PROCEEDINGS

Beef Improvement Federation 34th Annual Research Symposium and Annual Meeting

July 10-13, 2002
Holiday Inn Central
Omaha, Nebraska

Hosted By:

Nebraska Cattlemen

University of Nebraska Lincoln

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Darrh Bullock
804 W.P. Garrigus Building 0215
University of Kentucky
Lexington, KY 40506
859-257-7514 (O)
859-257-3412 (F)
dbullock@ca.uky.edu

Chris Christensen
37548 221 Street
Wessington Springs, SD 54382
605-539-9522
chrishei@dtgnet.com

John Crouch
American Angus Association
3201 Frederick Blvd.
St. Joseph, MO 64506
816-383-5100 (O)
816-233-9703 (F)
jcrouch@angus.org

Larry Cundiff
RLHUSMARC
P.O. Box 166
Clay Center, NE 68933
402-762-4171 (O)
402-762-4173 (F)
cundiff@email.marc.usda.gov

Sally Dolezal
621 Bent Tree Ct.
Derby, KS 67037
316-788-5212 (H,F)
316-250-6168 (C)
sdolezal@cox.net

Sherry Doubet
AM. Salers Assn.
7383 S. Alton Way #103
Englewood, CO 80112
303-770-9292 (O)
303-770-9302 (F)
amsalers@aol.com

S.R. Evans, Jr.
1604 Leflore Ave
Greenwood, MS 38930
662-453-5317 (H)
662-453-0532 (O)
662-453-3079 (F)
wcdoc@bellsouth.net

Galen Fink
7101 Anderson Ave.
Manhattan, KS 66503
785-776-9385 (O)
785-776-9385 (F)
finkbull@flinthills.com

Doug Frank
ABS Global
1525 River Road
P.O. Box 459
De Forest, WI 53532
608-846-6252
dfrank@absglobal.com

Ronnie Green
Future Beef Operations, LLC
19751 East Mainstreet
Suite 325
Parker, CO 80138
303-209-1866 (o)
303-570-9286 (c)
303-209-1845 (F)
rgreen@futurebeef.com

Jimmy Holliman
105 County Rd 944
Marion Junction, AL 36759
334-872-8530 (H)
334-872-7878 (O)
334-872-2013 (F)
jhollima@acesag.auburn.edu

Robert Hough
Red Angus Assn. Of America
4201 North I-35
Denton, TX 762073415
940-387-3502 (O)
940-383-4036 (F)
bob@bigred2.redangus1.org

Craig Huffhines
American Hereford Association
1501 Wyandotle
Kansas City, MO 64108
816-842-3757 (O)
816-842-6931 (F)
chuffhin@hereford.org

Loren Jackson
International Brangus Breeders
P.O. Box 696020
San Antonio, TX 78269
210-696-4343
210-696-8718
lorenj@int-brangus.org

Renee Lloyd
NCBA
5420 S. Quebec St.
Englewood, CO 80155
303-850-3373
303-770-7109
rlloyd@beef.org

Richard McClung (Vice-President)
13789 N. Valley Pike
New Market, VA 22844
540-896-5232 (H)
896-6545 (O)
540-896-6049 (F)

Herb McLane
Canadian Beef Breeds Council
210 6715 8th St. NE
Calgary Alberta, Canada T2E7H7
403-730-0350 (O)
403-275-8490 (F)
cbbc@cadvision.com

Terry O=Neill
P.O. Box 30435
Billings, MT 59109
406-373-6016 (O)
406-373-6048 (F)
tomahawk@mcn.net

Lynn Pelton
Simmental/Red Angus
HC 2, Box 41
Burdett, KS 67523
316-525-6632 (O)
316-525-6413 (F)
lspelton@GBTA.net

John Pollak
Cornell University
B 47 Morrison Hall
Ithaca, NY 14853
607-255-2846
EJP6@cornell.edu

Connee Quinn (President)
HC 66 /Box 16
Chadron, NE 69337
605-867-1071 (H)
605-867-1071 (F)
crq@lilly.com

Lora Rose
564 Geesaman Rd.
Colville, WA 99114
509-684-5690 (O)
509-685-9366 (F)
lrose@plix.com

Ronnie Silcox
Animal & Dairy Science
University of Georgia
Athens, GA 30602
706-542-9102 (O)
706-613-5979 (H)
706-542-9316 (F)
rsilcox@arches.uga.edu

Bob Weaber
American Simmental Association
B 47 Morrison Hall
Cornell University
Ithaca, NY 14853
607-255-2410 (O)
607-254-5413 (F)
rlw26@cornell.edu

Robert Williams
American Int=l Charolais Assn.
11700 N. W. Plaza Circle
P.O. Box 20247
Kansas City, MO 64195
816-464-5977 (O)
816-464-5759 (F)
robertw@charolaisusa.com

2002 Beef Improvement Federation
Holiday Inn Central I-80
34th Annual Meeting
Omaha, Nebraska
July 10-13, 2002

Wednesday, July 10, 2002

12:00 . Board of Directors Luncheon and Meeting

5:00 p.m. Nebraska Welcome Reception

7:30 p.m. Symposium Honoring Gordon E. Dickerson
Moderator: Jim Gosey, University of Nebraska, Lincoln

Defining Biological Efficiency of Beef Production
Dave Notter, Virginia Tech

Defining Economic Efficiency of Beef Production
Mike Tess, Montana State University

Words of Encouragement – What Would G.E.D. say to BIF Today?
Ronnie Green, Future Beef Operations

Thursday, July 11, 2002

8:00 a.m. Measuring Beef Cattle Efficiency
Moderator: Daryl Strohbehn, Iowa State University

Beef Cow Efficiency
Tom Jenkins, USMARC

Postweaning Efficiency of Beef Cattle
Danny Fox, Cornell University

9:45-10:15 a.m. Break

10:15 a.m. Measuring Cow-Calf Profitability
Barry Dunn, South Dakota State University

11:00 a.m. Question and Answer Session

"Designated Catalysts"
Dave Nichols, Angus breeder, Bridgewater, Iowa

Harlan Ritchie, Professor, Michigan State University, East Lansing, Michigan

Burke Teichert, Rex Ranches, Ashby, Nebraska

12:00 BIF Recognition Luncheon

2:00-5:00 p.m. Round Table Discussions

Emerging Technology
Chair, Ronnie Green, Future Beef

Multiple Trait Selection
Chair, Darrh Bullock, University of Kentucky

Live Animal, Carcass, and Endpoint
Chair, Robert Williams, American International Charolais Assoc.

6:30 p.m. Nebraska Hospitality Steak Fry
Strategic Air and Space Museum
Buses leave Holiday Inn – 6:00 p.m.

Friday, July 12, 2002

8:00 a.m. Predicting Beef Cattle Efficiency
Moderator: Robert Williams
American International Charolais Association

Genetic Prediction of Cow Efficiency
John Evans, Oklahoma State University

Multi-trait Prediction of Feed Conversion
William Herring, University of Florida

9:30-10:00 a.m. Break

Genetic Prediction of Efficiency in the Future
David Johnston, Australian Perspective
Animal Genetics Breeding Unit
University of New England, Armidale, Australia

John Pollak, United States Perspective
Cornell University

11:00 a.m. Question and Answer Session

"Designated Catalysts"
Donnell Brown, R.A. Brown Ranch
Throckmorton, Texas

Jerry Lipsey, Executive Vice-President
American Simmental Association, Bozeman, Montana

Lee Leachman, CEO, Leachman Cattle Company
Billings, Montana

12:00 BIF Awards Luncheon

2:00-5:00 p.m. Round Table Discussions

Genetic Prediction
Chair, Larry Cundiff, USMARC

Producer Applications
Chair, Sally Dolezal, Beef Industry Consultant

Whole Herd Analysis
Chair, Robert Hough, Red Angus Association of America

Night on the Town - *Dinner on your own*

Saturday, July 13, 2002

6:30 a.m.-7:00 p.m.

Nebraska Beef Industry Tour

Circle Five Feedyard - Henderson
Alan Janzen

U.S. Meat Animal Research Center - Clay Center
Steve Kappes & Larry Cundiff

Wagonhammer Ranches - Albion and Bartlett
Jay Wolf

TABLE OF CONTENTS

34TH Beef Improvement Federation
Symposium

Dedicated to

Gordon Edwin Dickerson

January 30, 1912 LaGrande, Oregon

August 27, 2000 Lincoln, Nebraska

GORDON EDWIN DICKERSON, 1912 – 2000: A BRIEF BIOGRAPHY[1]

L. D. Van Vleck[2] and L. V. Cundiff[3]
ARS, USDA, Roman L. Hruska U.S. Meat Animal Research Center
[2]Lincoln and [3]Clay Center, NE

An early leader in use of principles of quantitative animal genetics for livestock improvement was born in Lagrande, Oregon on January 30, 1912. That first son (of 8 children), Gordon Edwin Dickerson, moved with his parents back to Bloomingdale, Michigan in 1915. As Gordon stated, he loved growing up on their farm. In the eighth grade, he met Myra Warren (a ninth grader who was 14 days older). Those high school sweethearts were married just after Gordon's graduation in 1933 from Michigan State College. They were truly partners for the next 67 years. Three of their four sons were born in Madison, Wisconsin, where Gordon did graduate work in animal genetics with L. J. Cole and also served as an instructor in dairy science. The fourth son was born in Ames, Iowa.

Gordon's academic ability, creativity, and attention to detail were apparent in East Lansing where he graduated *cum laude* with a double major in Dairy Husbandry and Chemistry. His "senior" thesis, which involved fat secretion in the udder of dairy cows was the first written work that exhibited Gordon's life-long principle of obtaining the most possible information from each experiment or set of data.

Gordon's Ph.D. thesis (1937) at Wisconsin, which was an early analysis of DHIA data with what would now be considered primitive computing equipment, showed the same thoroughness and attention to detail. There he also began a life-long professional and close personal friendship with A. B. Chapman. As a Cole student, he worked through the early papers of Jay Lush and Sewall Wright and thoroughly absorbed the methods of path coefficient analysis, which he applied throughout his professional career of 50+ years. His work in the dairy department was primarily with DHIA data, which became the basis for the national dairy sire summary.

In 1947, "Gord" as he was known by Myra ("Dick" by his other peers) and Myra moved to Ames where Gordon (as most of us later knew him) began his first tour as a research geneticist with the USDA at the Regional Swine Breeding Laboratory directed by W. A. Craft, an earlier Ph.D. with Cole. In Ames during that period were many of the leaders in "modern" animal breeding including Jay Lush, Lanoy Hazel, Charles Henderson, and as a visitor, Alan Robertson, among many others who have distinguished themselves. Gordon was certainly a member of that "elite" group, although he would never have admitted or thought that. Somewhat surprisingly, Henderson, Hazel, and Dickerson were born in the 10-month period from April 1, 1911 (Henderson) to January 30, 1912.

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[1]Printed with permission of the Journal of Animal Science, Biographical Sketch Section, http://www.asas.org.

At the swine lab, some of Gordon's most remarkable papers were published. One paper described techniques, which are still used today, for analysis of designs for testing inbred lines. A most important paper with Hazel established the basic formulae for predicting genetic progress from selection taking into proper account accuracy of selection, intensity of selection, and generation interval for both males and females (with dairy cattle, the formula is expanded to four selection paths).

Gordon's path and his positive and stimulating influence on the paths of many colleagues moved to the University of Missouri in 1947 where he was in a short time, associate and, then, full professor. In a five-year span, he established a remarkable record of mentoring graduate students (8 Ph.D. and 3 M.S.). These features of his benevolent but demanding leadership first became apparent (at least to his graduate students who included Hauser, Squires, Gregory, Krueger, Warren, Arthaud, Gyles, Dillard and Neville). The range of research of his students also illustrated Gordon's wide interests including use of experimental animals. His Missouri students did research primarily with poultry, swine, and mice, although their careers were generally with beef cattle or poultry. Keith Gregory, who later became Gordon's director during his last tour as an USDA scientist, was the first Ph.D. student who started and finished with Gordon.

The Heterosis Conference held in 1950 in Ames featured the most important animal breeders of that time. Gordon's paper on '*Inbred Lines for Heterosis Tests*' continued a theme that would re-appear throughout his career. "What are the reasons why rates of genetic improvement are less than expected?" The inbreeding-heterosis interplay was one of those bases.

An even more classic paper from that period (published in 1954 after Gordon's path had once again moved on but written at Columbia) was NCR Publication No. 38 entitled *Evaluation of Selection in Development of Inbred Lines of Swine.* Gordon was lead author with Blunn, Chapman, Kottman, Krider, Warwick and Whatley. The paper summarized some 43 experiments from the north central region. A lasting and most powerful tool for animal breeders was developed in a line or two of that bulletin – the index in retrospect, which can be described in words as "What multiple trait index would have given the responses observed?" The index in retrospect provides a picture of how selection was actually practiced rather than of what was intended. For example, the intended index at the NCR stations was: $I = D + .50*W$ where D refers to dam productivity and W to 154 day weight. The index, in retrospect averaged over all experiments, was: $I = D + 1.10*W + 1.56*C$ for boars and $I = D + .88*W + 8.73*C$ for gilts where C represents a conformation score. What was actually practiced was quite different from what was intended – a powerful tool.

Marvel Baker, a colleague in the NCR project, asked 'Quo vadis' of Gordon and Myra as they were preparing for a major move; to the commercial poultry world of Kimber Farms (1952-1965). Kimber Farms in Nyles, California, had been a family business since the 1930's. Both Lush and Hazel for several years had collaborated with the geneticists there. Gordon began as a geneticist and later was director of research and member of the board of directors of Kimber Farms.

Despite continuation of a busy professional career, Gordon contributed much time, wisdom and foresight to his new community of Fremont, California. Their four sons all graduated from Washington United High School. Gordon was a trustee of the school board for two 4-yr terms and was president of the board during an expansion from two to five high schools. He was also a member of the Fremont Planning Commission (8 yr) shortly after incorporation of Fremont. As president and director, he led the Community Chest appeal. The Centerville Presbyterian church was served as elder and church school superintendent (7 yr). Gordon also worked with the Boy Scouts (12 yr) and was president of the PTA.

Gordon did not vanish from his profession during this period. His publication record during this period averaged over three papers per year. Many of those were invited presentations to be published in proceedings. These invitations were about one per year and, by their variety, illustrate Gordon's breadth of knowledge and insight. The presentations included a Cold Spring Harbor symposium on Quantitative Biology, a AAAS Symposium on Germ Plasm Resources, a NAS-NRC symposium on Statistical Genetics and Plant Breeding, a symposium at the World's Poultry Congress in Sydney, Australia, a symposium in England in honor of Sir John Hammond, the Macy Foundation Conference of Genetics, a symposium on application of new statistical methods sponsored jointly by the Biometrics and Genetics Society, and a symposium paper for the Poultry Science Association on *Breeding for Leucosis Resistance*.

A monumental gift to his profession during this period was his contribution on *Techniques for Research in Quantitative Animal Genetics* to the 1959 ASAP monograph on Techniques and Procedures in Animal Production Research. He later revised extensively that contribution for the second (1969) edition of ASAS Monograph on Techniques and Procedures in Animal Science Research.

For a short period (1965-67), he was with Bob Gowe in Ottawa with the Canadian Department of Agriculture working with quantitative genetics of egg poultry. While there, he became a life-long friend, mentor, and colleague of a young worker who became his first Ph.D. student a little later at the University of Nebraska. His commitment to Bob Gowe completed, Gordon and Myra made their final move in 1967 to a unique position marking a return both to USDA (Roman L. Hruska US Meat Animal Research Center)and academia (University of Nebraska).

Gordon's primary position (at USMARC under his former student, Keith Gregory) was to lead research in swine and sheep breeding and to coordinate work of graduate students in Lincoln. Naturally, Gordon became involved with much more. He was actively involved with design of the Germ Plasm Evaluation and Germ Plasm Utilization Programs for beef cattle and sheep, the composite breed experiments, cattle, sheep and swine; the beef cattle twinning experiment, the Hereford selection experiment, and many swine and sheep experiments. His main focus was on net life-cycle biological efficiency (i.e., the whole system). He also focused on definition and estimation of direct and maternal breed effects, heterosis, and recombination effects in breed evaluation and utilization experiments (e.g., inbreeding and heterosis in animals. Proceedings of the Animal Breeding and Genetics Symposium in Honor of Dr. J. L. Lush, Am. Soc. Anim. Sci., 1972). His efforts covered sheep, swine, and beef cattle and also involved a major effort with the rat as an experimental animal as well as computer simulations.

Gordon made a lasting impression on all he met and, in particular, his graduate students. His teaching style was unique and did not end in the classroom. His formal and informal seminars (with noon and late Friday afternoon schedules) were legendary. No one who participated ever regretted the opportunities. A quote from a UNL student, Dave Notter, illustrates his approach.

> "Gordon has a unique ability to hold complex ideas and systems in his mind; he can turn them over, view them from all sides with a critical eye and identify the essential components of difficult problems. As one works with him, one soon develops the philosophy that this is what science is really all about; a no-stone-left-unturned attack on the unknown or the unclear. He prepares his students to give their best. He demands it by example."

A similar view came from an earlier student at Missouri, Roy Gyles.

> "Dickerson taught by association, by example, by challenge. He was first at work and last to leave. No coffee break or football small talk attracted him. Steady at his desk all day with intermittent breaks to teach class. His lectures portrayed his personality. Nothing was taken for granted but questioned, viewed from one angle then to the next and pressed further as if to get a second milking. Self pity grasped me with lack of the basics. There was no exit only onward march."

If Gordon had a weakness, it was the mass of material he managed to include on an overhead or a slide for a class or even for a major presentation. Much of such material was an attempt to summarize biological components of efficiency of livestock production. These slides and graphs would present as much of the whole picture as was possible. These graphs were a way Gordon could conceptualize all aspects of a livestock production system. The detail, however, would seem overwhelming to those not so well versed.

Although all students at UNL during this period could claim to be one of Gordon's, the official list included Emsley, Gosey, Olson, Notter, Fogarty, Tess, Wang, Rios-Ramirez, Buckley, Olthoff, Setshwaelo, Mohd-Yusuff, and Green as Ph.D. students and Sherrill, Nunez-Dominguez, Guerra, and Gama as M.S. students. Visitors and post-docs who had the unique opportunity to be with Gordon were Kunzi, Smith, Van Vleck, Lindhe, Bennett, Kashyap, Wang, Baker, and Azzam.

A lasting contribution to his profession was Gordon's brash decision to ask that Lincoln, Nebraska be the host to the Third World Congress on Genetics Applied to Livestock Production (1986). The massive effort of Gordon and his colleagues at UNL and USMARC made this a truly World Congress that subsequently has met every four years in the leading centers of animal breeding research and teaching: Edinburgh, Scotland; Guelph, Canada; Armidale, Australia, and Montpellier, France. The seven-day event in Lincoln included more than 600 participants, 55 sessions, four volumes of proceedings, and tours of USMARC and the sandhills of Nebraska.

From the outset of this brief biography, the theme has been Gordon's path. The official duty stations provide just a skeleton of that path. The list of countries visited by Gordon and Myra (Myra has said she accompanied Gordon on all except twp) where he made presentations numbers 24 with an additional 13 which he visited while on business with Kimber Farms.

Probably more animal breeders have been a guest in the Everett Street home of Gordon and Myra than in any other in the world. Most visitors to Lincoln would experience the hospitality and generosity of the Dickersons' – some for an evening and others for longer periods in their basement apartment. Those gatherings of the world of animal breeding continued long after Gordon's official retirement in 1987. Several times each year they would host "potluck" dinners for all students and visitors in residence in Lincoln, especially at the time of the Thanksgiving holiday in late November when all who remained in Lincoln were invited to share their foods and customs with others. Many, many, students, visitors, and their families have fond memories of those gatherings with Gordon and Myra. Gordon and Myra were products of the "depression years" of the 1930's and were naturally in their own words "frugal". They, however, were known to be exceedingly generous with their time and hospitality.

After official retirement at age 75, Gordon continued both with his professional interests and with his commitment to improve his community and the world. Papers of his last students were completed. He continued to serve on graduate student committees and was a regular at weekly graduate seminars and journal club discussions. His last scientific paper (1995) came 61 years after his M.S. thesis and was a chapter on "Economic Importance of Prolificacy in Sheep". Until the late 1990's, he also was the unofficial captain of the departmental bowling team – the last trophy was dedicated to Gordon.

Although modest and humble, Gordon received many honors. He was a fellow of AAAS and ASAS. His awards included the top ones of many organizations: the 1990 International Award from Gamma Sigma Delta, the F. B. Morrison Award (1978) from ASAS, the Pioneer Award (1982) from BIF, the Continuing Service Award (1989) from NSIF, and the Science Hall of Fame Award (1990) from USDA. The 1990 group of five included with Gordon a Nobel Prize winner and the leading wheat and corn breeders in the U.S. as well as a fellow poultry scientist who had been administrator of ARS. Gordon was an active member of 11 scientific associations and 4 honorary societies. His personal frugality did not extend to his professional commitments nor to his commitment to the local and worldwide communities. In Lincoln, his community activities continued. He was a leader in the Capitol City Chapter of Kiwanis International, a member of the Mayor's Committee for International Friendship, and officer and program chair for the Lincoln Chapter of the United Nations Association.

Early in August 2000, Gordon and Myra attended the annual Dickerson reunion near Bloomingdale, Michigan. Shortly after their return, Gordon's physical journey ended on August 27 in Lincoln after 88 years of which 67 were with his life-time partner, Myra.

The preceding has highlighted professional contributions and highlights but not much of the personality and character which together with his scientific ability and achievements combined to make the life of Gordon Dickerson a model for his friends and colleagues. A sampling of letters to Myra after Gordon's death or in support of his nomination for a national award may give a glimpse of how unique Gordon was.

> "Truly, there have been few who have made such important contributions to genetics and animal breeding over so many years".

> "Gordon really loved all mankind for he is devoid of any prejudice of race, color or religion."

> "I often admired the elegant and unique way in which he would formulate his thoughts. He was an honest man with a fine sense of humor. I am ever so grateful he crossed my path."

> "I certainly wanted to write on Dr. Dickerson's behalf because he had such a positive impact on my life. I worship the man!"

> "I wondered what sort of man this was that had parted the clouds for me and let in the sunshine."

