdon and Brinks, 1982; Meyer et al., 1993; Kaps et al., 2000; Koch et al., 2004). Nevertheless, no studies have evaluated correlations in regard to the parent-of-origin effects influencing the variability of these traits. The latest is very intriguing considering results from human studies that have found an effect of aging and environment on methylations patterns (Bird, 2002; Christensen et al., 2009), which could produce different patterns of relationships between growth-related traits in comparison to what has been observed by analyzing the additive genetic component of the animals through classical Mendelian models.

Finally, detection of QTL under parent-of-origin control using high density genome markers, and estimation of correlations among parent-of-origin effects across time

for growth related traits in Bi x Bt reciprocal crosses, could provide important information in regard to epigenetic controls and dynamics influencing economically relevant traits in beef cattle. Moreover, this information could be useful to improve the current selection criteria and breeding strategies for operations using Bi x Bt crossbreeding.

Conclusions and implications to genetic improvement of beef cattle

In order to respond to the growing demand of food in the world, specifically for beef products, cattle systems need to either increase the number of animals or increase the efficiency of their production. Between these alternatives, the increase in efficiency appears to be the more sustainable option considering the limited additional land available for increasing the number of animals in the livestock systems.

The Southern and Southeastern regions of the United States, as well as countries with tropical or subtropical climates, can take advantage of crossbreeding between Bi and Bt breeds in order to improve the efficiency of their cattle operations, particularly regarding female fertility and longevity.

The existence of Bi x Bt reciprocal crosses differences for economically relevant traits in beef cattle, makes impossible for current quantitative or genomic enhanced prediction methods to obtain accurate genetic merit predictions for the sires and dams used in these reciprocal crosses, as well as for the offspring out of each reciprocal cross.

To improve the genetic merit prediction for crossbreeding programs involving Bi x Bt reciprocal crosses, fundamental understanding of genomic and molecular bases behind this phenomenon is needed. Furthermore, if the phenomenon could be explained by parent-of-origin effects, then the incorporation of these effects into genetic prediction models could make possible to retrieve specific breeding values for an animal as a sire or as a dam, accounting for the inheritance of genes through the paternal or maternal lineage. Therefore, improving the prediction of breeding values for animals used in Bi x Bt reciprocal crossbreeding systems, is needed to have a more controlled and precise genetic improvement, as well as a more efficient system in the long term.

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dbrown@rabrownranch.com

Vice President

Lee Leachman (west)

Leachman Cattle of Colorado
2056 West CR70
Fort Collins, Colo. 80524
970-568-3983 (O)
970-219-8519 (C)
lee@leachman.com

*Executive Director

Jane Parish

North Mississippi Research and
Extension Center
5421 Hwy 145 S. | Box 1690
Verona, Miss. 38879
662-566-8000 (O)
662-566-4969 (F)
662-312-7285 (C)
j.parish@msstate.edu

*Regional Secretary

(West) & NBCEC

Representative

Mark Enns

Campus Delivery #1171
Dept. of Animal Sciences
Colorado State University
Fort Collins, Colo. 80523-1171
970-491-2722 (O)
970-491-5326 (F)
mark.enns@colostate.edu

*Regional Secretary (East)

Darrh Bullock

University of Kentucky
807 W.P. Garrigus Building
Lexington, Ky. 40546
859-257-7514 (O)
859-699-8558 (C)
dbullock@uky.edu

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(Central)

Bob Weaver

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

*Historian

Robert Williams

Cain Cattle Company
1479 Stockyard
Pickens, Miss. 39090
816-519-1179 (C)
rwilliams@caincattle.com

Cattle Breed Registry Association Reps

Joe Epperly

North American Limousin Foundation
6 Inverness Court East, Suite 260
Englewood, Colo. 80112
303-220-1693 (O)
303-220-1884 (F)
303-884-3900 (C)
joe@nalf.org

Lauren Hyde

American Simmental Association
1 Genetics Way
Bozeman, Mont. 59718
303-717-0216 (O/C)
lhylde@simmgene.com