> "You said that you thought that 'I had married just plain Joe!' You certainly do have to change your mind, for in truth, you married a fellow who was rather close to a God to many, many people in the Animal Breeding Fraternity!! I have never heard anything but the most sincere praise for Gordon!! You certainly married one of 'the Greats', and so did he!"

This last note from a student who had Gordon as a member of his committee 30 years earlier may sum up many of the feelings and respect of Gordon's world-wide friends, neighbors, and colleagues,

> "He has been my model to imitate, unfortunately without success. For me, it is an honor to have had an advisor with such human and scientific attributes. It was good luck for me to have had the opportunity to meet him."

DEFINING BIOLOGICAL EFFICIENCY OF BEEF PRODUCTION

David R. Notter
Dept. of Animal and Poultry Sciences
Virginia Polytechnic Institute and State University
Blacksburg 24061

Introduction

"Efficiency" is a poorly defined and generally overused term in livestock production. The segmentation present in the beef industry provides wide latitude for limited, and potentially conflicting, definitions and makes achievement of an industry-wide consensus on the definition of efficiency difficult. Much of what we believe today about efficiency of animal production was introduced by Dickerson (1970) in a paper by the same name and was further developed by him and his students in an array of papers on biological and economic efficiency in beef cattle and other species that followed over the next 30+ years.

In ruminants, separate consideration of "biological" and "economic" efficiency is nearly impossible under U.S. conditions. The separate and highly significant contributions of both grazed forages and harvested concentrates to beef production, and the potential substitution of one feed source for the other, dictates that economic considerations must influence our view of biological efficiency. Key economic issues which necessarily influence the definition of biological efficiency include the relative costs of grazed forages versus harvested concentrates and the procedures used to assign costs to grazed forages. Similarly, the U.S. beef marketing system, with simultaneous consideration of quality and yield grades, introduces an element of complexity into any discussion of biological efficiency that is not present in any other species of meat animal.

Issues involving relative feed costs, differential product pricing, and other economic considerations will be gratefully relinquished to other speakers (Tess, 2002). This presentation will focus narrowly on a definition of biological efficiency as:

> *"the capacity to convert physical inputs (feed) into marketable product (beef) under prevailing production conditions."*

This definition of biological efficiency permits us to consider the basic dichotomy between the efficiency of use of grazed forages ("cow efficiency") and harvested concentrates ("growth efficiency"). This dichotomy is important, not because of intrinsic differences in efficiency of use of the two feed resources (although such differences certainly do exist), but because the biological traits supporting efficient use of the two resources are markedly different.

This definition of biological efficiency can be applied at both the individual-animal level and at the level of the industry. Consideration of biological efficiency at the industry level includes issues of genetic diversity, breeding structure, and capacity for short-term adjustments. At the industry level, the definition of biological efficiency may be augmented to include:

> *"population characteristics that provide the flexibility to rapidly adjust the characteristics of commercial offspring in response to changes in economic conditions."*

This definition allows incorporation of the full array of products and appropriate consideration of genotype x environment interactions. It likewise incorporates consideration of operational issues supporting performance recording programs and achievement of genetic change in chosen biological traits.

Traits that support efficient cow-calf production systems are generally different from those that define efficient postweaning calf growth. For that reason, biological efficiency will be considered separately for the cow herd and for the growing market animal. This approach is consistent with Dickerson's (1970) suggestion that total costs of production be separated into those for the producing and reproducing female population and those for growing progeny to market size.

Cow Efficiency

Biological efficiency in the cow herd is most clearly reflected in the number of calves weaned per cow exposed. The weight of weaned calves is generally of secondary importance in defining biological efficiency in integrated systems, but plays a significant role in defining economic efficiency for the cow-calf producer. If this information could be coupled with an accurate predictor of annual feed intake, a relatively comprehensive measure of cow efficiency could be derived. Additional characteristics of importance to cow efficiency include appropriate transmitted effects to support efficient postweaning growth in crossbred progeny. Achievement of high levels of cow efficiency would be facilitated by high levels of maternal calving ease to support use of terminal sires.

Ample research exists to suggest that cow size and milk production level have intermediate optimum levels appropriate to each production environment, management system, marketing scheme, and crossbreeding program (Notter et al., 1979a,b). Milk production level, in particular, will be dictated almost exclusively on economic grounds involving relative costs of cow and finishing diets and patterns of retained ownership. On solely biological grounds, milk production levels beyond those required to maximize calf survival and health and to set the stage for optimal postweaning growth are generally not needed (Notter et al., 1979a). Access to six to eight breed types representing various combinations of frame size, adult weight, and milk production potential, and with access to within- and across-breed EPDs, seems appropriate to permit prompt (one-generation) adjustments in cow performance traits to meet temporary or unpredictable changes in economic conditions.

Opportunities to reduce annual feed requirements for the cow herd or to improve efficiency of utilization of available forages may exist but will be difficult to exploit. Two possibilities involve either the identification of animals with lower maintenance requirements or the identification of animals with enhanced adaptive characteristics that permit them to harvest feed more efficiently in challenging grazing environments or better utilize low-quality feedstuffs. Some evidence for genetic variation in maintenance costs of breeding females exists in several species (see Archer et al., 1999, for review) but without direct measurement of feed intake under controlled (and therefore necessarily artificial) conditions or the identification of highly informative phenotypic indicators or genetic markers, accurate individual-animal evaluation will be difficult. Archer et al. (1999) hypothesize that selection for efficiency of feed use in growing animals, if properly defined and measured, may be feasible and have desirable correlated responses in cow efficiency. Adequate data to address that hypothesis do not now exist but are being collected by Australian scientists (Arthur, 2001).

The second situation involves issues of environmental adaptation and cow efficiency in suboptimal forage environments defined by limitations in either forage quality or availability. In such situations, adaptations that enhance the animals' capacity to harvest and utilize adequate nutrients may have large effects on cow efficiency. Records of reproductive performance, perhaps coupled with information on cow weights and (or) condition scores may be the most appropriate measures of environmental adaptation in such situations.

Reproductive Efficiency. The high proportion of total beef inputs expended on cow maintenance is one of the most significant limitations to increasing biological efficiency of beef production. Costs for cow maintenance, lactation, and growth account for 65 to 70% of the total energy required for beef production but perhaps only 35% of the total cost of production (Notter et al., 1979a), although this last figure can vary widely depending on the cost assigned to grazed forages.

Spreading costs of cow maintenance over larger offspring numbers thus remains the single most important strategy for improving biological efficiency of beef production. This goal can be achieved by:

- maximizing cow fertility,
- increasing cow fecundity by increasing twinning rates.

Options for incorporating measures of reproductive fitness into national genetic evaluation programs include direct measures of fertility such as pregnancy rates and calving dates and indirect measures of indicator traits such as reproductive tract scores in heifers and scrotal circumference in males. Factors limiting widespread emphasis on fertility traits in beef cattle genetic evaluation include the relatively high mean fertility levels already achieved in well-managed herds in favorable environments, the associated low heritabilities of most direct measures of fertility, the difficulty associated with accurate reporting of reproductive events in industry performance recording programs, and insufficient emphasis in most breeds on whole-herd recording.

The dynamics involved in selection to improve fertility are complex, with strong economic as well as biological origins. Nutrients obtained from grazing permanent pastures are commonly assigned low costs, supporting a tendency to correspondingly undervalue cow efficiency. Second, the categorical expression of fertility effectively places a ceiling on realized fertility that makes selection ineffective (and unnecessary) when mean fertility levels are high. The result is a situation in which the contribution of cow fertility to biological efficiency of beef production is paramount at low fertility levels, but trivial as pregnancy rates approach 90 to 100%.

Selection to genetically improve fertility in sub-optimal environments can be effective, as demonstrated by Davis et al. (1993), who documented a genetic response to bidirectional selection for pregnancy rate. More recently, pregnancy rates in Nellore yearling heifers in Brazil were likewise shown to be quite highly heritable (h^2 = .78; Eler et al., 2002). Adequate evidence likewise appears to exist to support use of yearling scrotal circumference in males as a useful selection criterion to increase yearling pregnancy rates in late-maturing, but not necessarily in early-maturing, breeds (Brinks et al., 1978; Martins Filho and Lobo, 1991; Notter et al., 1993).

Twinning has clear potential to increase the biological efficiency of beef production. Selection for increased ovulation and twinning rates in cattle has been successful. VanVleck and Gregory (1996) report that the frequency of twinning increased with selection from 3.4% in 1982 to 28.5% in 1993 (Figure 1). Current frequency of twinning in the herd is over 35% (Echternkamp and Gregory, 1999). Modest heritability estimates of .10 and .09 for ovulation and twinning rates, respectively, in that population were leveraged to yield annual rates of genetic change in twinning rates of over 1.8%/yr by an intensive screening process to identify founder animals with a history of twinning, use of A.I. to optimally utilize elite animals, and use of repeated measures of ovulation rate to increase accuracy of evaluation.

Performance of cows producing twins and of twin-born calves in this project (Table 1 and 2) were reviewed by Gregory et al. (1996) and by Echternkamp and Gregory (1999a,b). Twin-born calves had 13% lower survival rates in the first 3 d of life (81 *vs* 94%) but only 2% higher death losses from 3 d of age to weaning. Surviving twin-born calves grew 15% less rapidly to 200 d. Twin-born males grew 3% less rapidly postweaning, averaged 2% lighter at slaughter, and required an extra 20 d to reach slaughter weight. Number and weight of calves at weaning were increased by 65 and 58%, respectively, in cows producing twins. Twinning significantly increased the incidence of dystocia, which was 22% higher (42 vs 20%) in cows with twins, primarily due to malpresentation of one or more offspring (Echternkamp and Gregory, 1999a). In terms of postpartum reproductive performance (Echternkamp and Gregory, 1999b), conception rates in a 60- to 70-d breeding season were 77% for cows that produced singles but only 67% for cows that produced twins. Among cows that conceived, those that produced twins required, on average, an additional 9 d to conceive. Adjustment for effects on cow fertility and calving date in an annual calving season would reduce the advantage of twinning to approximately 42% for number of calves produced and to about 30% for weight of calf weaned. Guerra-Martinez et al. (1990), in a study of cows that twinned after ET, similarly concluded that input costs per unit of beef output could be reduced by 24% in the proportion of the herd that produces twins.

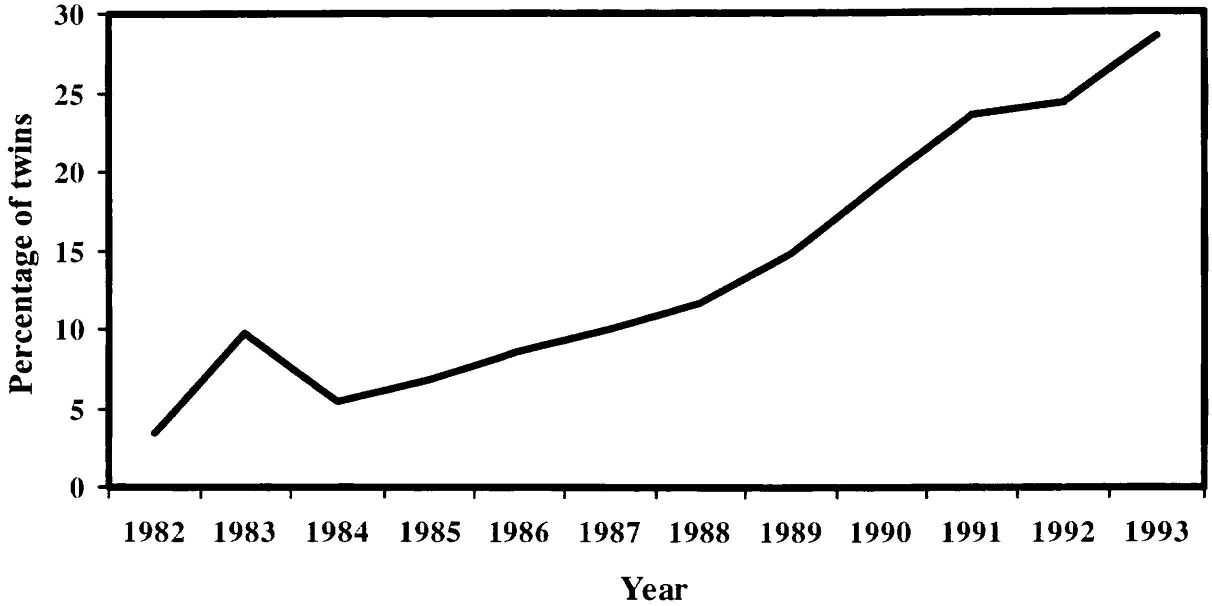

Figure 1. Percentage of twin births in a line of cattle selected for twinning (Van Vleck and Gregory, 1996).

An opportunity to increase output from the cow herd by perhaps 15% (a 42% increase in output with a 35% twinning rate) is hard to ignore, but there are mitigating economic factors. A high frequency of twinning would require more labor at calving to manage dystocia. Estrus synchronization and ultrasonic detection of twin births could assist in focusing additional labor on short periods of time. Spring and fall calving seasons could enhance realized annual fertility, but at a cost of additional management, feed, and labor. Creep feeding and possible early weaning of at least some calves would increase feed costs per calf, but would also be expected to enhance calf performance. Results in sheep suggest that twinning rates can only be increased to perhaps 60 to 70% before the incidence of triplet and larger litters becomes high enough to introduce a new level of potentially adverse effects on dystocia and calf survival.

Growth Efficiency

The biological traits influencing efficiency in the growing market animal, and particularly in the feedlot, differ considerably from those desired in the cow herd. Issues of appetite (positive and negative), lean growth potential, maintenance requirements, growth efficiency, and carcass fat level and distribution become primary. At best, most of these traits are largely independent of the traits defining cow efficiency. Some antagonisms may exist, but none are well documented. Nor are any of the antagonisms that may exist apparently large enough to seriously compromise an integrated program of genetic improvement.

Table 1. Performance of cows producing twins[a]

Item	Singles	Twins
Incidence of dystocia,%		
2-yr-old cows	41	52
≥3-yr-old cows[b]	16	45
Postpartum conception rate, %[c]	77	67
Days to conception[c]	89	98
Calves weaned/cow calving	.92	1.52
Wt of calf weaned/cow calving, lb	513	811

[a]Gregory et al. (1996), Echternkamp and Gregory (1999a,b).
[b]Weighted average of cow age classes.
[c]Weighted average of type of birth x number of calves suckled classes.

Table 2. Performance of single- and twin-born calves[a]

Item	Singles	Twins
Birth wt, lb	103	84
Perinatal survival, %[b]	96	83
200-day wt, lb[c]	570	510
Slaughter age, d[d]	448	468
Slaughter wt, lb[d]	1,320	1,296

[a]Gregory et al. (1996).
[b]Weighted by calving difficulty score.
[c]Weighted by number of calves nursed (0 or 1 for singles; 0, 1, or 2 for twins).
[d]Males calves only.

Feed Efficiency. Efficiency of feed use will be addressed by several speakers in this year's BIF proceedings, building upon the comprehensive analysis of feed efficiency in beef cattle conducted by Dickerson et al. (1974). Recent advances in methods for evaluation of efficiency of feed use have come from Australian studies (e.g., Arthur et al., 2001) using the concept of selection for reduced residual feed intake (RFI). Residual feed intake is the difference between actual feed intake and some predicted intake based either on tabular values or regression analysis. As applied by Arthur et al. (2001), RFI is the deviation of the actual feed intake from that predicted (by regression) for animals of the same average metabolic weight and ADG. This concept of RFI was used in beef cattle by Koch et al. (1963), who reported a heritability of the trait of .28, somewhat lower than the value of .39 ± .03 reported by Arthur et al. (2001), but still indicative of opportunity for genetic change. Analyses of RFI have also been conducted for layer chickens, pigs, and dairy cattle, with variable results (Emmans and Kyriazakis, 2000).

Residual feed intake is presented as an alternative to the more widely used feed conversion ratio (FCR, the feed:gain ratio) as a measure of biological efficiency of growth. It is thought to be more indicative of the intrinsic efficiency of feed use, and particularly of maintenance. The RFI likewise avoids some of the problems involved in the use of ratios as selection criteria. However, as pointed out by Dickerson (1970), RFI alone is unlikely to be a sufficient indicator of growth efficiency. Efficient growth involves the combined effects of rapid growth (to dilute maintenance requirements), desirable composition of gain, and efficient utilization of consumed feed. Alternatives to FCR must recognize all these determinants of efficient growth.

The dynamics of the feed conversion ratio are well known: rapid growth, with associated dilution of maintenance requirements, has the most important impact (phenotypically and genetically) on FCR and is effectively a prerequisite for lowering FCR. The impact of appetite (voluntary feed intake) and composition are variable, depending upon the stage of growth and the breed. In early life, when lean tissue growth predominates, appetite may be associated with desirable FCR, but at higher degrees of maturity, appetite and propensity to fatten commonly combine to yield an undesirable association between appetite and FCR. It seems clear that selection for FCR may result in less than optimal lean tissue growth efficiency and that selection for FCR should be combined with negative emphasis on measures of fatness (likely measured by ultrasonic BF thickness) to maximize biological efficiency of lean tissue production. Imposition of quality standards (minimum fatness levels) on the final product could favor unadjusted FCR as a selection criterion, but selection involving an index of ADG and residual feed index may be superior to direct selection on feed conversion ratio.

The picture that emerges favors high feed intake and associated rapid growth provided the appetite and lean growth potential are synchronized to prevent excessive fat gain. Lower appetite is acceptable and may be favored when lean growth potential is more limited. Leanness is favored, but only in animals of high growth potential. The concept of RFI attempts to account for these interactions among appetite, lean growth potentials, and growth rate. RFI also places more emphasis on potential differences in intrinsic maintenance requirements and may have a favorable association with maintenance costs in the breeding herd (Arthur et al., 2001). Genetic associations among efficiency traits in Australian Angus cattle (Table 3) reveal that RFI has a substantial genetic association with FCR and feed intake. FCR is much less closely associated with intake but is more closely associated with ADG. Associations of backfat thickness with both RFI and FCR are less than might be anticipated. RFI is nothing more (and nothing less!) than a linear index of mean metabolic weight, ADG, and feed intake and in that sense may be, in some ways, superior to FCR. But the index weightings implicit in RFI are likely not optimal for prediction of growth efficiency.

Table 3. Genetic correlations among residual feed intake (RFI), feed conversion ratio (FCR), mean weight, average daily gain (ADG), feed intake (FI), and backfat thickness (BF) in Australlian Angus cattle[a]

	Trait				
Trait	FCR	Mean wt	ADG	FI	BF
RFI	.66	-.06	-.04	.69	.17
FCR		-.01	-.62	.31	.03
Mean wt			.53	.65	n/a[b]
ADG				.54	n/a[b]
FI					.27

[a]Arthur et al. (2001).
[b]Not reported.

Modification of the Growth Curve. Intense interest in potential to modify the growth curve arose in the 1970's (e.g., Brown et al., 1976) but was largely dismissed as impractical, at least under conditions emphasizing use of field records in selection. However, an historical analysis of weight:age relationships in broiler chickens (Emmans and Kyriazakis, 2000) provides compelling evidence of genetic change in the growth curve. Over the period 1950 to 2000, adult weights of broiler males were estimated to have increased by 75%, whereas their maturing rate increased by over 150%. Since maturing rate is anticipated to decline with increases in mature size, this pattern represents a clear modification of the growth curve. Knap (2000) provides similar evidence that mature lean body mass in pig sire lines has remained relatively stable over time, whereas rate of protein deposition has clearly increased. The persistence of high lean growth rate in pigs appears to also have been extended to later ages (accounting for increases in slaughter weights). Interestingly, this pattern is much less clear in dam lines where increases in growth rate appear more likely to be accompanied by the expected increases in mature size.

Results from broiler chickens and from mouse experiments confirm that selection for body weight at a fixed age is expected to have substantial effects on appetite and fatness unless there is corresponding negative selection emphasis on these traits. Results from the most recent cycle of the U.S. MARC Germplasm Evaluation Program (Cundiff et al., 2002) show remarkable uniformity among U.S. breeds in postweaning ADG of steers and 400-d weight of heifers (Table 4) despite significant differences favoring calves sired by continental European breeds in measures of fatness and yield of retail product. Conclusions involving appetite-driven effects on growth and on the shape of the growth curve for these breeds will be intriguing but must await data on adult body weights and frame scores for the various types. Appetite-driven changes in growth rate would not be expected to have a positive effect on biological efficiency of lean tissue deposition but could influence the growth curve and have a positive effect on economic efficiency by increasing the percentage of animals in the USDA Choice quality grade.

Table 4. Means for growth and composition traits of cattle sired by various breeds[a]

Sire Breed	Weaning weight, lb	Postweaning ADG, lb/d[b]	400-d wt, lb[c]	% Retail product[b]	Yield grade[b]
Hereford	524	3.46	829	59.5	3.35
Angus	533	3.40	877	58.8	3.32
Red Angus	526	3.40	872	57.7	3.76
Simmental	553	3.47	848	62.1	2.95
Gelbvieh	534	3.33	812	62.3	2.80
Limousin	519	3.30	835	63.0	2.63
Charolais	540	3.43	830	62.2	2.77

[a]Cundiff et al. (2002).
[b]Of steers.
[c]Of heifers.

Use of the Myostatin Gene? The recent discovery that two different mutant forms of the myostatin gene are responsible for muscular hyperplasia ("double muscling") in the Piedmontese and Belgian Blue breeds (Kambadur et al., 1997) leads to new opportunities to manage and use muscular hyperplasia. Individuals carrying one copy of either of the alleles associated with double muscling are superior to noncarriers in muscularity and leanness, though substantially less extreme than homozygous double-muscled individuals (Table 5). Casas et al. (1998) reported that a single copy of a mutant *mh* allele increased retail product yield by 4.4% and reduced mean yield grade by 0.7 units. However, marbling score was also reduced by about 10%. Short et al. (2002) reported that a single copy of mutant *mh* increased percentage of primal cuts by 2.1%, but also reduced marbling score from 6.0 to 5.4. Birth weights were consistently increased in calves carrying a single copy of *mh*, but estimates of the magnitude of increase have been inconsistent, ranging from 2.9 (Short et al., 2002) to 7.0 (Casas et al., 1999) and 10.0 lb (Casas et al., 1998). In all these studies, the incidence of calving difficulty was not significantly increased in adult cows producing calves that carry the *mh* allele. However, the incidence of calving difficulty was increased from 13 to 43% in heifers delivering calves carrying one copy of *mh* (Short et al., 2002).

The *mh* allele appears to have little effect on appetite or postweaning gain and therefore does not improve feed conversion ratio. However, efficiency of lean tissue gain is clearly improved (Short et al., 2002). Negative effects of *mh* on marbling score and quality grades will likely limit realization of the advantages of improved lean gain efficiency in traditional markets. However, several studies indicate that Warner-Bratzler shear measures and tenderness scores of cattle that carry the *mh* allele are at least equal to those of noncarrier despite their lower marbling scores (Wheeler et al., 2001; Short et al., 2002). Use of the *mh* allele will thus require development of new marketing options that do not rely on the U.S.D.A. grading scale to indicate quality characteristics (Keele and Fahrenhrug, 2001).

Table 5. Effect of 1 copy or 2 copies of an inactivated myostatin allele on performance to traits in beef cattle[a]. Tabular values are expressed as a percentage change relative to normal cattle

Trait	Study[b] 1[a]	2	3
Birth wt, lb	+2.9 (+9.7)	+7.0	+10.0
Dystocia incidence, %:			
Heifers	+30.2 (+36.7)		
Cows	-0.7 (+7.1)	+5.0	
Weaning wt, lb	-2 (-8)	+20	
Postweaning gain, lb	0 (-4)	+24	
Final wt, lb	+2 (-6)		
Dressing %	+1.8 (+5.3)		
Lean yield, %	+2.1 (+6.1)		+4.4
Marbling score	-0.6 (-2.0)		-0.5
Yield grade	-0.6 (-2.0)		-0.7
Gain efficiency, %[c]	-2.7 (-3.0)		
Lean gain efficiency, %[c]	+4.8 (+20.6)		

[a]Tabular values show the mean difference between calves that carry 1 or 2 copies of the inactive allele and those that do not. Effect of 2 copies of the mutant allele are shown (in parentheses) only for study 1.

[b]Study 1 is Short et al. (2002); study 2 is Casas et al. (1999); study 3 is Casas et al. (1998).

[c]Efficiency was measured as grams of gain (or lean gain) per Mcal of feed consumed.

The most likely use of the *mh* allele would be through the production of heterozygous market animals by mating homozygous *mh/mh* sires to noncarrier cows. However, the opportunity to use DNA testing to discriminate between carrier and noncarrier animals provides additional options for managing this allele. Thus Short et al. (2002) envision the possibility of maintaining a herd of *mh/+* carrier females which would be mated to homozygous *mh/mh* sires. Offspring would be 50% carriers and 50% double muscled. All double-muscled offspring would be marketed. Females would be genotyped and only heterozygous individuals retained as replacements. Advantages in lean gain efficiency from this system could, however, only be realized in a marketing system that does not place emphasis on marbling scores.

Interesting options also exist for introgression of *mh* alleles into different genetic backgrounds, particularly those with high genetic merit for appetite and marbling score. Short et al. (2002) report that Piedmontese-sired calves lacking the *mh* allele grew less rapidly postweaning than Hereford-sired calves, but had similar marbling scores. These results suggest that supplemental selection for leanness (represented by both low appetite and high lean growth potential) has occurred in the Piedmontese (and also likely in the Belgian Blue) to augment effects of *mh*. These effects could potentially be modified by placing *mh* in a different genetic background.

Conclusions

The biological efficiency of beef production is best viewed as a characteristic of the industry rather than the individual. Biological efficiency reflects options as much as optimums. Efficient cows are those that produce calves regularly and easily; most of the other biological characteristics of the cow herd are negotiable, depending upon markets and production environments. But if they don't calve regularly and easily, they won't be efficient.

The biological efficiency of the growing calf is more directly about balance: high lean growth potential, with an appetite in synchrony, is the basis for high biological efficiency. But the filter of the market, with an association between intramuscular fat and quality, adds art to the science, along with a healthy dose of unpredictability. Economic efficiency always trumps biological efficiency, so we arrive at the conclusion that biological efficiency is the servant of economic efficiency. And that master is best served by having the biological diversity to rapidly accommodate changes in markets and economic variables. We regularly act in ways that fail to maximize biological efficiency of lean tissue production. We need not apologize for that, since the success of the commercial cattleman is measured in profit, not efficiency. But neither should we forget it.

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Gordon Dickerson: Defining Economic Efficiency of Beef Production

M.W. Tess and K. C. Davis
Animal and Range Sciences Department
Montana State University

Summary

Dr. Gordon E. Dickerson was a visionary and productive scientist whose many scientific contributions included a systems approach to the genetic improvement of economic efficiency of beef production. His most important contributions to the improvement of beef efficiency include: 1) insisting on an economic definition of the biological objectives of livestock production, 2) promoting multi-disciplinary approaches to the study of production systems, 3) comparing different domestic species to identify opportunities for genetic improvement, 4) elucidating the economic impacts of changes in beef cattle performance traits, 5) demonstrating the utility of index selection for genetically managing undesirable genetic antagonisms in production systems, 6) demonstrating the benefits of structured crossbreeding systems in exploiting heterosis and breed complementarity, 7) calling for value-based pricing of market animals to provide economic incentives for genetic improvement, and 8) stimulating a significant volume of experimental work targeted at answering scientific questions posed via his research.

Introduction

To describe the contributions of Dr. Gordon E. Dickerson to the understanding and improvement of beef production efficiency is to view just a portion of a large mosaic. His influence reaches far beyond just production efficiency and far beyond just beef cattle. Like a pioneer scout riding far ahead of the wagon train marking out places to camp, he navigated areas to research long before the livestock industry was ready to apply many of his ideas. Production efficiency was one of those "camps."

We will attempt to highlight and organize Dr. Dickerson's contributions to the genetic improvement of beef production efficiency. Because I (MWT) regard Dr. Dickerson as my mentor and friend we will refer to him subsequently as simply Gordon. I could not respect a scientist more highly than I respect Gordon Dickerson.

Biological Objectives

Proper definition of breeding goals motivated much of Gordon's work on production efficiency. He repeatedly emphasized that management decisions, and especially genetic decisions -- i.e., choices among breeds, choices among mating systems, and decisions regarding the relative emphasis of different traits in selection schemes -- should all be based on "biological objectives" (Dickerson, 1969, 1970, 1976, 1982c). He defined biological objectives as "the relative economic importance of the major components of performance in terms of the approximate direct effect of each on cost per unit of production" (Dickerson, 1969). Because changes in production/marketing systems can change biological objectives Gordon stressed that genetic decisions should be made with an eye to the future of animal production (Dickerson, 1970, 1982b). Due to the implications of genotype x environment interactions (Dickerson, 1962), he recommended that each biological type should be evaluated under the production/marketing system for which it is best suited (Dickerson, 1978).

During his day, Gordon felt that genetic research had placed high priority on developing effective methods to effect genetic change, but had given little consideration to which traits to change or how much to change them (Dickerson, 1982bc; Dickerson and Willham, 1983). This gave further impetus to his work on biological objectives. One could easily draw the same conclusion today, some 20 years later.

Economic versus Biological Efficiency

The fact that "biological" objectives were in fact based on economic costs and returns rather than just biological inputs and outputs was intuitive to Gordon (Dickerson, 1982c; Dickerson et al., 1982). Biological inputs (e.g., feed energy) were only worthy of consideration if they were associated with an expense. For example, water is a major "biological" input into animal production systems, yet seldom considered in efficiency studies due to its low relative cost. Hence, even though several of his publications dealt with solely biological components (e.g., Mcal energy and weight of product), the fact that the inputs (or outputs) represented major sources of expense (or return) justified their study (e.g., Green et al., 1991ab). He also recognized that non-feed costs represented major sources of expense in livestock production, and were not always directly related to animal performance. Further, Gordon realized that production systems used different types of inputs, each with potentially different prices, and yielded different types of products, each with potentially different market values. Hence, the relative economic value of inputs and outputs needed to be considered explicitly (Dickerson, 1976, 1978, 1982c). He argued that purely biological measures of efficiency could only be calculated by "ignoring" these facts, and that species comparisons based on biological efficiency were forced to "ignore" the differing costs of energy for ruminants and monogastrics (Dickerson et al., 1982).

Gordon preferred to define biological objectives in terms of efficiency (e.g., cost per unit of value produced) rather than profit (e.g., income minus expense). He stated that efficiency was more "realistic" than profit because sale prices tend to fluctuate around a narrow margin above production costs, so that lower costs benefit consumers more than producers (Dickerson, 1976). Hence, he considered efficiency "predictive" of consumer prices (Dickerson, 1982), and profit an "illusory criterion" (Dickerson, 1969).[1]

[1] Interestingly, ratios that Gordon always referred to as measures of efficiency would be considered unacceptable today by the *Journal of Animal Science*, which insists that "efficiency" is an output/input ratio while input/output is termed "conversion."

Multi-Species Systems Approaches

Gordon was one of the first animal scientists to truly embrace a systems approach in the study of livestock production. From his earliest works on biological objectives (e.g., Dickerson, 1970) he demonstrated a rare ability to see a production system from a broad perspective and then dissect and analyze its dynamic and interacting components. Further, Gordon was evangelistic in his plea for a multi-disciplinary approach to systems analysis (e.g., Dickerson, 1982b; Dickerson and Willham, 1983), and led the way by his own example. His collaborators and co-authors included scientists from ruminant and non-ruminant nutrition, physiology, meats, agricultural engineering, and economics, as well as genetics.

One of the most amazing aspects of Gordon's work was that it focused on so many different species. Some of his earliest work on biological objectives was based on comparisons across species including rabbits, chickens (both meat and eggs), turkeys, sheep, pigs, dairy cattle, and beef cattle (Dickerson, 1970, 1976, 1978). His efforts were influenced by several other contemporary researchers and coworkers who worked with species such as broilers (Moav and Moav, 1966), pigs (Harris, 1970), and beef cattle (Cartwright, 1970).

A trademark of Gordon's papers from this era was his ingenious use of complex single-equation models (Dickerson, 1970, 1976, 1978, 1982a). The example shown in Figure 1 is a composite of several versions, all of which were quite similar. His papers and presentations included elaborate, and sometimes decorative, graphs and charts derived from exercises with these single-equation generalized models of animal production. I am still impressed by the fact that all of these results were calculated by hand using nothing more than an electronic calculator (i.e., not a computer)!

Although researchers like Tom Cartwright were first to develop dynamic computer simulation models of livestock production (Sanders and Cartwright, 1979ab), it could be argued that Gordon and his students made more extensive use of the technique; certainly they worked in more species. Gordon's graduate students modified and applied the model developed by Sanders and Cartwright (Notter et al., 1979abc), developed and experimented with a dynamic computer model of swine production (Tess et al., 1983abc; Bennett et al., 1983ab, Smith et al., 1983), modified and exercised (Wang and Dickerson, 1991abc) a dynamic model of sheep production (Blackburn and Cartwright, 1987), in addition to using systems approaches to several other beef cattle problems (e.g., Dickerson, 1984; Green et al., 1991ab; Núñez-Dominquez et al., 1992).

Effects of Beef Performance Traits on Efficiency

It is perhaps his interest in comparing species that provided Gordon some of his most unique and productive insights into the dynamics of economic efficiency of beef production systems. These insights motivated him to focus his work in beef cattle on four primary areas: growth rate, body composition, milk production, and reproductive rate.

Growth Rate and Mature Size. Certainly much of Gordon's understanding of the effects of growth and mature size on efficiency came from exercises with his single equation models (Dickerson, 1970, 1976, 1978; e.g., Figure 1). However Dave Notter's thesis research (Notter et al., 1979b) represented a more thorough investigation of the effects of growth rate within integrated production systems. Conclusions from these works were reviewed in several subsequent papers (e.g., Dickerson 1982a, 1983,1985).

Gordon largely viewed growth rate and mature size as highly correlated traits, as did other researchers (e.g., Sanders and Cartwright, 1979ab). His research demonstrated that the effects of mature size were largely a matter of trade-offs. He showed that increasing growth rate reduced maintenance costs (both feed and non-feed) for growing animals, especially if harvest weight remained constant (Dickerson, 1983). More rapid growth improved production system efficiency most when it provided a means of increasing slaughter weight without increasing fatness, because the high costs of maintaining and replacing breeding cows were spread over more output (Dickerson, 1976). However, rapid growth was also associated with proportional increases in mature size, which led to increased breeding female feed maintenance costs, increased age at puberty and longer gestation length. He showed that because breeding female costs constitute a much higher proportion of total costs in species that have lower reproductive rates, lowering breeding female costs was a key to improving beef production efficiency (Dickerson, 1976). His papers also emphasized that, in many systems, increased growth rate was associated with increased dystocia and calf mortality, and longer rebreeding intervals (Dickerson, 1970, 1978, 1982a).

As a partial remedy to these opposing effects of growth rate, Gordon was one of the first researchers to suggest the idea of growth curve "bending"[2] – i.e., the concept of selecting for rapid early growth but restricting birth weight and mature size (Dickerson, 1970, 1976). This also led to what many breeders and researchers call the "Dickerson Index" (Index = Yearling weight – 3.2 Birth Weight) (Dickerson et al., 1974).

Body Composition. Gordon tended to regard lean meat production or edible protein output as the desired product of meat-animal production systems (Dickerson, 1985). Hence, he often defined the denominator of efficiency as "product value," implying that carcass composition determined value per unit of weight. His early work even included adjustments for carcass marbling (Dickerson et al., 1974). His work of 30 years ago, in which he called for a more value-based carcass pricing system to provide incentives for genetic change (Dickerson, 1983), seems right in step with the grids used today in the beef industry; perhaps another indication of his forward thinking.

Gordon's multi-species/multi-discipline approach to livestock production probably fueled his fascination with body composition. Although Gordon should certainly be remembered as a world-class geneticist, his work included a great deal of research on the effects of body composition on input costs in animal production. His experimental work addressed such things as the effects of body composition on maintenance requirements (Tess et al., 1984a; Olthoff and Dickerson, 1989; Buckley et al., 1991; Baker et al., 1991), digestibility, and energy and nitrogen metabolism (Yen et al., 1983), the energetic cost of protein and fat deposition (Tess et al., 1984b), and dietary protein requirements for different biological types of animals (Tess et al., 1983b). These studies showed that selection for increased leanness or substituting for leaner biological types

[2] This conclusion is largely based on the date of the paper, which gave no reference to another source. To my knowledge Gordon may have been the first to use this term (1976), although he suggested the concept in 1970.

were expected to improve the energetic efficiency of growth, primarily due to the high water content of lean tissue, yet increase protein requirements (percent of diet), and increase maintenance requirements. He sought to apply these concepts to beef production systems (Dickerson, 1978, 1983, 1985).

Milk Production. Although he often included milk production in his discussion of biological objectives, compared to measures of growth, body composition and reproductive traits, milk yield received relatively less emphasis in Gordon's papers. This suggests that he thought that genetic specification of milk production was not critical to economic efficiency in most beef systems. It may also reflect the fact that Gordon usually modeled beef production as an integrated system (i.e., conception to slaughter), rather than systems that marketed calves at weaning.

Gordon's principle contribution to the understanding of milk production in beef systems was via Dave Notter's thesis research (Notter et al., 1979a). Their results suggested that for midwestern integrated systems, economic efficiency was relatively insensitive to milk production level. Economic efficiency declined if milk production was low enough to decrease calf survival or high enough to decrease weight weaned per cow exposed due to decreased cow condition and reproduction. Higher milk yield was more economical if breeding cow TDN price was lower relative to feedlot TDN price.

Reproductive Rate. Another by-product of Gordon's multi-species comparisons was his interest in improving the reproductive rate of beef cattle. Comparisons of production costs between beef cattle and species like swine convinced him that, due the high costs of maintaining brood cows, the beef industry had potentially much more to gain from increasing reproductive rate than other species (Dickerson, 1970, 1976).

By the early 1980's Gordon proposed that beef cattle might benefit from genetic improvement of litter size (i.e., twinning) in spite of the low heritability for twinning rate in beef cattle (Dickerson and Willham, 1983). He fully realized the risks associated with multiple births in beef cattle, including increased dystocia, freemartin calves, and increased mortality (Dickerson, 1983). He further understood that increased twinning rate, like most other forms of genetic change, would require adjustments in nutrition and management (Dickerson, 1982b). Using data from an embryo-transfer experiment, he and his coworkers concluded that twinning had the potential to improve economic efficiency by up to 24% (Dickerson et al., 1988; Guerra-Martinez et al., 1990).

Certainly his ideas, and most likely his persistence, influenced the development of the "twinning herd" at the U.S. Meat Animal Research Center, which was established to evaluate the effectiveness of selection for increased twinning as well as to identify the management adaptations required to facilitate increased reproductive rate in beef cattle (Gregory et al., 1990).

Perhaps twinning is one piece of Gordon's vision for the beef industry that has yet to be applied. For most beef producers the problems still outweigh the advantages. However, the current era of rapid structural change in the beef industry may yet find a place for such an "outside the box" idea.

Effects of Mating Systems and Breed Choices on Efficiency

As a geneticist, Gordon's contributions to the understanding of direct and maternal breed effects, heterosis and epistasis rank among his most important works (Dickerson, 1969; 1973). I would guess that these papers have been "standard fare" in graduate animal breeding courses for 30 years. Never one to miss the big picture, seldom did Gordon write about biological objectives or economic efficiency without including the importance of choices among breeds and mating systems (Dickerson, 1970, 1976, 1978, 1982a, 1983, 1984).

The research reported by Notter et al. (1979c) and Núñez-Dominquez et al. (1992) represent his most complete economic studies of crossbreeding systems for beef cattle. These studies clearly demonstrated that economic efficiency was most improved in systems that exploited both individual and maternal heterosis, and that the wise use of terminal sire breeds with smaller maternal breeds was an effective way to reduce or eliminate the negative effects associated with increased lean growth and mature size on maternal performance.

Gordon viewed heterosis as too important to ignore, and saw structured crossbreeding as an important tool by which to manage the biological and economic trade-offs associated with genetic change. I think he would be disappointed in the apparent departure from structured crossbreeding seen in the beef industry today.

Reflections

As a geneticist, Gordon Dickerson had a persistent and unique focus on livestock improvement. His philosophy might be captured in his introduction to the Third World Congress on Genetics Applied to Livestock Production:

> "Perhaps we should not be too critical of the emphasis placed by earlier breeders on pleasing color patterns, horns, and beauty of conformation. Such intangible esthetic rewards for the breeders' efforts are not as easily snatched away by the unfeeling laws of supply and demand, as are the returns from increased efficiency of production. However, to the extent that our role is to help reduce costs of animal products to consumers, we do need to focus on those genetic changes in form and function that are most relevant" (Dickerson, 1986).

Gordon had an amazing talent to appreciate and study the interactions of biological components as they contributed to the function of larger whole systems. In many ways he was ahead of his time. The weight of his contributions lays in that they are still as fresh and valuable today as they were two and three decades ago.

He owned a rare ability to nurture and encourage the best from his students and collaborators. Perhaps his influence on his coworkers was best felt through his questions . . . probing, penetrating questions. For all his brilliance, what made Gordon so easy to respect were his humility and his kind and gentle spirit. He was genuinely interested in others and communicated value to those around him. If he were here today, I'm sure he would praise the contributions of his partners, and discount his own. He never sought the spotlight for himself. He was that kind of man --- a genuinely good man. It remains an honor for me (MWT) to have worked with him.

Figure 1. General equation for bio-economic efficiency for animal production (Adapted from Dickerson, 1970, 1976, 1982a).

$$\frac{\text{Expense}}{\text{Product}} = \frac{\overbrace{(R_d + I_d + B_d \cdot F_{md} + F_{pd})}^{\text{Per breeding female}} + \overbrace{N_o[D_o(I_o + B_o \cdot F_{mo} + F_{po}) + S_o]}^{\text{And her offspring}}}{P_d \cdot V_d + N_o \cdot P_o \cdot V_o}$$

Where,

R_d = annualized replacement cost per breeding female.

I_d = annual non-feed cost per breeding female (i.e., dam).

B_d = average metabolic body size of breeding female.

F_{md} = annual maintenance feed cost per B_d.

F_{pd} = annual above-maintenance feed cost per breeding female.

N_o = annual number of offspring marketed per breeding female.

D_o = days from weaning to market age for offspring.

I_o = daily non-feed cost for offspring during the postweaning period.

B_o = average metabolic body size of offspring during the postweaning period.

F_{mo} = daily maintenance feed cost per B_o.

F_{po} = daily above-maintenance feed cost.

S_o = annual non-feed cost per offspring marketed.

P_d = annual product marketed per breeding female.

V_d = value per unit of breeding female product.

P_o = annual product marketed per offspring.

V_o = value per unit of offspring product.

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BEEF COW EFFICIENCY- REVISITED

T. G. Jenkins and C. L. Ferrell*

Roman L. Hruska U.S. Meat Animal Research Center, ARS, USDA, Clay Center, Nebraska 68933-0166

Introduction

It is comforting to address an issue with a historical signature, e.g., information addressing efficiency being presented by Armsby and Fries (1911). They observed that "type" of an animal affected the ability of that animal to convert feed to weight. Kleiber (1936) identified potential approaches that might affect the efficiency of food utilization by animals. At the symposium sponsored by the British Society of Animal Production with the topic of the relationship between size and efficiency, Robertson (1973) concluded that efficiency must be considered in terms of the function of the producing units. Dickerson (1978) aggregated components of the production cycle to define efficiency in a systems concept. In 1984, Michigan State University and Colorado State University sponsored the "Beef Cow Efficiency Forum" addressing issues such as definition of efficiency, both in biological and economic terms and identification of factors contributing to observed differences. A workshop implemented to evaluate the current awareness of efficiency of food utilization met in Armidale, Australia in May, 2000.