Dan Moser

American Angus Association
3201 Frederick Avenue
St. Joseph, Mo. 64506
816-383-5196 (O)
816-261-1490 (C)
dMoser@angus.org

Tommy Perkins

International Brangus Breeders
Association
P.O. Box 809
Adkins, Texas 78101
210-696-8231 (O)
417-860-6757 (C)
tperkins@gobrangus.com

Jack Ward

American Hereford Association
P.O. Box 014059
Kansas City, Mo. 64101
816-842-3757 (O)
816-842-6931 (F)
jward@hereford.org

Kari White

American Gelbvieh Association
350 Interlocken Blvd, Suite #200
Broomfield, Colo. 80021
719-469-8923 (C)
kario@gelbvieh.org

State or Provincial BCIA Producer Reps

Lex Carter (west)

Carter Cattle Company
907 South 1500 West
Pingree, Idaho 83262
208-681-9711 (C)
208-684-3378 (O)
lcarter@stgen.com

Tommy Clark (east)

C Squared Cattle Company
14236 Cattle Drive
Culpeper, Va. 22701
540-825-8578 (O)
540-937-0029 (C)
cattleclark@gmail.com

John Genho (east)

4432 Sperryville Pike
Woodville, Va. 22749
540-987-3385 (O)
540-522-6014 (C)
jgenho@livestockgenetics.com

Joe Mushrush (central)

Mushrush Red Angus
2346B N Road
Strong City, Kan. 66849
620-273-8581
620-340-7461 (C)
redcows@mushrushredangus.com

Matt Perrier (at-large)

Dalebanks Angus Ranch
1823 G50 Road
Eureka, Kan. 67045
620-583-4305 (C)
mattperrier@dalebanks.com

Marty Ropp (central)

Allied Genetic Resources
2245 Ropp Road
Normal, Ill. 61761
406-581-7835 (O)
mropp@alliedgeneticresources.com
Also serves as *Past President

Others

NCBA Representative

Josh White

National Cattlemen's Beef
Association
9110 East Nichols Ave., Suite 300
Centennial, Colo. 80134
303-850-3379
720-476-0023 (C)
jwhite@beef.org

NAAB Representative

Jared Murnin

Origen, Inc.
10 W Arrow Creek Road
Huntley, Mont. 59037
406-321-1542 (C)
jaredm@ORigen-beef.com

*Canadian Beef Breeds

Council Rep

David Bolduc

Canadian Beef Breeds Council
320, 6715 – 8 Street N.E
Calgary, Alberta T2E 7H7
Canada
403-730-0350 (O)
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403-625-0499 (C)
cudlobe@platinum.ca

Liaisons

*USDA Extension Service

Megan Rolf

Kansas State University
252 Weber Hall
Manhattan, Kan. 66506
785-532-1450 (O)
785-317-6364 (C)
megrolf@ksu.edu

*USDA Ag Research

Service

Mark Thallman

U.S. Meat Animal Research Center
P.O. Box 166
Clay Center, Neb. 68933-0000
402-762-4261 (O)
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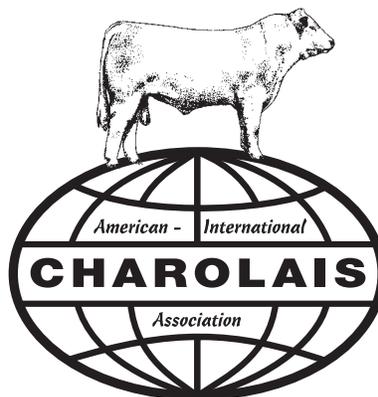
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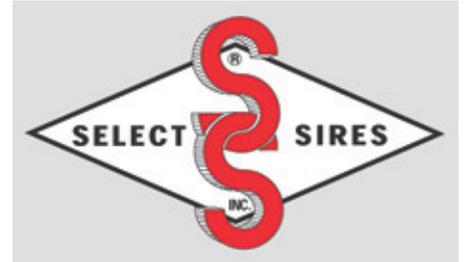
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