For the discussion today, the challenge is to consider the efficiency of the producing cow. In what context is the term "cow efficiency" to be used? Is this term to be applied at the system level? Can the view that production events occurring during the cow calf phase contributes more to phenotypic variation in beef production efficiency than the postweaning phase of the market animal be supported? If one defines efficiency as the conversion of feed energy resource to a marketable product, earlier results from the Meat Animal Research Center suggests that emphasis on the cow calf phase is appropriate. Feed energy consumption during the cow calf component of the production cycle involving breed crosses differing in genetic potential for post weaning growth, mature weight and milk yield, represented approximately 72% of metabolizable energy consumed during the period from conception to slaughter (Ferrell and Jenkins, 1982). Alternatively, does the industry need to be concerned about the effective use of feed resources by the individual producing female? If the latter, what traits should be identified to measure? Does sufficient phenotypic and genetic variation exist for selection to be effective? What is the relationship between feed efficiency during the postweaning period and cow efficiency? Should component trait improvement be made from within breed selection and efficient cows realized by the commercial producer through mating systems? More critically, is a biologically efficient cow an economically efficient cow? Are ratios such as progeny weaning weight to dam weight or dam weight to some power effective in identifying biologically efficient cows? If ratios can be used, then do traits contributing to the phenotypic variation of the ratio of output relative to input need to be characterized? If the response to this is yes, then the issue may become more focused, namely partitioning the variation into its causal components, genetic and environmental. The anticipated presence of genotype by environment interactions for most traits contributing to the output of the cow calf operation (Butts et al., 1971) further complicates the partitioning of phenotypic variation in production efficiency into its component parts.

The role of the producing cow is to produce progeny of some weight by the end of a variable lactation period. For biological efficiency, productivity may be expressed relative to some measure of input; today a measure of food energy will be considered to be the input. The objective of today's discussion is to review work in the area of beef cow efficiency and identify traits that may contribute to differences in biological efficiency.

Experimental Evidence

To evaluate the conversion of feed to weight of calf at weaning under varying feed environments, a five year study was conducted involving nine breeds of cattle (Jenkins and Ferrell, 1994). These breeds varied in genetic potential for weight at maturity (at 25.0% fat, empty body weight), observed peak milk yield (Jenkins and Ferrell, 1992), post weaning gain and fat deposition potential (Gregory et al., 1994 a,b). Means for these traits are reported in Table 1. To evaluate production efficiency (lb calf weaned/lb dry matter consumed/cow exposed) dry matter intakes and measures of production were recorded for individual mature cows sampled from Angus, Braunvieh, Charolais, Gelbvieh, Hereford, Limousin, Pinzgauer, Red Poll and Simmental breeds of cattle. Four cows of each breed were assigned to one of four dry matter (DM) intake levels: 58, 76, 93, or 111 g DM/Wt$^{.75}$; the daily allotment of feed was established using the cow's initial weight on test. Individuals remained on their assigned feeding levels throughout the study. Calves had minimal access to feed resources other than their dam's milk supply. Calves were weaned at approximately 200 d of age. Component production traits measured included calf birth weights, milk yields, calving rates, weaning weights and cow weights. Breed means for five (5) years for these traits and dry matter intakes are reported in Table 2. On a dry matter basis, the composition of the diet was 77.5%, 17.5 %, and 5.0% of ground alfalfa, corn and corn silage, respectively.

The efficiency ratio in table 2 is mean weaning weight adjusted for conception rate. Output relative to dry matter intake did not differ among the breeds at mean yearly dry matter intakes. However, as reported by Jenkins and Ferrell (1994), feed availability effected the ranking for breed mean efficiencies. At lower feed availability, breeds that were moderate in genetic potential for growth and milk production (Angus, Red Poll, and Pinzgauer) were more efficient because of higher conception rates. Breeds with higher genetic potentials for growth and milk production were less efficient on the lower levels of intake because the cows did not cycle or conceive during the breeding season if they were nursing a calf. However, at the highest levels of feed intake, breeds with the highest genetic potentials for growth and milk production were the most efficient because feed availability was sufficient for the genetic potentials to be expressed. Cows of breeds with more moderate potential effect for milk or growth simply became fatter at the highest feed availability. If the same reranking occurs among cows within breeds, the problem of improving cow effiency becomes more complex.

Table 1. Breed means for traits of interest for nine breeds

Breed	Mature weight, lb[a]	Peak milk yield, lb[b]	Postweaning ADG, lb/d	Fat %[c]
Angus	1217	22.5	2.8	4.00
Braunvieh	1422	33.1	3.0	2.98
Charolais	1521	24.0	3.1	2.80
Gelbvieh	1380	26.0	2.9	2.76
Hereford	1338	19.8	2.8	4.00
Limousin	1300	21.4	2.8	2.65
Pinzgauer	1386	24.0	2.8	3.08
Red Poll	1113	24.5	2.8	3.83
Simmental	1440	29.5	3.1	2.86

[a]Weight adjusted to 25.0% empty body fat.
[b]Yield at time peak lactation as measured by weigh-suckle-weigh.
[c]Percentage fat 9-10-11 rib section at 450 days of age.

Table 2. Breed means for production traits pooled over intake levels and production years[a]

Breed	Cow weight, lb	Yearly dry matter intake, lb	Calving rate[b]	Survival[c]	Birth weight, lb	Weaning weight, lb[d]	Efficiencyl b/lb*100[e]
Angus	1179	8865	0.95(.22)	0.84(.37)	77	372	3.99
Braunvieh	1256	9640	0.82(.38)	0.87(.33)	108	436	3.71
Charolais	1488	9907	0.73(.45)	0.94(.22)	104	469	3.46
Gelbvieh	1285	9813	0.88(.32)	0.87(.34)	97	419	3.76
Hereford	1261	9052	0.81(.40)	0.90(.30)	82	357	3.19
Limousin	1247	9323	0.87(.33)	0.93(.26)	93	415	3.87
Pinzgauer	1179	9104	0.86(.35)	0.94(.24)	104	443	4.18
Red Poll	1045	8743	0.96(.19)	1.00(0)	86	427	4.69
Simmental	1300	9574	0.81(.39)	0.80(.40)	104	417	3.53

[a]Based on 16 observations/breed/year for 5 years (4 cows/intake levels within breed).
[b]Per cow exposed.
[c]Per calf born.
[d]Per calf weaned.
[e](Lbs of calf weaned per cow exposed per lbs of dry matter consumed)*100.

Provided with this information that ranking among breeds varies with feed availability, it becomes readily apparent that a general discussion about genetic sources of variation on production efficiency becomes quite meaningless if considered in the context of a simple ratio. Production efficiency is a composite trait. Genetic variation expressed in this ratio represents a summation of the genetic variation among the constituents of this composite. This index, efficiency, is dependent upon the system. The definition and the partitioning of the observed phenotypic variation does not lend itself to a simple additive model. The question to be addressed is how do the four traits (mature weight, postweaning ADG, peak milk yield, and ability to fatten) used to characterize the breeds in the study reported affect cow efficiency and then identify other traits that may be considered as additional sources of variation.

Discussion of Traits of Interest

Mature weight and post weaning gain. Variation between and within breeds for asymptotic weight has been documented by numerous researchers (Brown et al., 1972; and Jenkins et al., 1991) and post weaning gain (Woldehawariat, 1977). Previous discussions considering the affect of size on efficiency have suggested that cow size per se does not does not affect efficiency directly but there can be indirect effects. Robertson (1973) concluded that the question of size and efficiency of dairy production was academic while Dickerson (1978) pointed out numerous ways that differences in body size may affect production efficiency. Among breeds of similar lactation potential, the preweaning gains of the Charolais and Limousin were greater than the more moderate size Angus and Hereford. The genetic correlation between weights at young ages and mature size is positive both between breeds and within breeds (Brown, Brown and Butts, 1972; Thiessen, 1986).

The positive genetic correlation between weight at maturity and birth weight negatively affect efficiency when excessive calf birth weights adversely affect reproduction. Cundiff et al. (1986a) reported significant breed of sire effects for gestation length, birth weights, calf survival and dystocia in a study involving 14 breeds of cattle. Higher birth weights, incidence of dystocia and lower calf survival rates were observed among breeds with heavier mature weights.

Factors that affect the energy required for production either directly or indirectly influence the efficiency ratio. Larger mature size is associated with greater daily energy requirement for maintenance, a direct influence. The energetic needs for production are increased. If energy availability is limiting in mature beef cows, low birth rate of cattle be further compounded by reduced reproductive performance, which may be attributed to greater energetic restriction resulting from larger body size and associated increased requirements for maintenance. This reduction in reproductive effectiveness represents an indirect influence on efficiency. As evidenced in the study reported here and the study of Morris et al. (1993), as the nutritional environment becomes limiting reproductive performance declines. The composite trait, calving rate, can be decomposed into traits such as postpartum interval, ovulation rate, conception, dystocia and postnatal survival. Nugent et al. (1993) characterized the nine breeds of this study according to mature weight and lactation potential to investigate the interaction between biological type and dry matter intake on postpartum interval. At the lower energy intake levels, extended postpartum intervals were observed for the biological types with heavier mature weights.

Lactation. Genetic variation for lactation traits has been managed to alter yield at time of peak lactation and total lactation yield both for breeds within the dairy and beef cattle industry. Provided adequate nutrition levels, the correlation between milk yield and efficiency was reported as 0.38 for beef cattle (Nedava 1970, as reported by Taylor, 1973). The direct effect of higher lactation yields is through the increase in weight of calf weaned.

As with increased genetic potential for mature size and post weaning growth, increased genetic potential for peak milk yield affects the efficiency ratio. This effect is mediated both through increased output and higher energy requirements; a readily apparent increase in energy requirement associated with higher yields plus an indirect increase associated with higher maintenance energy requirement that is expressed during lactation (Nelville, 1974). Additionally, higher maintenance requirements per unit metabolic size in non lactating cows characterized as having higher milk production potential have been reported (Ferrell and Jenkins, 1985; Taylor et al., 1986; and Montaño-Bermudez and Nielsen, 1990). This greater energetic need may affect the cow efficiency through introduction of an energetic constraint to reproduction by extending the post-partum interval and reducing fertility. Coupling large mature size and increased per unit cost associated with milk production potential creates a major constraint on the efficiency of production for a cow herd.

Available information suggests that increased milk production potential may offset part of the effect of increased mature size on component traits of reproduction. Morris et al. (1993) observed younger ages at puberty in Friesian cross females than for lower milking Chianina, Limousin, Charolais, and Blonde d'Aquaintaine crosses. Among cows characterized a having genetic potential for larger mature size, Nugent et al. (1993) reported the response to increasing dry matter intake on length of postpartum interval was more immediate for biological types with greater milk production potential.

Lean to fat. Cundiff et al. (1986b) reported differences in proportion of fat and lean yield among 19 breed crosses. Gregory et al. (1994b) documented breed variation exists for fat deposition at time of slaughter among the nine breeds reported earlier. Estimates of empty body composition from mature cows at various levels of dry matter intake indicate variation in the ability to deposit fat (Table 3). Observed breed differences in lean:fat at varying ages may be indicative of variation among breeds for appetite. Based on an evaluation involving 25 breeds, Thiessen et al. (1984) reported a genetic coefficient of variation for *ad libitum* intake of approximately 0.12 – 0.15 for cattle ranging from 12 to 72 weeks. Assuming that feed intake is proportional to mature weight to 0.73 power, then variation among breeds may be evaluated for animals fed *ad libitum* that are in weight equilibrium (Taylor et al., 1981). Using feed intake and weight data from the *ad libitum* animals at weight stasis during the second phase of the cow efficiency study this proportionality held among mature cows of the nine breeds; daily dry matter intake = $0.429Wt^{.73}$. The constant is an index of the relative food capacity of mature animals (Kleiber, 1961) and should characterize the genetic potential for appetite. Breed estimates of the regression constant ranged from a high of 0.493 for Angus to a low of 0.429 for Limousin suggesting substantial genetic variation in appetite. (Table 4).

Table 3. Body components relative to empty body for nine breeds fed at four intake levels (%)

	Feeding rate g DMI/kg$^{.75}$							
	58				76			
	Water	Prot	Fat	Ash	Water	Prot	Fat	Ash
Angus	58.5	15.7	20.0	5.6	45.8	15.0	34.5	4.7
Braunvieh	642.	17.3	12.0	6.5	59.4	16.9	18.1	5.6
Charolais	62.3	17.5	13.7	6.5	60.2	17.2	16.8	5.8
Gelbvieh	64.4	17.6	12.2	5.8	58.2	16.8	19.5	5.5
Hereford	57.8	16.1	20.6	5.5	55.2	16.4	23.0	5.4
Limousin	66.4	17.7	9.8	6.1	59.6	16.8	18.6	5.0
Pinzgauer	60.5	17.0	16.6	5.9	56.2	16.2	21.8	5.7
Red Poll	66.7	17.3	9.1	6.9	59.1	16.6	18.5	5.8
Simmental	66.4	17.6	9.7	6.3	60.7	17.6	16.0	5.7
	Feeding rate g DMI/kg$^{.75}$							
	93				111			
	Water	Prot	Fat	Ash	Water	Prot	Fat	Ash
Angus	52.1	15.1	28.0	4.8	48.2	14.3	32.9	4.6
Braunvieh	52.3	15.4	27.4	4.9	54.9	15.7	24.5	4.9
Charolais	51.0	15.1	29.3	4.6	58.3	16.7	19.6	5.4
Gelbvieh	58.9	17.3	18.1	5.6	55.7	16.4	22.9	5.0
Hereford	53.9	15.6	25.4	5.1	50.9	14.9	29.1	5.1
Limousin	56.0	16.2	22.9	4.9	58.1	16.9	20.1	4.9
Pinzgauer	49.9	14.8	30.8	4.5	49.7	14.4	31.1	4.8
Red Poll	51.7	15.3	28.1	4.9	51.0	14.7	29.6	4.7
Simmental	53.8	15.7	25.7	4.8	56.4	16.9	21.5	5.2

In general, breed ranking for body fat at 450 d (Table 1), was similar to the ranking among the breeds for appetite, with Angus, Hereford and Red Poll being of higher rank for appetite. The exception to this trend was Charolais who tended not to deposit fat during the post weaning period but whose estimate of appetite was similar to the Angus, Hereford and Red Poll. At the more restricted levels of dry matter intake, there was a tendency for those breeds exhibiting greater appetite potential at the *ad libitum* levels to exhibit greater reproductive success.

Table 4. Relative appetite differences among nine breeds of cattle (dry matter intake regressed on body weight to 0.73)

	Constant
Pooled	0.429
Angus	0.493
Braunvieh	0.423
Charolais	0.480
Gelbvieh	0.425
Hereford	0.454
Limousin	0.367
Pinzgauer	0.412
Red Poll	0.465
Simmental	0.409

[a]lb DM/Wt$^{0.73}$

Maintenance

Variation in cow production efficiency was demonstrated among nine breeds of cattle that differed in genetic potential for mature size and post weaning gain, lactation and fattening ability as the nutritional environment varied. Maximum efficiencies within breeds occurred at intake levels that did not limit reproduction of the cows, and provided sufficient energy for milk yields to meet the growth potential of the breed as expressed in the calf. At lower intake levels, differences among in the breeds in maintenance requirements contributed to differences in efficiency. Energy expended for maintenance is influenced by intake levels. Animals of greater genetic potential for productivity exhibited less ability to reduce maintenance requirements in response to reduced feed availability (Frisch and Vercoe, 1977; Taylor et al., 1986). Ferrell and Jenkins (1985) reported that during the postweaning phase Simmental were less efficient than Hereford at restricted levels but at *ad libitum* intakes more efficient. Jenkins et al. (1990) demonstrated that a breed with greater potential for mature size and lactation yield had greater daily heat production at restricted feeding rates than a breed with lower production potential. However, as rate of dry matter intake per unit weight increased, the ranking reversed between the two breeds.

If feed utilization is to be improved, reducing the amount of energy expended on maintenance without reducing appetite appears to be desirable. A measure of energy expenditure for maintenance, fasting heat production, has been shown to be moderately heritable (.25-.30; Nielsen et al., 1997a) in mice. By mating males of highest or lowest rank for fasting heat production, these researchers significantly changed the mean heat energy loss in the selected population by the fifteenth generation. As pointed out by the authors, the cost of measurement prevents this protocol from being adopted for use in an industry selection program. Byerly (1941) in poultry and Koch (1963) in beef cattle proposed adjusting feed intake of an animal for predicted requirements for performance and maintenance thus enabling individual animals of higher rank for efficiency to be identified. This approach, now referred to as residual feed intake, has been evaluated by poultry and dairy scientists, e.g.; Sabri et al., 1991 and Ngwerume and Mao (1992). Currently, a large study is being conducted in Australia to improve feed efficiency in beef cattle (see Feed Efficiency in Beef Cattle, 2000). Selection for residual feed intake (RFI) is applied during the postweaning period and favorable responses in feed efficiency have been reported for both the postweaning period and in the producing female.

An implicit assumption to application is the energy expenditure associated with maintenance is constant relative to a scaled measure of weight. As part of the 5-year study to evaluate production efficiency, the maintenance efficiencies (weight maintained per day per unit energy, Taylor et al., 1986) for the nine breeds were determined at the four feeding rates. Following the last calf crop, cows were allowed to remain open and continued to receive their assigned ration. Weight stasis (maintenance) was defined as a constant weight sustained for over 8-week period. A significant breed by feeding level interaction was observed for maintenance efficiency, the amount of weight maintained per unit of energy consumed. All breeds exhibited the highest level of maintenance efficiency at the most restrictive feeding rate, with the exception of the Red Poll, (Table 5). In general, as level of feed availability increased, the efficiency of maintenance declined. It is interesting to note that the breed most efficient at the lowest level of feed intake, the Red Poll, were the least efficient in maintaining body weight at the restricted level. As feed became more available, their maintenance efficiency did not change. This is significant because researchers selecting to lower the energy requirements associated with maintenance have reported unfavorable correlated responses in traits important to female performance. Among mice selected for lower fasting heat production during the postweaning period, Nielsen et al. (1997b) reported body mass similar to mice selected for high heat production, lower feed intake, greater empty body fat percentage, reduced ovulation rate and a decrease in litter size. These results imply that selection criteria to reduce the maintenance requirements of the producing females could have a negative effect on reproductive performance.

Table 5. Least squares means for maintenance efficiency by breed and feeding rate[a]

	Feeding rate (g DMI/kg$^{.75}$)			
	58	76	93	111
Angus	14.3	13.6	12.6	11.6
Braunvieh	15.7	11.5	11.2	14.3
Charolais	14.2	11.7	10.9	11.0
Gelbvieh	14.6	10.0	10.0	11.2
Hereford	14.6	11.9	11.9	12.0
Limousin	13.0	10.1	13.0	14.6
Pinzgauer	15.7	12.3	12.1	14.3
Red Poll	11.8	11.7	11.1	12.4
Simmental	14.5	11.3	9.3	12.5

[a]Maintenance efficiency = weight of cow (lb.) maintained per daily ME intake, Kcal.

Conclusion

Variation exists among cattle populations to improve the conversion of feed resources to a final product. A biologically efficient cow is one producing a calf each year she remains in the cowherd. The nutrition-reproduction axis may influence this success. Energy expenditure for maintenance may affect the reproduction of the cow. Energy expenditure for maintenance appears to be correlated to genetic potential for mature size and lactation. At restricted feed availability, an increase in maintenance efficiency among breeds with greater potential for size can be associated with longer postpartum periods for mature cows resulting in a lower reproductive rate thus lowering cow efficiency. At lower intakes, variation in milk production exists among breeds with higher milk production potential, resulting in lowered efficiency of gain for calves with higher growth potential.

Sufficient additive variation exists to alter fasting heat production in cattle, and selection criteria are being evaluated that allow “non-productive” energy expenditures to be reduced. More information to clarify the definition of an efficient cow, selection protocol, and potential correlated responses is needed. Genotype by environment interaction (abundant vs sparse nutritional testing environment) potential effects on cow efficiency requires investigation.

Rather than seeking to reduce energy requirements for maintenance, perhaps stabilizing these requirements over a wide range of nutritional scenarios is more desirable. Enhancing an animal’s genetic potential to conserve energy under sparse energy environments (feed resources and/or body fat) could be counterproductive to developing an efficient cow. Do other approaches to improving cow efficiency exist?

With genomic information increasing every day, what phenotypes can we measure to associate with bovine gene map? Using genomics information, will we be able to identify heifers that are well suited to producing a calf every year within a defined production environment? An efficient cow for one producer may be ineffective under a different management program.

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DETERMINING POST-WEANING FEED EFFICIENCY IN BEEF CATTLE

D. G. Fox, L. O. Tedeschi, and M. J. Baker
Department of Animal Science
Cornell University

Introduction

Feed efficiency can be described as the efficiency of use of the energy consumed from the ration fed for maintenance and growth. Selection procedures are needed that result in identifying animals with improved efficiency of use of absorbed (metabolizable) energy for maintenance and growth without altering body weight at the target chemical composition. However, it is not practical to determine feed metabolizable and net energy values for maintenance and growth for individual animals on farms. Therefore indirect measures must be used to estimate energetic efficiency. We can compute the average expected feed required for the observed daily gain and body weight, using equations developed from experimental data to predict average expected maintenance and growth requirements for the observed body weight and daily gain, and net energy values derived from feeds (Guiroy et al., 2001; Perry and Fox, 1997). Individually fed animals that consume less than the average across a group being evaluated for feed efficiency would have a higher efficiency of use of the feed consumed and/or a lower maintenance requirement; those with a higher intake than expected would likely have a lower efficiency of use of the feed consumed and/or a higher maintenance requirement. Residual feed intake (RFI) has been proposed as a procedure to estimate this difference by subtracting observed DMI of an individual from DMI predicted by an equation developed from the relationship between DMI, ADG and metabolic mean body weight across individually fed contemporaries (Archer et al., 1999; Carstens et al., 2002). In most progeny tests, however feed efficiency for individual animals must be estimated from information available for animals fed in pens under typical feedlot conditions. In this case, a ratio of expected feed required to the observed gain is the only practical measure of feed efficiency. Because our feed required procedure accounts for differences in the effect of body weight and composition of gain on energy requirements, animals with a lower feed to gain ratio may have had a greater intake over maintenance, a greater efficiency of use of the energy consumed, or a combination of both.

Accurate determination of feed required for the observed growth to the target body composition requires accounting for factors affecting animal requirements and feed energy values for maintenance and growth. This paper focuses on determination of feed required for individual animals when pen-fed, using the Cornell Value Discovery System (CVDS), which is a mechanistic model we have developed for that purpose.

Predicting animal requirements and feed energy values

Because of the wide variations in breed types and their crosses used for beef production in North America and environmental conditions in which they are fed prior to marketing as finished beef, modeling systems to predict feed requirements and cost of gain must be able to account for differences in basal maintenance requirement, the effect of environment on maintenance requirement, the effect of body size, implant program and feeding system on finished weight and growth requirements, feed energy values, and dry matter consumption.

Accounting for body composition at the marketing target. The critical first step for predicting feed required for the observed growth and incremental cost of gain and body composition as cattle grow is to identify the body composition at the marketing target. Carcass value in most markets and cost of gain can be related to proportion of protein and fat in the carcass. Body fat in finished cattle when marketed typically varies from 16 to 21% empty body fat (EBF) in the French (INRA, 1989) and Brazilian (Leme et al., 2000) markets to over 30% EBF in segments of the Japanese and Korean Markets. Most other markets range between these two. The single most recognizable quality grade in the world is USDA choice. Premium brand name products typically utilize the prime and upper 2/3 of the Choice grades and are increasing the value of U.S. beef products. Table 1 shows a summary of data from our experiments (Guiroy et al., 2001) that support the value of the Choice and prime grades level of fatness to minimize the percent of the beef that is unacceptable to consumers in the U.S.

Table 1. Relationship of carcass and empty body fat to quality grade (total of 1,355 animals; Guiroy et al., 2001). Values in a row are means for that grade

Number of animals	USDA Quality Grade [a]	Mean carcass fat, %	Mean EBF [b], %	EBF SEM	Taste panel score [c]	Percent unacceptable [c]
45	3.5	23.55	21.13^{u}	0.63	5.3	40
470	4.5	28.98	26.15^{v}	0.19	5.6	13
461	5.5	31.64	28.61^{w}	0.20	5.8	8
206	6.5	33.02	29.88^{x}	0.29	6.2	0
90	7.5	34.23	31.00^{xy}	0.44	-	-
51	8.5	35.24	31.94^{y}	0.59	-	-
32	9.5	35.80	32.45^{z}	0.74	-	-

[a] Standard = 3 to 4; Select = 4 to 5; low Choice = 5 to 6; mid Choice = 6 to 7; high Choice = 7 to 8; low Prime = 8 to 9; mid Prime = 9 to 10.
[b] Column means with different superscripts are significantly different at P < 0.05.
[c] Taste panel scores (from 1 to 8) and percent unacceptable values are from a subset of this data base.

This analysis showed that EBF was significantly ($P < 0.05$) higher with each incremental increase in grade up to the mid Choice grade. Taste panel scores and percent unacceptable followed the same trend. This data also indicated we can correlate grade to changes in body composition as cattle grow. The most critical factor in this table for our model is the percent EBF at Standard (21.1%), Select (26.2%), and low Choice (28.6%) USDA grades since these are the body composition endpoints for different marketing targets used to identify feed requirements during growth.

Accounting for differences in requirements for growth. Previous studies indicate cattle of different mature sizes have different fat and protein content of the weight gain at the same weight during growth (Fox and Black, 1984). Therefore we developed a size-scaling procedure to account for differences in energy and protein requirements for growth among cattle of different frame sizes and sexes (Fox and Black, 1984; Fox et al., 1988; Fox et al., 1992; Fox et al., 1999; Tylutki et al., 1994) which was adapted by the National Research Council Nutrient Requirements of Beef Cattle (NRC, 2000). This growth model was also found to be accurate for predicting requirements for dairy heifers (Fox et al., 1999), and was adapted for use in the Nutrient Requirements of Dairy Cattle (NRC, 2001). In this model, the animal's weight at 28% fat (or mature weight if replacement heifers) is divided into the weight of the standard reference animal at that composition. This ratio is then multiplied by the animal's actual weight to adjust it to the standard reference animal for use in the energy requirement equation developed by NRC (1984). The standard reference animal represents the cattle body size used to develop the equations to predict the net energy content of weight gain.

Table 2 shows an example of requirements for growth computed with this model for two mature sizes of cattle. This table shows that as mature size increases, weight at the same energy content of gain increases, because larger size animals are at an earlier stage of growth at the same weight and therefore have more protein and less fat in the gain. It also shows that energy requirements increase with increasing stage of growth and rate of gain.

Table 2. Relationship of stage of growth and rate of gain to body composition

28% fat weight, lb	Weight during growth, lb		
1100 lb	600	800	1000
1300 lb	708	944	1180
% of 28% fat wt.	55	73	91
ADG, lb/day	Net energy required, Mcal/day		
2.0	3.23	4.01	4.74
3.0	5.04	6.26	7.40
4.0	6.92	8.58	10.14

Three data sets were used to test this system (NRC, 2000). With two of the data sets (82 pen observations of *Bos taurus* implanted steers and heifers varying in breed type, body size and diet type and 142 serially slaughtered nonimplanted steers, heifers and bulls varying in body size aggregated by slaughter groups), this system accounted for 94% of the variation in energy retained with only a 2% underprediction bias.

however, it cannot be assumed that this accuracy will apply to individual animals at a particular point in time during growth, since these results were obtained from pen averages and total energy retained. Many factors can alter estimates of finished weight of individuals, such as previous nutrition, implant programs, level of intake and energy derived from the diet, limits in daily protein and fat synthesis, and daily energy retained. The challenge is to be able to predict those effects in individual animals based on information that will be available in feedlots and is practical to apply. As a first step, Guiroy et al. (2002) has developed adjustments to finished weight for the effect of anabolic implants, which changes the finished BW from 31 to 92 lb for steers and 66 to 85 lb for heifers, depending on implant strategy.

Accounting for differences in requirements for maintenance. The model used for this purpose is described by Fox and Tylutki (1998). The effects of breed type are accounted for by adjusting the base NEm requirement of 77 kcal/kg$^{0.75}$ BW for *Bos indicus* and dairy types (-10 and +20% compared to *Bos taurus*). The effects of previous nutrition are accounted for by relating body condition score to NEm requirement. On a 1 to 9 scale, maintenance requirement is reduced 5% for each condition score below 5 and is increased 5% for each score above 5. The effects of acclimatization are accounted for by adjusting for previous month's average temperature (ranges from 70 kcal/kg$^{0.75}$ BW at 30 °C to 105 kcal/kg$^{0.75}$ BW at -20 °C). This adjustment is continuous, with no effect at 20 °C. Current environmental effects are accounted for by computing heat lost vs heat produced, based on current temperature, internal and external insulation, wind, and hair coat depth and condition. This becomes important when the animal is below the computed lower critical temperature, and can range from no effect at 20 °C to twice as high (thin, dirty hide at -12 °C and 1 mph wind).

Determining ration energy values. Accurate predictions of dry matter intake (DMI) and NEg are highly dependent on having feed net energy values that accurately represent the feeds being fed. Tedeschi (2001) evaluated the accuracy of alternative methods for determining feed energy and protein values: NRC level 1, which uses tabular values; NRC level 2, which uses the Cornell Net Carbohydrate and Protein System (CNCPS) model; and a summative equation commonly used by feed analysis laboratories to predict feed energy values from chemical composition (Weiss, 1993, 1999; Weiss et al., 1992). The regression analyses of observed and predicted ADG are shown in Table 3.

Metabolizable energy (ME) was predicted by the CNCPS to be first limiting in 19 treatment groups. Across these groups, the observed ADG varied from 1.76 to 3.17 lb/d (0.8 to 1.44 kg/d). When ME was first limiting, the ADG predicted by the CNCPS model accounted for more of the variation (80%) than did the summative equation or tabular (73 and 61%, respectively). Metabolizable energy allowable ADG predicted with the tabular system gave an overprediction bias of 11%, but the bias was less than 2% when predicted with the CNCPS or summative equation. The MSE were similar in all predictions, but the CNCPS model had the highest accuracy (lowest RMSPE). Metabolizable protein was predicted by the CNCPS to be first limiting in 28 treatment groups (Table 3). Across these groups, the observed ADG ranged from 0.26 to 3.0 lb/d (0.12 to 1.36 kg/d). The ADG predicted by the CNCPS model accounted for more of the variation (92%) than did the summative equation or tabular (79 and 80%, respectively). Metabolizable protein-allowable ADG predicted with the tabular gave an overprediction bias of 4%, whereas the bias was less than 2% when predicted with the CNCPS or summative equation. Similar to the ME first limiting analysis, the CNCPS model had the highest accuracy (lowest RMSPE: 0.11).

Table 3. Evaluation of the use of feed tabular energy values or predicted by a summative equation or by the rumen fermentation simulation model of the Cornell Net Carbohydrate and Protein System (CNCPS) to estimate ADG (kg/d) when ME or MP are first limiting[a]

	ADG, kg/d			Regression statistics [b]			RMSPE
	Min.	Mean ± SE	Max.	r^2	MSE	bias,%	
ME first limiting (n = 19)							
Observed	0.80	1.11 ± 0.04	1.44	-	-	-	-
NRC, 2000	0.73	1.25 ± 0.06	1.78	0.61	0.01	-11.4*	0.23
Weiss et al., 1992	0.74	1.13 ± 0.06	1.62	0.73	0.01	-2.2	0.14
CNCPS v. 4.0	0.79	1.10 ± 0.05	1.48	0.80	0.01	0.4	0.10
MP first limiting (n = 28)							
Observed	0.12	0.78 ± 0.07	1.36	-	-	-	-
NRC, 2000	0.11	0.81 ± 0.09	1.78	0.80	0.03	-4.3	0.21
Weiss et al., 1992	0.13	0.78 ± 0.09	1.73	0.79	0.03	-0.5	0.22
CNCPS v. 4.0	0.12	0.77 ± 0.07	1.45	0.92	0.01	1.9	0.11

[a] Data were obtained from Boin and Moura (1977), Fox and Cook (1977), Danner et al. (1980), Lomas et al. (1982), Abdalla et al. (1988), Ainslie et al. (1993), and Wilkerson et al. (1993) (only in the MP sub-dataset evaluation).
[b] Observed values (Y) were regressed on predicted ADG (X) using tabular TDN (NRC, 2000) or predicted TDN by the Weiss et al. (1992) equation or CNCPS v. 4.0. A positive bias means that Y values (observed) are greater than X values. MSE is the mean square error from the regular regression, SE is the standard error, and RMSPE is the root of the mean square prediction error. Asterisks indicate statistical difference from zero using the t-test (unequal variance) at α=0.01 (**), α=0.05 (*), or no difference (no asterisk).

Predicting individual animal feed requirements

The system of equations we developed (Guiroy et al., 2001) to predict individual animal feed requirements is summarized in Table 4, which is implemented in the Cornell Value Discovery System (Tedeschi et al., 2002). Feed net energy values used in this model are determined as described in the previous section.

Individual feed required is the sum of the feed required for maintenance (FFM), and the feed required for growth (FFG). Feed for maintenance is a function of the net energy required for maintenance and the net energy value of the diet for maintenance (NEm). Similarly, FFG is a function of the energy retained in the weight gain (NEg) and the NEg concentration of the diet. Animal differences in mature body size are accounted for as described previously. Perry and Fox (1997) and Guiroy et al. (2001) presented a detailed description of the development of these equations. Table 5 shows a summary of the calculations for an actual Angus steer fed in a group pen.

Table 4. Equations to predict individual dry matter requirements[a]

(1) EBW = 1.316 HCW + 32.29; (Garrett, 1987)

(2) EBF, % = 17.76207 + 4.68142 FT + 0.01945 HCW + 0.81855 QG – 0.06754 LMA

(3) AFSBW = (EBW + ((28 - EBF%) x 14.26)) / 0.891

(4) EQSBW = SBW (478/AFSBW); (NRC, 2000)

(5) RE = 0.0635 x $EQEBW^{0.75}$ x $EBG^{1.097}$; EQEBW is 0.891xEQSBW; (NRC, 2000)

(6) FFG = RE/diet NEg

(7) FFM = NEm required/diet NEm; NEm required can be calculated as described by Fox et al. (1992) and NRC (2000)

(8) Individual DM required is FFM + FFG

(9) Adjusted individual DM required = individual DM required x (total actual pen DM consumed/ total pen DM required)

[a] EBW = empty body weight; EBF = empty body fat; FT = fat thickness (cm); HCW = hot carcass weight; QG = quality grade; LMA = *Longissimus dorsi* muscle area (cm^2); SBW = shrunk body weight; AFSBW = weight at 28% body fat; EQSBW or EQEBW = shrunk or empty body weight equivalent to the standard reference animal; EBG = empty body gain; RE = retained energy, Mcal/day; FFM = feed for maintenance; FFG = feed for gain; and DM = dry matter.

Evaluation of the CVDS feed required model. The set of equations to predict dry matter required by individuals (Table 4) was evaluated with data from the studies of Nour (1982), Perry et al. (1991), Perry and Fox (1997) and Guiroy et al. (2001). This data set included 365 individually fed steers of diverse biological types in which chemical body composition was determined and carcass measurements were taken, and complete information on feeds fed were available to accurately predict diet net energy values in each experimental group. Guiroy et al. (2001) presented a complete description of this data base.

Table 5. Example calculation with the feed requirement model[a]

Inputs	Results
Initial shrunk weight = 713 lb	Daily gain = 4.64 lb
Final shrunk weight = 1265 lb	28% fat weight = 1241 lb
Days on feed = 119	Net energy for gain = 10.82 Mcal/day
Hot carcass weight = 803 lb	Feed DM for gain = 17.64 lb/day
Quality grade = 5.0	Net energy for maintenance = 6.83 lb/day
Rib eye area = 79.4 cm2	Feed DM for maintenance = 7.49 lb/day
Backfat depth = 1.5 cm	Total feed DM required = 25.16 lb/day
Diet NEm = 0.91 Mcal/lb	Feed efficiency = 5.42
Diet NEg = 0.61 Mcal/lb	

[a] Group inputs included pen dry matter intake for the entire feeding period, and ration NEm and NEg values.

We evaluated DM requirements predicted by the Cornell Value Discovery System against actual DM consumed (Guiroy et al., 2001). The equations presented in Table 4 accounted for 74% of the variation in actual DM consumed, with essentially no bias (0.34%) and a coefficient of variation of 8.18%.

The equation shown in Table 4 to predict EBF percentage from carcass measurements commonly taken in U.S. packing plants was developed with a large database (Guiroy et al., 2001). This equation accounted for 61% of the variation in EBF with a coefficient of variation of 11.9% and no bias since the intercept and the slope of the regression equation were not different ($P > 0.10$) from zero and one, respectively. This equation was validated with a separate data base of 951 steers and heifers from a variety of breeds and diets fed; it explained 51% of the variation in EBF%, with a coefficient of variation of 10.7% and no bias. The 39% of the variation in EBF in the development data base and 49% of the variation not explained by this equation in the evaluation data base can be explained by the variation in the carcass measurements used by the equation at a similar empty body fat (Guiroy et al., 2001). When the same analysis to predict individual feed requirements evaluated using this predicted rather than the observed EBF (%), the variation accounted for by the model was not reduced. This result indicates that we can accurately predict individual feed requirements using a prediction of EBF from carcass measurements available from U.S. packing plants.

However, an alternative approach is needed to predict AFSBW. A small data set was available to evaluate the ability of model equations that use hip height and age to predict AFSBW. The data set consisted of 29 bulls of five different breeds fed to finished weights. When only SBW, hip height and age were available to predict AFSBW, the regression accounted for 58% of actual AFSBW variation. However, when carcass measurements from ultrasound on the live animal were used to generate inputs for the equation of Guiroy et al. (2001) to predict AFSBW, the regression between observed and predicted AFSBW had an r^2 of 0.75. Feed required for the observed ADG with AFSBW computed with hip height and age or with ultrasound used to predict carcass fat depth, rib eye area and quality grade accounted for 93 and 96%, respectively of the variation in feed required with AFSBW computed from actual carcass measures. These results suggest the use of ultrasound can be used to obtain fat depth, rib eye area, and marbling values required by the Guiroy et al. (2001) equation to predict AFSBW.

In common feedlot situations, each owner owns more than one animal in a pen. Therefore a concern is the accuracy of predicting the total of their animals' share of the total feed consumed by the pen. A reduction in the error of prediction of DM required is expected when predicting groups of animals instead of individuals within a pen. To measure this reduction, the predicted and observed individual DM requirements of the 365 individually fed animals used to validate our feed allocation model were summarized by groups of 5, 10, 20, 40, or 80 animals; these groups were randomly created for this analysis. The coefficient of variation was reduced more than 50% (from 8.18 to 3.76%) when predicting DM required for groups of 5 animals instead of individuals, and was less than 2% in groups of more than 20 animals. This analysis showed that even though we can account for 74% of the variation in individual animal feed requirements with a coefficient of variation of 8.18, the error in our prediction is greatly reduced when predicting groups of animals, which is an important concept for producers using this system to allocate feed consumed among groups of cattle within a pen.

A feedlot data set of 12,105 steers and heifers was developed to evaluate the feed allocation model in the CVDS. The feedlot data was provided by Dr. Matt Cravey, Micro Beef Technologies, Inc. (Amarillo, TX), which was collected with their computerized electronic individual cattle-tracking system. Total feed DM delivered vs the sum of each individual animal predicted DM required was compared using our model. Results from this evaluation shows DM required was predicted with very little bias with our modified model (underprediction of –0.91% for steers, and overprediction of 0.89% for heifers). The small bias for each sex indicates the model works equally well for steers and heifers. An underprediction bias of up to 2% in the total DM consumed by feedlot cattle can be expected due to feed fed that was lost and not consumed by cattle (bunk cleaning, wind, etc). A bias is also expected by using a fixed maintenance requirement of 0.077 Mcal/d/kg$^{0.75}$ SBW, which likely varies within and between feedlots due to animal interactions with actual environmental conditions. However, in this data set evaluated, the effects of environment are accounted for in the diet NEm and NEg provided by the feedlot consultant, since those values reflect diet NE values required to have predicted and observed ADG agree in the historical data base used to develop their performance projection program.

Using the Cornell Value Discovery System DAYSTEP model to predict feed required over the same stage of growth

During most post-weaning growth programs (progeny tests in feedlots; bull tests) calves are fed for either a fixed period of time (bull and heifer tests; commodity fed in commercial feedlots) or until finished (individual cattle management systems; ICMS). For example, a calf fed post weaning from 500 to a 28% fat weight of 1200 lb had a mean body weight of 850 lb (71% of 28% fat weight), while another calf fed from 700 to a 28% fat weight of 1200 lb had mean body weight of 950 lb (79% of 28% fat weight). The expected feed required for the second calf would reflect an average higher fat content of the gain because of being farther along the growth curve when started. Therefore adjustments are needed to be able to compare their feed requirements over the same stage of growth.

The CVDS contains a DAYSTEP model that utilizes the maintenance and growth and feed energy models described previously along with an feed intake model to predict daily gain, body weight, and feed required on a daily basis as an animal grows (Fox et al., 2001; Tedeschi et al., 2002) to their observed final weight. Because the CVDS model computes daily energy requirements, DMI, and body weight, the computation of the predicted feed required during a common stage of growth (from 60 to 80% of mature or finished weight) for each animal allows us to compare animal performance, accommodating the wide range of post-weaning feeding programs under which progeny are evaluated.

Within the CVDS is a DAYSTEP model that predicts DMI and ADG for each day while on feed. The predicted DMI is iterated until predicted and observed ADG of that period match. The predicted DMI is internally interpolated using the relative DMI (RDMI) factor. Then feed required is computed from 60 to 80% of their 28% fat weight. The NRC (2000) provided DMI equations that can be used to account for the effects of variables that influence individual animal performance in each production situation: diet energy density, degree of maturity, and environment (temperature and mud effects). Therefore, we used a modified version of the DMI equations and adjustments adopted by NRC (2000) in our DAYSTEP model. Table 6 summarizes the sequence of calculations in the DAYSTEP model used to predict days required to reach a target composition.

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Within the CVDS is a DAYSTEP model that predicts DMI and ADG for each day while on feed. The predicted DMI is iterated until predicted and observed ADG of that period match. The predicted DMI is internally interpolated using the relative DMI (RDMI) factor. Then feed required is computed from 60 to 80% of their 28% fat weight. The NRC (2000) provided DMI equations that can be used to account for the effects of variables that influence individual animal performance in each production situation: diet energy density, degree of maturity, and environment (temperature and mud effects). Therefore, we used a modified version of the DMI equations and adjustments adopted by NRC (2000) in our DAYSTEP model. Table 6 summarizes the sequence of calculations in the DAYSTEP model used to predict days required to reach a target composition.

Table 6. Sequence of calculations in the DAYSTEP model

Step	Description
1	Determine NEm and NEg concentration of the diet using the CNCPS model
2	Determine the expected shrunk body weight (SBW) at 28% body fat (Choice AFSBW)
3	Predict daily DMI based on current SBW, diet energy, environmental conditions, and Choice AFSBW
4	Predict feed required for maintenance (FFM, kg) based on current SBW and environmental conditions as follows: FFM = NEm required / diet Nem
5	Predict NE available for gain (NEFG, Mcal) from DMI and diet NEg ; NEFG = (DMI – FFM) × diet Neg
6	Predict daily Shrunk Weight Gain (SWG) from NEFG and the current SBW equivalent to the standard reference animal (EQSBW)
7	Compute the new SBW of the animal by adding SWG in step 6 to the initial SBW
8	Repeat steps 5 to 9 for each additional day until animal reaches actual finished SBW
9	Adjust predicted DMI until actual and predicted ADG match
10	Compute body weight at 60 and 80% of 28% fat weight
11	Predict ADG and feed required for the growth period between 60 and 80% of 28% fat weight.

Evaluation of the DAYSTEP model in predicting growth and feed efficiency predictions. The previously described data base containing 365 individually fed steers with measured body composition and feed energy values predicted with the CNCPS version 4.0 were used to evaluate the DAYSTEP model predictions. The model accounted for 90% of the variation in individual animal ADG with no bias and deviation tendency. As a result, the observed weight at the actual total days on feed was accurately predicted (r^2 of 0.86) with no bias and no deviation tendency. When ADG was predicted using the mean body weight and actual DMI, the variation accounted for was reduced to 80%, compared to the model daily DMI adjusted for the overall ratio of actual/predicted DMI. This approach results in a higher DMI early and lower DMI later in the feeding period relative to body weight and composition, in agreement with the data of Thornton et al. (1985).

We then evaluated observed vs predicted feed efficiency in this data set using the DAYSTEP model. The model accounted for 83% of the variation in actual feed efficiency with no systematic bias (Figure 1). These results indicate the use of Cornell Net Carbohydrate and Protein System model (Fox et al., 2000) to predict feed energy values and the Cornell Value Discovery System model (Fox et al., 2001; Tedeschi et al., 2002) to predict individual animal feed requirements from body weight, ADG and body composition accounted for all but 17% of the differences in feed efficiency.

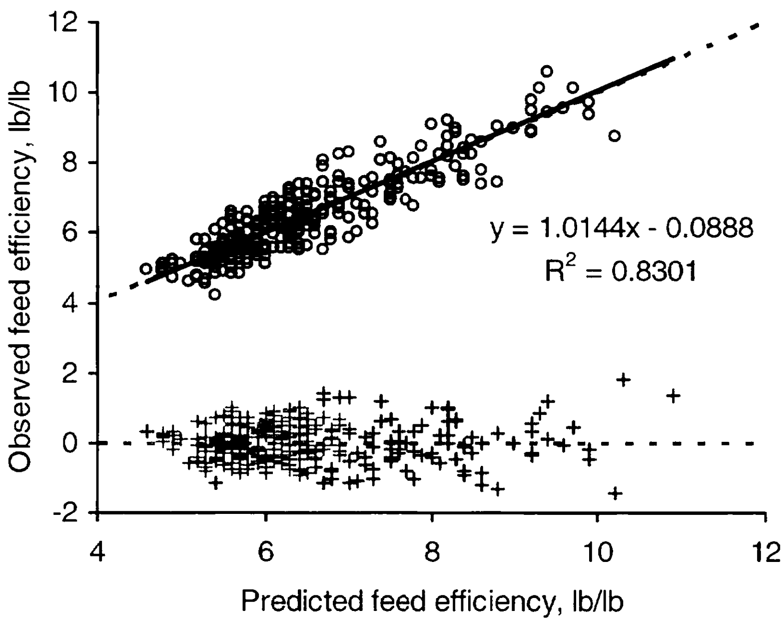

Figure 1. Comparison of observed and predicted feed efficiency (DMI lb/ ADG lb) (○) and residual (+, observed minus predicted) of 297 individually-fed steers.

The variation not accounted for in this system (17%) is due to individual animal variations that the system cannot fully account for, including differences in maintenance requirements, diet digestibility and metabolizability, and body composition. Adjustment for prediction errors are made when determining individual animal costs by multiplying the ratio of the total actual pen DM consumed to the total pen DM required times each animal's DM required (Equation 9 in Table 4). The acceptance by producers of this approach to allocating feed has been high.

As indicated earlier, predicted feed efficiencies to be used for genetic evaluation should be computed over the same stage of growth. We used this data base of individually fed animals to regress actual feed efficiency on three alternative criteria for evaluating feed efficiency (Figure 2). First, the DMI, ADG and mean SBW were computed over the same stage of growth (SRu) (from 0.6 to 0.8 degree of maturity) with the DAYSTEP model, using 28% EBF as the mature weight. Then three variables related to feed efficiency were computed, including (a) DMI/ADG, kq/kg; (b) ADG/DMI, g /kg; and (c) ADG/$SBW^{0.75}$, g /$kg^{0.75}$ of mean SBW.

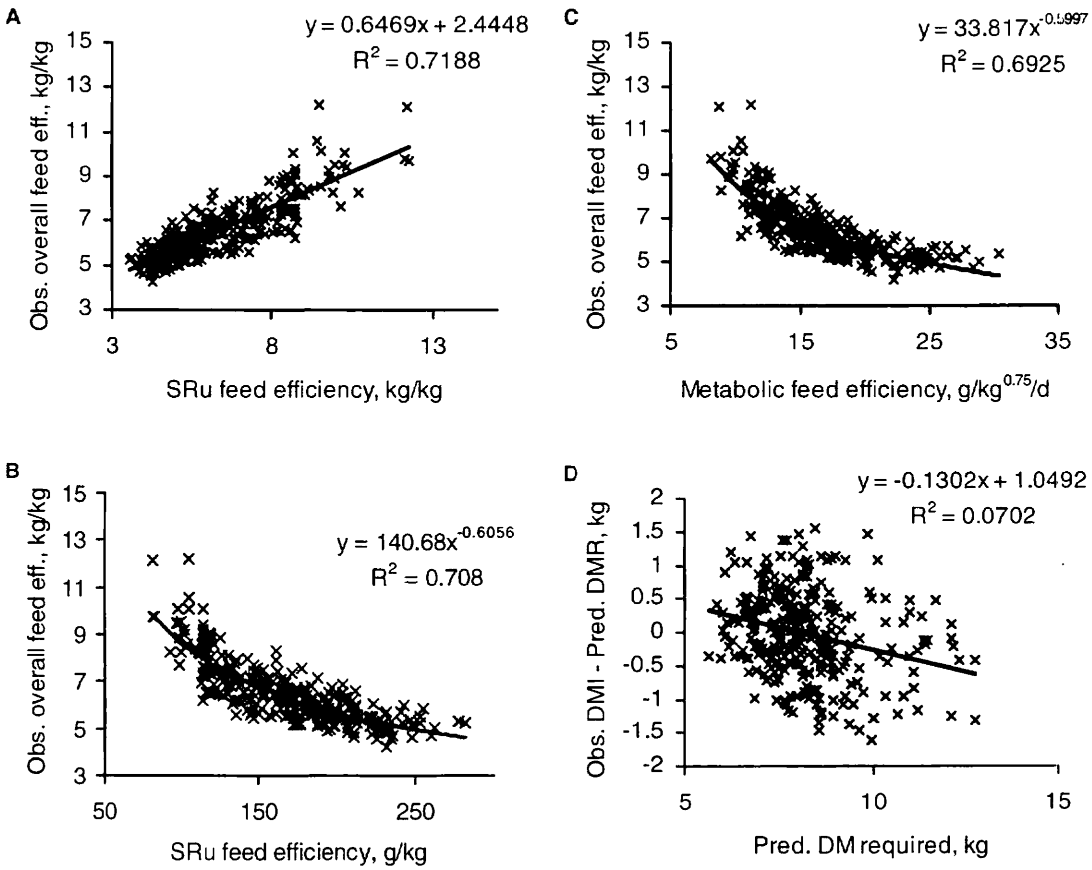

Figure 2. Comparison of overall feed efficiency with feed efficiency at same stage of growth in DMI/ADG (A) and ADG/DMI (B), metabolic feed efficiency (C), and (D) residual analysis of DMI observed and DMR predicted by the model.

Because an average of 30% of the variation in feed efficiency was not accounted for by these measures, figure 2 panels A, B, and C indicate that the feed efficiency computed over the same stage of growth is needed, whether expressed as kg DMI/kg ADG, g ADG/kg DMI, or g ADG/kg $BW^{0.75}$. Panel C also shows that dividing the ADG by the metabolic mean BW gives a value that is highly related to feed efficiency. The logic of this measure is that maintenance requirement is accounted for by dividing ADG by metabolic body weight during the same stage of growth. The animals with a high ADG per unit of metabolic body weight had better overall feed efficiencies with less variation, suggesting this value could be used to select for feed efficiency.

Using the same data base, panel D of Figure 2 shows no bias in prediction of dry matter required for individual steers, indicating the CVDS model consistently predicted actual dry matter intake across wide variations in animal type.

Due to the interest in evaluating individuals for differences in residual feed intake (RFI), we used our data base to compare our feed required approach with the residual feed intake approach to identifying differences in feed efficiency. First, actual DMI or DMI required was regressed on ADG and metabolic body weight. Then actual DMI for each animal was subtracted from DMI predicted with each of these two equations. The feed required approach accounted for more of the variation with less bias (figure 3), likely because of accounting for differences in composition of gain. Thus the advantages of predicting feed efficiency from feed required to evaluate animals for feed efficiency are: 1) it is not necessary to measure individual feed intake, and 2) differences in body composition are accounted for, and 3) feed required values reflect the effects of environment on maintenance requirements and diets fed to the animals being compared.

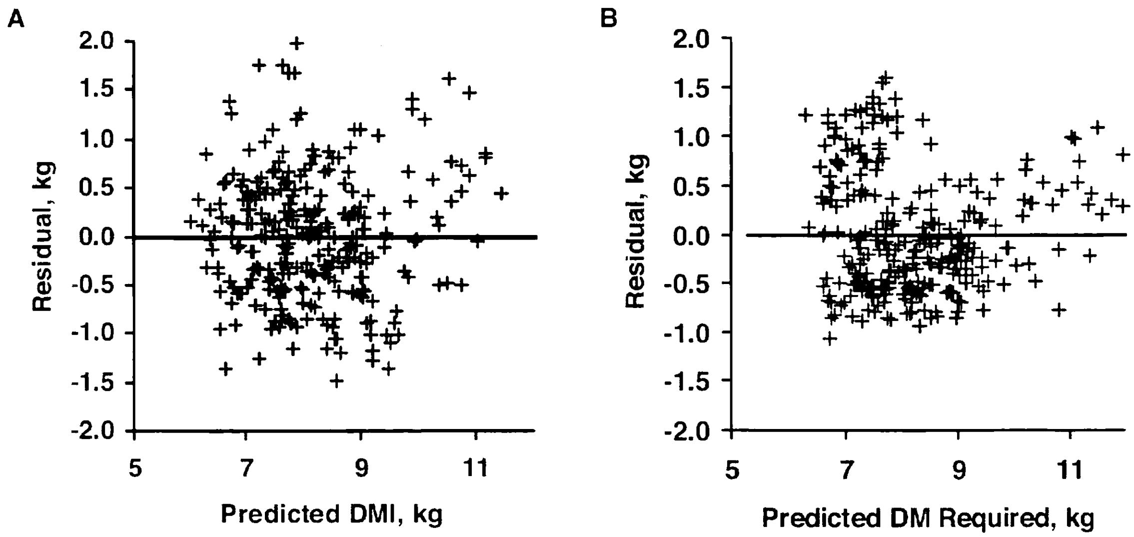

Figure 3. Residual feed intake analysis with 284 individually-fed steers. (A) Regression of dry matter intake on ADG and mean $BW^{0.75}$. The regression was $Y = -0.83 + 2.33 \times ADG + 0.068 \times BW^{0.75}$ with an R^2 of 0.72 and MSE of 0.45. (B) Regression of dry matter required on ADG and mean $BW^{0.75}$. The regression was $Y = 5.45 - 1.68 \times ADG - 0.0095 \times BW^{0.75} + 0.051 \times ADG \times BW^{0.75}$ with an R^2 of 0.80 and MSE of 0.37.

Example application of the Cornell Value Discovery System in evaluating pen fed bulls

Data from the New York State Bull test conducted from December 16, 2000 to April 7, 2001 with 93 bulls are used to demonstrate how the CVDS is used to predict feed efficiency for individual bulls being evaluated. The diet ingredients were analyzed for NDF, lignin, crude protein, soluble protein, and cell wall-bound protein for use in the CNCPS model to predict the diet energy content (ME of 1.25 Mcal/lb DM). The diet formula and CNCPS ME value were entered into the CVDS program along with each individual animals' information (initial and final body weight, hip height and age, and ultrasound fat depth, ribeye area, and marbling, and body weight at the time of ultrasound). Empty body weight (EBW) was computed from shrunk body weight (SBW) multiplied by 0.891 and hot carcass weight (HCW) was computed from EBW using Garrett's equation (Garrett, 1987, Table 4). Hip height and age was used to compute frame score and 28% fat weight as described by Fox et al. (1992), and the ultrasound information was used to predict 28% fat weight using the equations of Guiroy et al. (2001) as described in Table 4 (steps 2 and 3). The DAYSTEP model in the CVDS was then used to compute the feed required for each animal over the actual feeding period, and during the same stage of growth, as described in Table 5.

Before computing individual feed efficiencies and cost of gain, we first determine if the sum of individual feed requirements agree with the total of the feed actually fed over the feeding period. This provides a check on the accuracy of the inputs (diet energy values, and animal inputs and measurements), and how well the model is working in this situation. Figure 4 shows the percentage of the total feed DM consumed that was predicted by the sum of the individual bull predicted feed required for the observed ADG.

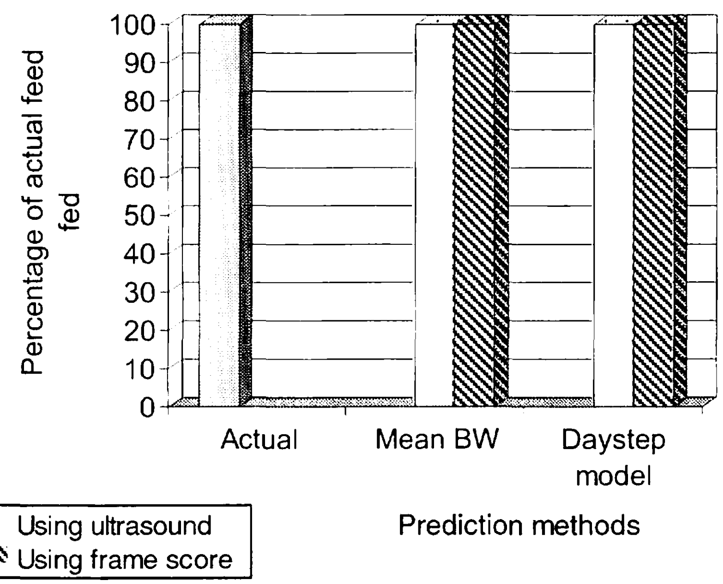

Figure 4. Comparison of feed actually fed and required as predicted by the Cornell Value Discovery System using ultrasound or frame score to predict 28% fat weight. The actual amount fed was 244,930 lb.

Two approaches of predicting feed required were compared; using mean body weight or using body weight accumulated on a daily basis with the DAYSTEP model. Within each, 28% fat weight was predicted by the two methods (hip height and age or ultrasound). Feed actually fed was predicted within 1 to 2% whether using mean BW or DAYSTEP approaches. The accuracy was not affected by using either frame score or ultrasound to predict AFBW. Our results indicate the DAYSTEP model accurately predicted the amount of feed required across all bulls, and gives us confidence in the individual bull feed efficiencies predicted by the CVDS model.

The animal performance data (average, minimum, maximum, and SD) are summarized in Table 7. The feed required data are computed for each animal for the entire 112 day test and the feed efficiency data are for the same stage of growth. Table 7 shows that there was considerable variation in age and initial and final weight, indicating differences in stage of growth during the test. Thus the large differences in feed required reflect differences in average weight and stage of growth as well as intake over maintenance. For that reason, the feed efficiency for each bull that was computed for the same stage of growth by the CVDS model is the value that should be used in genetic evaluations for feed efficiency. Then, the most efficient animals post weaning are those that have the highest feed efficiency and are within the window of acceptability on finished weight at the target composition and grade.

Table 7. Description and performance of bulls during a performance test[a]

Variables	Average	Min	Max	SD
Age, mo	9.4	7.6	11.5	1.2
Initial BW, lb	857	551	1158	133
Final BW, lb	1280	860	1620	161
AFBW by FS[b], lb	1337	1091	1467	80
AFBW by US[b], lb	1304	951	1643	138
ADG, lb/d	3.63	2.21	4.73	0.47
Feed Required, lb/d	24.1	15.6	30.8	2.74
Feed efficiency[c]				
DMI/ADG, lb/lb	6.68	5.81	7.53	0.31
ADG/DMI, g/kg	150.1	132.8	172.1	7.05
$ADG/BW^{0.75}$, $g/kg^{0.75}$	21.6	20.8	25.5	0.99

[a] Database contained 93 bulls fed during a 112 d test.
[b] Adjusted final BW based on Frame Score (FS) and Ultrasound (US).
[c] Using AFBW computed by frame score.

Summary

The Cornell Value Discovery System provides a method for determining feed required for individuals fed in a group on a biological basis, considering differences known to affect requirements (breed type, body weight and mature size, stage and rate of growth, and diet composition). An analysis of our data indicated these variables accounted for 83% of the variation in feed efficiency; the remaining 17% of the variation in feed efficiency (primarily differences in basal maintenance requirement and efficiency of use of absorbed energy) are, at present, impractical to measure in commercial feeding situations. The only way we know of for estimating ME efficiency is to measure individual feed intake and diet metabolizability at maintenance and production levels of intake.

For steer and heifer progeny finished in feedlots, feed required for individuals can be determined by using a prediction of final EBF from carcass measures to determine feed required for growth for the purposes of accurately allocating cost to individual animals. For herd replacement animals, feed required for individuals can be determined by using ultrasound measurements needed by the equation used to predict body fat and expected 28% fat weight. In both situations, the DAYSTEP model in the CVDS can be used to predict feed efficiency over the same stage of growth.

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MEASURING COW-CALF PROFITABILITY AND FINANCIAL EFFICIENCY

Barry H. Dunn, Ph.D.
Assistant Professor of Animal and Range Sciences
South Dakota State University

Introduction

Efficiency is defined as the ratio of the useful energy delivered by a dynamic system to the energy supplied to it (Webster's, 2002). Efficiency represents an output/input relationship. It is a ratio often expressed as a percent. There are two standard definitions of profit (Webster's, 2002). The first and most widely used in previous papers and discussions concerning the economic efficiency of beef cattle production is the excess revenue over expenditures, or net income (NI). Net Income in itself is not a complete measure of efficiency (Heady, 1952). The second definition, which is the primary measure of economic efficiency used in business applications, is the ratio of NI for a given fiscal period to the amount of capital invested, commonly known as return on assets (ROA). In order to properly evaluate the economic efficiency of a business activity, a profit measurement that includes both NI and the assets necessary to create NI is required.

There are several critical steps for the accurate measure of efficiency using ROA. The first is that in the calculation of NI, accrual adjustments to income and expenses must be made. Secondly, due to policy changes outside the control of management, NI should be calculated pre-tax. The third is that assets should be recorded at their financial, or cost, basis. It is inappropriate to use market values or opportunity costs (Hawkins et al., 1993, Oltmans et al., 1992, Van Horne, 1995). The careful use of the Standardized Performance Analysis (SPA) guidelines as adopted by the cattle industry in 1992 (NCA) allows for the calculation of NI and ROA in methodology that meets these generally accepted business guidelines.

Calculation of Profit: Net Income

Net Income is calculated with SPA by using the simple equation in Figure 1.
Net Income represents dollars available for family living and a return to capital with both revenue and expenses adjusted for changes in inventory.

$$\$NI = [(\text{Total lbs. X \$/lb.}) +/- \$\text{Inventory Adj.}] - (\$\text{Total Cost} +/- \$\ \text{Inventory Adj.})$$

Figure 1. Formula for calculating net income.

The biological efficiency and levels of production of beef cattle will have an effect on annual costs and impact NI. However, NI does not account for the differences in the capital investment necessary to support various production systems or different levels of production within systems. A cow-calf operation can generate $50,000 of NI with an investment of $1,000,000 or $2,000,000. As an investment opportunity, the business that can generate the highest NI with the lowest investment is the most attractive and competitive. Net Income by itself does not provide the sensitivity for that evaluation. Heady (1952) said it this way:

> *"Net profit can no longer be used as a gauge of whether resources are used efficiently."*

NI is also not sensitive to differences in marginality. For example, a $1.00 increase in NI can result from increasing gross revenue $2.00 and total expenses $1.00 or by increasing gross revenue $2000 and total expenses by $1999. The largest increase in NI that results from the smallest change in revenue and cost is the most attractive and competitive.

An example of the limitations of NI would be the contrast between a February versus June calving season for a cow-calf production system. In the past, the discussions about the advantages of each of these systems have centered on production issues, annual costs, and marketing. Depending on the geographical location of the operation, one could also predict dramatically different requirements for buildings, other improvements, and equipment. The presence of additional buildings, improvements, and the equipment necessary to mitigate the affects of cold weather and precipitation represents a different level of capital investment and may also drive an increase in operational costs like depreciation, utilities, and maintenance costs. This would be reflected in an increase in total annual costs, but NI would not capture the increased investment.

When managers rely solely on NI as feedback for profit, unexpected outcomes may occur. If an operation finds itself without enough NI to cover family living, or debt service and repayment, a common response is to either increase in size or to look for off-farm job opportunities. An increase in size of an inefficient operation can serve to only magnify problems rather than solve them. Off-farm employment can lead to a drop in overall production efficiency.

In summary, because it is not sensitive to differences in level of investment or marginality, NI is not a good choice to use as a measure of efficiency for beef cattle operations. The use of NI as the sole measure of profit may also have unexpected outcomes that affect the entire firm.

Calculation of Profit: Return on Assets

The rate of return on total assets provides a measure of management efficiency for the use of the total assets of a firm. Return on Assets is calculated with SPA using the equation in Figure 2.

$$\text{ROA, \%} = \frac{\text{\$NI + \$ Interest − Family Living}}{\text{Total \$ Invested in Land, Cattle, Buildings, Improvements and Equipment.}} \times 100$$

Figure 2. SPA formula for calculating ROA.

Return on Assets is calculated before taxes and before interest expense since interest represents a return to creditors, not the manager. Return on assets is usually calculated for a fiscal year, but can be calculated for periods. Assets are included at cost, thus depreciation is included. Family living is subtracted from NI. This is a very comprehensive measurement of the firm's ability to generate profit.

While ROA is an inclusive measure of managerial efficiency, it is indifferent to the source of capital and does not reflect levels of equity or debt. It should not be confused with return on equity, which takes into consideration debt.

It is important to recognize that ROA is not an evaluation of past investment decisions in terms of their present value. ROA is an evaluation of past management decisions but is a reflection of those decisions on the present earning capacity of a production system created with those investments.

Since ROA is a reflection of the impact of past decisions on present performance, including opportunity costs is inappropriate because they represent decisions not made. Return on Assets evaluates the impact of actual decisions made by management.

Profit: A Set of Relationships

When considering profit, it may be helpful to use a factory and machine analogy. An example would be a business that produces widgets. The production of widgets requires a factory. The factory represents a productive capacity that requires an investment in land, buildings and facilities, equipment, and machinery. A portion of the investment would represent owner's equity. The portion not covered by owner's equity would be debt. The operation of the factory in the production of widgets requires the expenditure of dollars to pay for annual operating expenses. The company receives income from the sale of widgets. The economic efficiency of the firm is dependent on many factors including the efficiency of the individual machines in the plant. However, in a larger context, the total investment of the plant and the ability to sell widgets into the market place are also very important.

A simplified formula may help in understanding the relationships between the different major components of ROA (Figure 3).

$$\text{ROA, \%} = \frac{(\text{Lbs. X \$}) - \text{\$ Total Costs}}{\text{\$ Assets}} \text{ X } 100$$

Figure 3. Simplified formula for ROA

High levels of profit as defined by ROA can come from many combinations of levels of production, the value of that production in the market place, the annual expenses required for production, and the level of investment required to build and maintain the productive capacity of the firm (Figure 4).

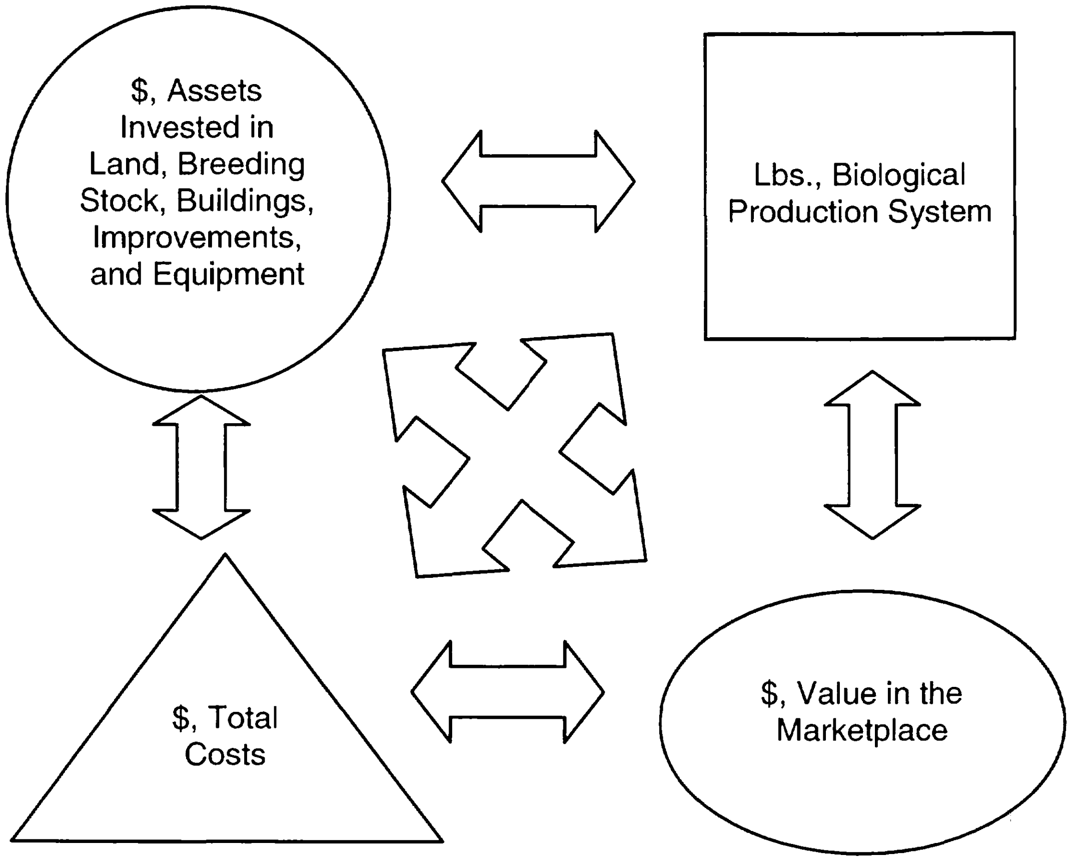

Figure 4. Profit is a set of relationships.

It is possible to have high levels of profit with a variety of scenarios. For example:

- High annual expenses, and either or both high levels of productivity or high levels of income and low levels of investment.
- Low levels of productivity if expenses are low or the value in the marketplace is high with low levels of investment.
- High levels of investment with high levels of production and value in the marketplace with low annual costs.
- Low levels of investment and high levels of productivity and value in the marketplace with low annual expenses.

The examples above make setting generic targets for investment, expenses, production, and income, commonly known as benchmarking, extremely difficult for cow-calf production. Beef cattle in the United States are produced in a wide variety of environments and production systems representing many different goals.

Another benefit of looking at profit as a set of relationships is that it may provide insight into what part of the equation is driving the others. For example, does the production system drive investment and annual costs? Or perhaps the marketing decisions drive the production system, which in turn drives other segments. Perhaps the cash flow drives marketing, as loan payments are due at a specific time and cash is required. This type of insight is critical for successful management.

The results of a field study of 148 beef cow-calf enterprises in the Northern Great Plains (Dunn, 2000) indicate that high levels of profit as measured by ROA are a function of below average levels of investment, average levels of production, low annual costs, and excellent marketing (Table 1). High profit herds had the same output per cow as measured by pounds weaned per cow exposed as Medium Profit herds, but had lower annual costs, higher revenue, lower investment, and higher NI and ROA.

In terms of risk management, low levels of annual expenses would seem to be a natural place for managers to focus their energy and effort. However, there should also be a high level of sensitivity to the general relationship of inputs and outputs as shown in Figure 5. A reduction in total costs is desirable if production is not impacted beyond a certain threshold. By the same token, the point of diminishing returns is an extremely important point to identify in all production systems. Beyond the point of diminishing returns, additional inputs do not result in corresponding levels of output. These thresholds may not be readily visible in a complex system like beef cattle production.

Table 1. SPA measurements for Low, Medium, and High Profit herds (Dunn, 2000)

	Low Profit	Medium Profit	High Profit
Lbs. weaned/cow exposed	413	455	455
$ Total income/beginning year breeding female	390.75[g]	423.08[g]	495.35[h]
$ Total cost/beginning year breeding female	637.68[d]	386.87[e]	270.23[f]
$ Net income/beginning year breeding female	-247.02[a]	36.29[b]	225.13[c]
$ Total investment/beginning year breeding female	1538[g]	2308[h]	1397[g]
ROA, %	-15.5[a]	2.88[b]	18.16[c]

[abc] Means within the same row with different superscripts differ ($P < 0.01$).
[def] Means within the same row with different superscripts differ ($P < 0.05$).
[gh] Means within the same row with different superscripts differ ($P < 0.10$).

Dunn (2000) looked at fifteen output/input relationships for a variety of production measures including pregnancy percent, weaning weight, weaned weight per exposed female, and weaning percent, and used total expenses per acre, per beginning year breeding female, and per cwt. of weaned weight as measures of input and found no statistical relationships. If the relationships can be identified, the slope of the production function curve in Figure 5 may also vary with different criteria. For example, the slope of the curve representing a production function could be fairly steep for traits relating to reproduction, but relatively flat for a trait like weaning weight. Isolating these relationships for various traits, and within different geographical regions, would be extremely valuable to all segments of the industry. Certainly more investigation is necessary.

Valuation of Assets: Financial Versus Economic

One of the most confusing and controversial topics in the analysis of the profitability of a beef cattle enterprise is in the determination of the value of assets on the balance sheet and in the income statement. SPA provides two methodologies for analysis, and they value assets differently. They are used for different purposes. The first is a financial analysis, which values assets at their cost or depreciated value (book value). The second is an economic analysis, which values assets at their market value. The only appropriate use of a financial analysis is to evaluate managerial efficiency (Hawkins et al., 1993, Oltmans et al., 1992, Van Horne, 1995). The only appropriate use of an economic analysis is to evaluate an entry or exit strategy for a business (Hawkins et al., 1993, Oltmans et al., 1992, Van Horne, 1995). When using an economic analysis, deferred taxes must be included. It is inappropriate and confusing to mix the methodologies.

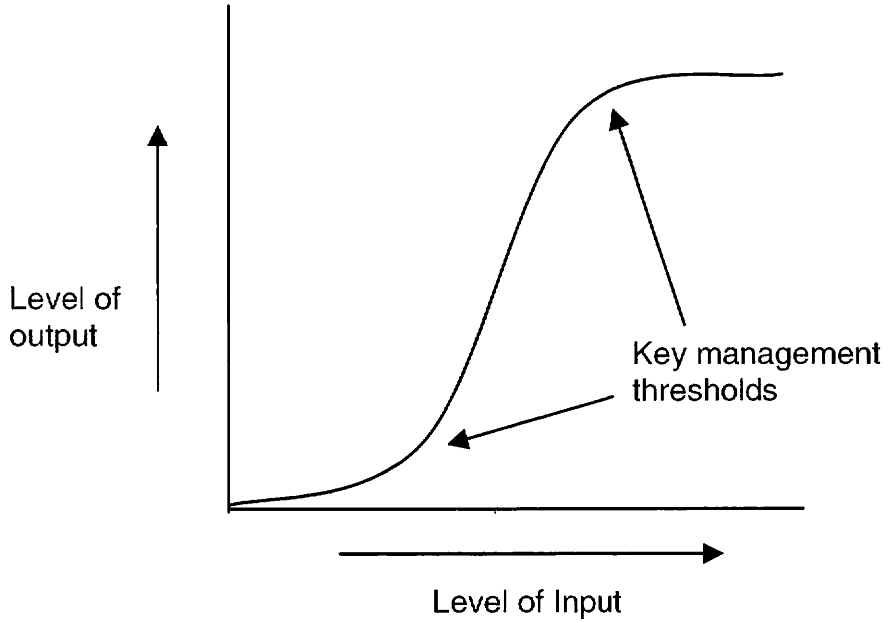

Figure 5. Classic input/output relationships as described by a production function (Heady, 1952).

A financial analysis can be viewed with a timeline highlighting the cumulative activity that is impacting the fiscal year under examination (Figure 6). The effect of the managerial activity from many decisions over what may be a long period of time is being measured during a specific fiscal year. The examination actually takes place after the year is complete. In the example in Figure 6, the year under examination is 2001. The examination is taking place in 2002. The activity and decisions that led up to the performance in 2001 actually took place over a long period of time. Some of the events may have been passive, such as the inheritance of property. Others were the direct result of management decisions, like buying land, turning out the bulls for the breeding season, or purchasing a baler.

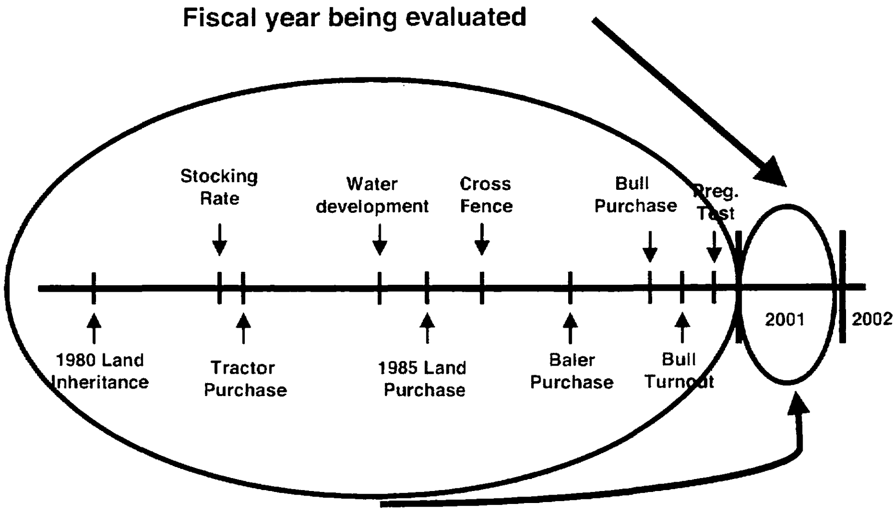

Figure 6. Timeline of a financial analysis. Assets valued at cost or depreciated value. Cumulative affect of management.

In contrast to a financial analysis, an economic analysis records the value of all assets at their market value on the dates chosen for the analysis (Figure 7.). While the manager has chosen the mix of assets and made the marketing decisions, the affect of which is being analyzed, the actual value of the asset mix is extremely sensitive to influences outside the manager's control. For example: inflation, deflation, the weather, governmental policies, and world events.

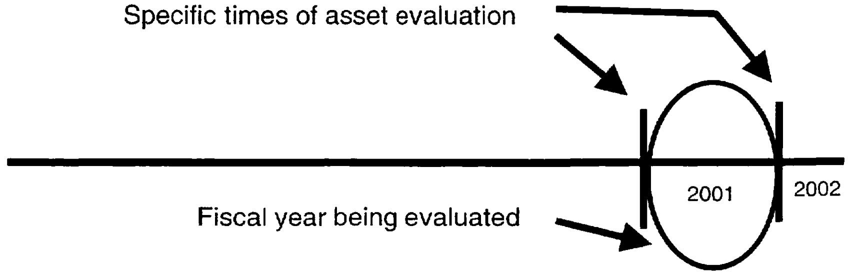

Figure 7. Economic analysis. Assets valued at market value at time of evaluation.

An example of the confusion created by using market values and mixing methodologies in the analysis of managerial efficiency is provided in Table 2. Based on a financial analysis, the example operation is profitable, showing a positive NI of $33 per beginning year breeding female. In the economic analysis, the market value of hay has increased in value to $300 per beginning year breeding female due to a regional change in supply or demand. For this example, the value of all other assets remains the same and depreciation drops to $0.00. With the addition of the deferred taxes of $100, the operation is then losing $241 per beginning year breeding female.

When methodologies are mixed, depreciation is added in along with the increased value of hay, but not deferred taxes, and the loss is $192 per beginning year breeding female. Is the business profitable? If calculated correctly, yes it is. But that determination must be made using the correct methodology.

Another problem using market values when evaluating profitability is that using opportunity costs suggests that the manager is willing to “take” the opportunity. In the previous example, if the cost of the hay necessary to maintain a cow for a year was $75 and the market value of that hay was $300, and the manager decided to sell the hay to capture the increased market value of the hay, the corresponding decision that then must be made is to sell the cows and exit the business. In this example, the original analysis was to evaluate profitability. It did not begin as a decision to stay in or exit the business.

Charging an opportunity cost for pasture is another common practice that misleads people. If $120 is added in for an opportunity cost of pasture, the loss in Table 2 for the mixed methodology balloons to $312 per beginning year breeding female. But renting the pasture was not part of the manager's decision and has no place in this analysis. Although anecdotal, there are many real life examples of the above scenarios where misusing the tools of analysis has led to inappropriate decisions.

Table 2. An example of confusion created using mixed methodologies for the determination of net income. Costs are on a dollar per beginning year breeding female basis. For economic and mixed analysis, raised feed changed to market value. All assets remain the same value over the fiscal year.

	Financial Analysis	Economic Analysis	Mixed	Opportunity costs
Total Revenue	430	430	430	430
Vet Med.	19	19	19	19
Depreciation	51	0	51	51
Labor	33	33	33	33
Purchased Feed	62	62	62	62
Raised Feed	75	300	300	300
Pasture Rent	0	0	0	120
Inventory Adj.	18	18	18	18
Other Costs	100	100	100	100
Deferred Taxes	0	100	0	0
Interest	39	39	39	39
Total Cost	397	671	622	742
Net Income	33	- 241	- 192	- 312

Per What? The Importance of Using the Right Denominator.
Using efficiency measurements in beef cattle management can be a very important management tool (Jacobs, 1984). Income, costs, and investment can be expressed per cwt. of weaned calf just as market figures are presently. They can also be expressed on a per cow basis as shown in Tables 1 and 2. What is the most appropriate and sensitive denominator to express differences in managerial efficiency? Perhaps a unit of land would be better. Perhaps per cwt. of weaned calf as suggested by Harlan Hughes (2000) is the best measure. Dunn (2000) evaluated SPA records on a per beginning year breeding female, per acre, and per cwt. of weaned calf basis. The most statistically sensitive measure to differences in managerial efficiency was on a per cwt. of weaned calf basis.

Expressing efficiency ratios on a per cow or per acre basis can be misleading. For example, if the breakeven cow costs on a ranch were $400 per beginning year female and the cows weaned 400-pound calves, then the breakeven per cwt. is $1.00. If the same cows weaned 600-pound calves, then the breakeven per cwt. is $0.67. If the ranch being analyzed used an expression on a per acre basis, the same type and

magnitude of problem may arise. Expression of a breakeven on a per cwt. basis allows for a clear interface with the marketplace.
However, some measurements using different denominators are very useful. Total investment per cow is widely used when pricing or buying a ranch property. Stocking rate is on a per acre basis. Total pounds weaned per acre does provide useful information concerning productivity. However, this is a case where if it is low, does it reflect a problem with the cow-herd or an ecological limitation? Reproductive performance of the cowherd is easily communicated on a per cow exposed basis as outlined by SPA (NCA, 1992).

Summary

The careful use of the Standardized Performance Analysis (SPA) guidelines as adopted by the cattle industry in 1992 (NCA) allows for the calculation of measurements critical to the successful management of a beef cattle enterprise. Knowledge of the definitions and an understanding of how the measurements are calculated are both critical for the correct use and application by management.

Net income by definition is not a measurement of managerial efficiency. Return on assets is a comprehensive measure of profit and managerial efficiency. It is calculated with accrual adjustments, on a financial basis, and using pretax net income. The use of market values or opportunity costs is inappropriate in the development of a financial analysis. Profit as defined by return on assets is a relationship between the production, marketing, annual expenses, and investment of a beef cattle business. Profit can arise from many combinations of these four basic units. Due to the extreme variation in the geographical and ecological regions where beef cattle are raised, and the different goals and objectives under which cattle are raised, care should be taken when developing benchmarks for biological or financial performance. However, there is strong indication that in consideration of risk and opportunity, a management strategy of low levels of investment, average levels of production, low levels of total annual costs, and above average marketing will help cattlemen achieve profitability and financial efficiency. The concept of diminishing returns needs to be carefully considered when making decisions concerning investment and annual expenditures.

The expression of efficiency measures should be in units that are most sensitive for the expressed purpose. The use of measurements on a per cwt. basis can be a powerful tool for management intervention for the improvement of many important facets of beef cattle production.

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A NEW GENETIC PREDICTION FOR COW MAINTENANCE ENERGY REQUIREMENTS

By John L. Evans[1], Bruce L. Golden[2], and Bob L. Hough[3]
[1]Oklahoma State University – Department of Animal Science, Stillwater 74078
[2]Colorado State University – Department of Animal Sciences, Fort Collins 80523
[3]Executive Secretary – Red Angus Association of America, Denton, TX 76207

Introduction

The increased competition from alternative protein resources such as pork and poultry is challenging the beef cattle industry to be more critical of profitability and sustainability. To ensure financial sustainability in both domestic and global markets, beef cattle producers need to produce a quality product more efficiently. Therefore, the most accurate selection and mating decisions should be made using information that determines the risks and returns (Golden et al., 2000).

Beef cattle are biologically less efficient and require a higher total life cycle dietary energy intake in comparison to other meat animal species (swine and poultry) (Ritchie, 2000). According to Dickerson (1978), a higher proportion of feed energy is required to produce a unit of edible protein in beef cattle relative to other meat animal species (Table 1). Beef cattle are at a disadvantage when evaluated against swine and poultry for product efficiency; however, as a ruminant, cattle can utilize forages that monogastrics are unable to digest (Ritchie, 2000). Therefore, it is important to select and produce cattle that will efficiently convert forage resources to high quality protein.

Table 1. Mean feed energy requirements per unit of protein deposition in different livestock species[1]

Species	MJ Feed / kg of meat protein
Broiler Chicken	336
Turkey	363
Rabbit	438
Pork	633
Lamb	1,787
Beef	1,849

[1]Adapted from Dickerson (1978)

The average maintenance requirements for a mature cow represent approximately 70 percent of her feed expenses (Ferrell, 1988). In a summary of SPA data (1991-1999) for the southwestern states (Texas, Oklahoma, and New Mexico), the average feed cost per cow was 42% of the total annual production cow cost (McGrann, 1999). In order to be profitable and sustainable, it is important that cattle producers be able to select animals that fit their production environment. Some animals simply have lower energy requirements for maintenance and are able to maintain their body tissues with fewer calories. For example, many producers probably have at least one cow that always rebreeds, seems to always be fatter than others in the herd despite poor feed conditions, and will produce a calf each year no matter what the environmental conditions.

What is maintenance energy?

The maintenance energy requirement of an animal is the energy required to sustain their body tissues with no net change in body tissue. Simply stated, it is the amount of feed required so an animal is not gaining or losing weight. This level of energy intake does not include the additional energy needed for an animal to grow, sustain a pregnancy, lactate, or withstand changes in weather.

Previous research has reported maintenance energy requirements in beef cattle to be heritable (Hotovy et al., 1991) and differences are present between breeds (Ferrell and Jenkins, 1985). A 1985 study by Meat Animal Research Center (MARC) scientists, Ferrell and Jenkins, compared several breeds and measured their requirements for maintenance energy (Table 2). Their results showed that maintenance energy needs are different across breeds, especially breeds with above average milk production. Having genetic predictions for maintenance energy requirements could provide cattle producers with an additional selection tool to manage inputs and enhance cow efficiency; however, collecting and recording large volumes of individual feed intake and calorimetry data is both an expensive and time consuming process and is not practical on a breed-wide basis.

Table 2. Estimates of metabolizable energy required for maintenance (MEm) of various breeds or breed crosses[a]

Breed or breed cross	Physiological state	MEm, kcal/(kg$^{.75}$.d)
Angus-Hereford	Non-pregnant, non-lactating, 9-10yr	130
Charolais X	" " "	129
Jersey X	" " "	145
Simmental X	" " "	160
Angus	Non-pregnant, non-lactating, 5-6yr	118
Hereford	" " "	120
Simmental	" " "	134

[a]Adapted from Ferrell and Jenkins, 1985

In the past, mature size has been used as an indicator trait of maintenance energy requirements. On average, animals with heavier mature weights will require more energy intake to maintain their basic body functions when compared to a smaller mature weight animal. Using the relationship between mature size and maintenance energy, an animal's body weight can be used to estimate their maintenance energy requirements. Previously, research has shown that mature weight alone is not the most accurate for this purpose; however, it is more practical than other methods, such as calorimetry.

Maintenance energy requirement is more properly estimated when the mature weight is adjusted to account for differences in body size (surface area) to obtain what is known as metabolic body weight. Metabolic body weight is calculated as a fractional power of shrunk body weight, with the most commonly agreed upon adjustment being body weight to the three quarter power ($BW^{0.75}$) (NRC, 1996). Previous work has shown that $BW^{0.75}$ is proportional to an animal's fasting energy expenditure; therefore, an individual's maintenance energy requirement will scale with weight. All other factors being equal, this means that a small animal will be expected to have a higher metabolism per pound than a larger animal.

Another important source of variation for maintenance requirements is an animal's visceral organ mass, including the stomach, liver, intestines, and cardiac tissue. Additional research by Ferrell and Jenkins showed differences were present between breeds for visceral organ mass because of specialized functions within breed, such as lactation, which places a higher physiological demand on energy requirements. Therefore, differences in visceral organ mass should be associated with differences in level of milk production. If all factors except visceral organ mass are equal, individuals with genes for higher milk production are more likely to have a larger visceral organ mass compared to individuals with genes for lower levels of milk production. In a Texas A&M study (Solis et al., 1988), they reported differences among individuals for milk potential will also manifest as differences in visceral organ mass.

Cattle with genetic merit for higher milk production will often have higher maintenance requirements (Table 2). In fact, a University of Nebraska study (Montano-Bermudez et al., 1990) estimated that milk production was responsible for 23 percent of the variation for maintenance energy requirements. In a related study, Van Oijen et al. (1993) showed that the low milk producing breed groups were consistently more biologically and economically efficient for cattle marketed both at weaning and slaughter. Additionally, a recent research project at Oklahoma State University reported that dry matter intake in Brangus cattle was positively associated with milk production in both mature cows and heifers (Johnson, 2002).

Maintenance Energy EPD

Unlike an indicator trait such as mature weight, an EPD for maintenance energy requirements in beef cattle would fit well into a developing list of economically relevant traits because of its direct effect on the profitability of a cow-calf enterprise (Golden et al., 2000). Cattle producers that emphasize selection to increase growth and milk with no regard for the change to genetic merit for cow herd nutritional requirements risk a detrimental impact on maintenance requirements and production costs. A genetic prediction for maintenance requirements would enable cattle producers to effectively select animals with an optimum level of energy expenditure, to better match cattle to their forage and production environment, and to provide additional insurance for harsh weather conditions.

The development of an economically relevant EPD for cow maintenance energy requirements was feasible because of research at Colorado State University and the USDA-ARS Fort Keogh Laboratory in Miles City, MT. We used equations from the current version of the National Research Council guidelines for beef cattle nutrition and research results of Dr. MacNeil with the USDA-ARS Lab. We combined this information with available genetic predictions in National Cattle Evaluation for mature weight and milk (maternal weaning weight) to construct a prototype maintenance energy requirement EPD (Evans, 2001).

The equations used in this study to predict maintenance energy requirements include mature weight and milk EPD. Using known relationships between mature weight and maintenance energy requirements, we calculated the maintenance requirement using metabolic body weight or weight to the three quarter power and converted it to megacalories (Mcal).

Using mature weight to explain differences in cow maintenance energy requirements is a good place to start; however, mature weight alone might be insufficient to explain differences among animals for maintenance energy requirements. Previously reported research shows that individuals and breeds of similar biological type for mature size are not necessarily equivalent for maintenance energy, especially when we evaluate them at different levels of production (i.e., lactation)(Montano-Bermudez et al., 1990).

Although the milk EPD is not derived directly from milk production and is determined from the maternal component of weaning weight, it is well documented that the milk EPD adequately represents differences in actual milk yield (Mallinckrodt et al., 1993). These differences in milk producing potential can be related to differences in energy requirements for lactation and variation in visceral organ mass. Interestingly, this higher energy demand does not dissipate when a cow is in the dry period of production (Solis et al., 1988). Even though a cow is not milking, she still must maintain the body tissues that drive her higher milk production.

Researchers have also determined how animals lactate over time and what the energy values are for milk components (Wood, 1969; NRC, 1996). Using this information, we are able to represent lactation with a mathematical function (lactation curve) and use milk EPD to predict an animal's milking ability. The genetic merit of an individual for higher or lower milk production would affect their prediction for cow maintenance energy requirements. Therefore, animals of the same mature size but different levels of milk production would consequently have different maintenance energy requirements. This approach to predicting maintenance energy helps explain additional differences among animals in a population and improves the accuracy of each maintenance energy requirement prediction.

Trait Expression

Currently, the trait for mature cow maintenance energy is expressed as megacalories per year (Mcal/yr). Because this is a relatively new trait, we are still determining if this is the most appropriate way to express the trait. The benefits of using megacalories instead of other units of measure are that it is easy to translate to other energy units and it conforms to what is accepted by the nutrition community and National Research Council guidelines for nutrition in beef cattle. Additionally, people are familiar with calories on nutrition labels, so expressing the trait in these units is not completely foreign.

It will be important to express the trait for maintenance energy requirements in such a way that cattle producers will thoroughly understand the interpretation and correctly apply it in their breeding programs. One way to enhance the understanding of a maintenance energy EPD would be to use example diets (i.e. pasture grass, grain, or hay) to provide a frame of reference for producers to interpret and compare animals for maintenance energy requirements. Using an example diet and reasonable estimates of feed prices, a cattle producer could directly assess the economic risk of using one sire over another sire in a breeding program.

Current Research

A prototype EPD for cow maintenance energy requirements has been completed for the Red Angus breed (Evans, 2001). There is a summary of the results in Table 3 and the EPD are expressed on an annual scale (Mcal/yr). The results of this analysis show that differences are present among all animals and sires for maintenance energy requirements. For all animals, there is greater than a 1,000 Mcal per year difference between the highest and lowest animal. A cattle producer could use this EPD in a selection program to modify maintenance energy needs in his/her herd and select cattle whose maintenance energy requirements are most appropriate for the environment in which they will be managed.

How does this maintenance EPD work? For example, we have a herd of Red Angus cows and two sires available at breeding time. Sire A has a maintenance energy EPD of 400 Mcal/yr and sire B has an EPD of 0 Mcal/yr. On average, we expect the progeny from Sire B to require 400 fewer Mcal per year for maintenance energy requirements relative to progeny of sire A. You might be asking yourself how many days on feed does that value equal? If we take an average Red Angus cow, she will require 11 Mcal per day or 4,015 Mcal per year of energy. Reducing her energy needs per year by 400 Mcal would result in a 10% reduction in annual feed inputs. If all other factors remain constant, this reduction in the number of calories should result in fewer feed inputs and a lower cost of production. If the average annual feed cost per cow was $167/year (McGrann, 1999), the reduction in feed inputs for maintenance energy requirements would result in more than a $16 reduction in feed inputs.

Table 3. Mean, standard deviation, and range of EPD (Mcal/yr) for mature cow maintenance energy for Red Angus cattle

	All Animals (N = 56,582)	Sires (N = 5,912)
	EPD	EPD
Mean	22.4	23.8
Standard Deviation	102.1	94.8
Minimum	-427.9	-381.9
Maximum	581.9	434.0

A change in maintenance energy requirements for any one animal might be viewed as unimportant; however, these changes do accumulate across an entire herd and over multiple generations. Selecting animals to reduce maintenance energy requirements could impact a producer's profitability through a reduction in production costs given all other performance indicators were unaffected.

The genetic trend for maintenance energy requirements is illustrated in Figure 1. This trend shows the average EPD for maintenance energy requirements in the Red Angus breed for years 1945 to 1995. There is a 2.0 Mcal/yr change in the genetic trend for all years; however, mature weight data collection started in 1970. After 1966, the rate of change for the genetic trend increased to 3.8 Mcal/yr. This trend was maintained until 1989 followed by a decreasing rate of change and leveling of the genetic trend for maintenance energy requirements.

New Directions

The EPD that we proposed for maintenance energy requirements is a prototype. More research is necessary to improve the accuracy of the genetic predictions. Currently, we are just using mature weight and milk (maternal weaning weight) to predict mature cow maintenance energy requirement. We selected these traits because the genetic predictions and methods were available to develop an EPD for the trait. Alternative indicator traits and direct measures of maintenance energy are needed to improve the accuracy of this EPD. Other candidates for indicator traits might include body condition, visceral organs (i.e., liver size), and cell-level indicators of maintenance energy requirements. Additional research will be required to determine how these sources of information can be incorporated into the current genetic prediction.

Body condition score data are another source of information to enhance the accuracy of an EPD for maintenance energy requirements. The trait for body condition score is easy and cost effective to collect and body condition is a heritable trait (Marlowe et al., 1985). Including body condition score information has the potential to account for differences among animals with the ability to store excess energy because of lower maintenance energy requirements. However, further research is needed to determine the most appropriate way to include body condition data into an EPD for maintenance energy requirements.

The visceral organ mass, more specifically the liver, represents one potential source of information for the prediction of maintenance energy requirements. In beef cattle, the liver is one of the most metabolically active organs and consumes approximately 22% of an animal's energy expenditure as a function of an animal's fasting heat production, but it only accounts for 1.6% of animal's weight (Ferrell, 1988). Compared to other visceral organs, the liver is a good candidate for an indicator trait of maintenance energy requirements.

A challenge with collection of data for liver size is how to collect the information without harvesting the mature animal. Previously, ultrasound technology has been studied as a method to predict the size of the liver (Braun, 1990). Research conducted at Colorado State University evaluated the application of this technology using feedlot cattle. The research results showed no relationship between several linear measures of liver size using ultrasound technology and actual liver weight (Ruppert, 2001). Further research is needed to determine the application of ultrasound technology for the prediction of liver size, in addition to the most appropriate age and class of animals to use.

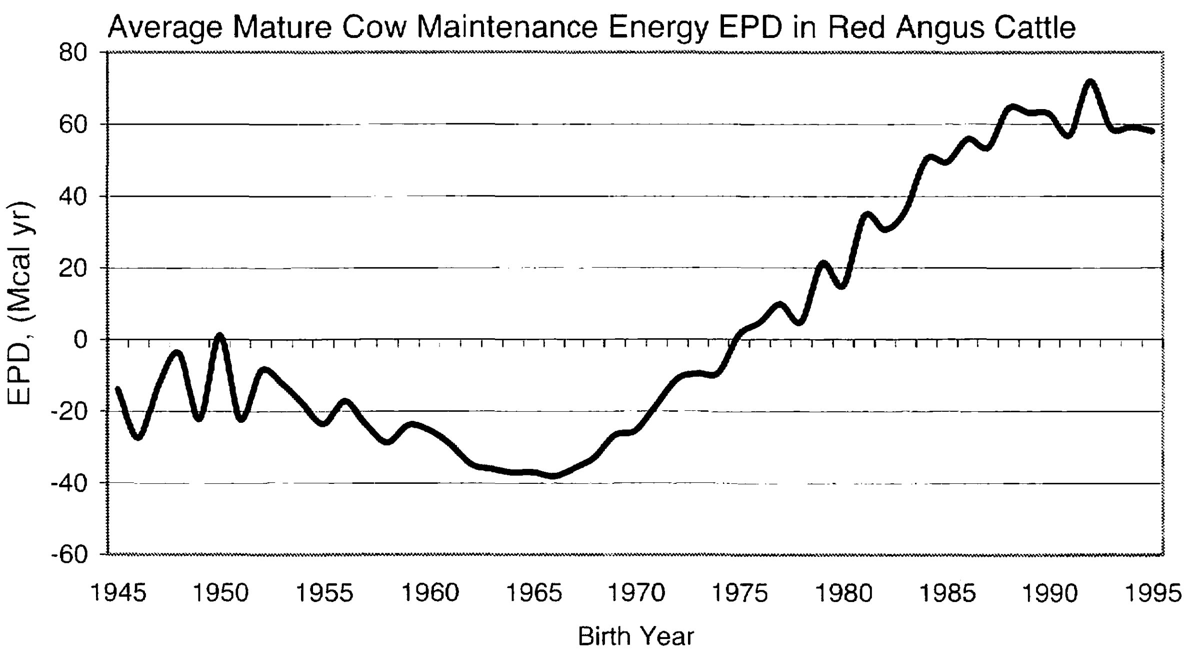

Figure 1. Average EPD (Mcal / yr) for mature cow maintenance energy requirements by birth year in Red Angus cattle.

Summary

A predictor for mature cow maintenance energy requirements should provide both commercial and seedstock producers with a selection tool for a trait that directly impacts cost of production. An EPD for maintenance energy requirements will add to a developing list of economically relevant traits and provide producers with the tools to practice balanced selection for traits with direct impact on profitability. If adopted by the industry, producers will need to continue their efforts to collect mature weight information and other indicator trait information. Furthermore, researchers will need to continue to research and enhance this new economically relevant trait.

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MULTI-TRAIT PREDICTION OF FEED CONVERSION IN FEEDLOT CATTLE[1]

W.O. Herring[2] and J. K. Bertrand[3]
[2]University of Florida, Marianna and [3]University of Georgia, Athens

Introduction

Compared to growth and more recently, carcass traits, the underlying genetic variation that controls feed and forage utilization has remained unexploited in beef cattle selection programs. This is quite surprising since feed costs for a feedlot steer can easily approach $200. The opportunity to reduce costs through genetic means seems to be present since the scientific literature indicates that feed intake and efficiency traits are heritable. However to date, no Expected Progeny Differences for efficiency traits have been published by North American breed societies due to the expense associated with collection of individual feed intake records, which are needed to maximize selection response. The purpose of this paper is to provide an overview of efficiency traits and their interrelationships with other economically important traits and to offer an example of how feed efficiency has been incorporated into a multi-trait selection program in the United States.

Efficiency Traits

Efficiency in feedlot cattle is often described as *feed conversion* (or its inverse *feed efficiency)*, the units of feed consumed divided by the units of animal gain over a specific time period. For feedlot cattle, this would be the pounds of feed consumed from feedlot entry through harvest divided by the pounds of gain. Factors influencing efficiency include age, diet, temperature, breed, growth promoting implants, ionophores and many other management and environmental variables. The NRC (2000) suggests that calf-feds are probably more efficient than yearlings when placed on feed and, in general, younger animals consume less feed per unit of body weight than older ones. All of these factors are important to consider when comparing *feed efficiency* or *feed conversion* among groups of cattle from various production systems.

While *feed conversion* is useful for evaluating phenotypic performance of feedlot cattle, it is a problematic variable for genetic improvement due to the component traits being expressed at different rates and/or possible nonlinearity of the component traits. Further, selection on the ratio could lead to undesirable changes in the component traits. Table 1 illustrates fictitious groups of cattle, all with a feed conversion of 5.5. However, each has differing growth and intake rates. While the 'low growth' cattle converted equally to the 'high growth' cattle, the lower growth group would not be acceptable if the production objective was to maximize profit. In Angus Sire Alliance steer data (described later), it has been observed that there are sire groups with

[1] Thanks are expressed to Circle A Angus Ranch, Iberia, MO for providing growth, feed intake and carcass data from their progeny testing program and to Ignacy Misztal of the University of Georgia for providing software (http://nce.ads.uga.edu/~ignacy/).

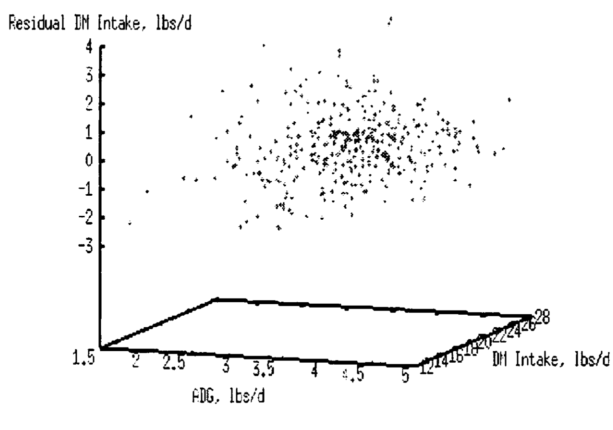
identical feed conversion rates, and yet, they differ for average daily gain. Therefore, breeders should be cautious on selecting for feed conversion alone.

Table 1. Example of cattle with feed conversion of 5.5 lb dry matter intake per lb gain but with differing growth and intake rates

Growth rate	ADG, lbs·d^{-1}	Daily DM Intake, lbs·d^{-1}
High	4.0	22.0
Medium	3.0	16.5
Low	2.0	11.0

To escape some of the problems of dealing with ratios, Koch et al. (1963) suggested using *residual feed intake* as a measure of efficiency. Those researchers suggested that intake could be adjusted for the level of production by regressing intake on growth rate and average body weight. The residuals or *residual feed intake* (observed values -- predicted values) should then reflect efficiency of feed use. Animals with more negative values should be more efficient, since they are consuming less than the regression predicts they should. *Residual feed intake* should also be phenotypically independent of growth and weight traits used in the regression procedure since variation from those traits has been removed. This is important to note in selection programs, since efficient animals may not have acceptable levels of growth. As shown in figure 1, there is not a phenotypic relationship between residual dry matter intake and average daily gain in our Angus steer data. By definition, *residual feed intake* is phenotypically independent of those traits for which it has been adjusted.

Figure 1. Residual dry matter intake plotted with average daily gain and dry matter intake in finished Angus steers (n=353).



Genetic Parameters

Numerous reports in the literature illustrate there is underlying genetic variation for efficiency traits and genetic covariation of those same traits with other economically important traits. Koots et al. (1994a and 1994b) compiled heritability and genetic correlation estimates of numerous beef production traits. Table 2 provides those heritabilities for feed conversion, efficiency and intake, demonstrating that each is moderately heritable and would respond to selection. In fact, the reported heritability for feed conversion of .36 is 33% larger than that reported for weaning weight direct (h^2=.27).

Table 2. Heritabilities for efficiency traits of beef cattle from various literature estimates[1]

Trait	Heritability
Feed conversion (f/g)	.36
Feed efficiency (g/f)	.42
Feed intake	.41

[1]Koots et al. (1994a)

Koots et al. (1994b) also summarized the reported genetic relationships of those same efficiency traits with numerous other economically important traits. Table 3 highlights a few selected genetic correlations. Feed conversion was reported to be moderately and favorably related to post-weaning gain and feed intake, indicating that single trait selection for lower feed conversion would result in higher degrees of growth with less feed intake. Conversely, those researchers summarized that feed conversion was unfavorably, but not as strongly related with weaning weight direct and external fat thickness.

Table 3. Genetic correlations of beef cattle efficiency traits with growth and carcass traits from various literature estimates[1]

Trait	Feed conversion (f/g)	Feed intake
Weaning weight direct	.16	.67
Post-weaning gain	-.53	.53
Fat thickness	-.24	.14
Marbling score		.09
Feed intake	.38	-

[1]Koots et al. (1994b)

As described earlier, residual feed intake has gained interest from researchers as a trait that may describe animal efficiency without the problems associated with ratios. Again, residual feed intake is the deviation between the observed and predicted values where intake is regressed on production traits, usually average daily gain and metabolic body weight (mid-test weight$^{.75}$). Several recent studies have estimated heritabilities for residual intake along with genetic relationships with other production and carcass traits. Table 4 provides heritabilities reported from recent studies for residual intake along with average daily gain, feed intake and feed conversion in Angus bulls and heifers, Charolais bulls and Hereford bulls. With the exception of the estimate for feed conversion reported by Herd and Bishop (2000), heritabilities for feed intake and conversion are moderate and similar to those reported by Koots et al. (1994a). In the studies reported by Arthur et al. (2001a and 2001b), heritability for residual feed intake was .39 for both Angus bulls and heifers and Charolais bulls. Herd and Bishop (2000) reported a lower heritability of .16 for residual intake in Hereford bulls, similar to that of feed conversion reported in the same study. Nonetheless, there appears to be sufficient genetic variation to make selection progress for residual intake.

Table 4. Heritabilities from recent studies for growth and efficiency traits in three beef breeds

Trait	Angus bulls and heifers[1]	Charolais bulls[2]	Hereford bulls[3]
Average daily gain	.28	.34	.38
Feed intake	.39	.48	.31
Feed conversion	.29	.46	.17
Residual intake	.39	.39	.16

[1]Arthur et al. (2001a)
[2]Arthur et al. (2001b)
[3]Herd and Bishop (2000)

Similar to Koots et al. (1994b), more recent studies continue to confirm strong genetic relationships for feed intake and feed conversion with average daily gain, with feed conversion and average daily gain being related in a favorable direction. There appears to be no genetic relationship with residual intake and average daily gain for the three breed-sex class combinations reported. Since residual feed intake was created by regressing intake on average daily gain and weight, there should be no phenotypic relationship present; however, Kennedy et al. (1993) points out that the phenotypic adjustment does not guarantee that residual intake will be genetically unrelated to production, but in these studies it does appear to be unrelated.

Table 5. Recent reports of genetic correlations among efficiency traits

	Feed intake		Feed conversion		Residual feed intake		
	Angus[1]	Charolais[2]	Angus[1]	Charolais[2]	Angus[1]	Charolais[2]	Hereford[3]
Average daily gain	.54	.39	-.62	-.46	-.04	-.10	.09
Feed intake			.31	.64	.69	.79	.64
Feed conversion					.66	.85	.70

[1]Arthur et al. (2001a)
[2]Arthur et al. (2001b)
[3]Herd and Bishop (2000)

Residual intake is highly genetically correlated in favorable directions with feed intake and feed conversion. These studies in Angus, Charolais and Hereford cattle indicate that if selection against residual intake (for lower, or more efficient cattle) was practiced, correlated responses in lower intake and better feed conversion would result.

Less information is available on the genetic relationships that exist for residual intake with meat quality and composition traits, particularly in steers. However, Arthur et al. (2001a) reported a genetic correlation of .17 between residual intake and ultrasound rib fat in Angus bulls and heifers, indicating that a small but favorable relationship with leanness (for terminal breeding programs) may exist. That report is further substantiated by the genetic correlation of -.43 between carcass lean content and residual intake in Hereford bulls reported by Herd and Bishop (2000).

The Angus Sire Alliance
The Angus Sire Alliance was initiated in 1996 by Circle A Angus Ranch, Iberia, MO, as a program that combines marketing and technology efforts to test and identify the most

profitable terminal Angus genetics. The technical aspects of the program have been described at earlier BIF meetings (Herring and MacNeil, 2001).

Production and Carcass Data: Angus seedstock producers nominate a young sire to be tested in the program by providing semen and the sire for breeding use in Circle A Angus Ranch commercial operations. Sires are bred artificially to commercial Angus females at all three of their commercial cow-calf ranches in Iberia, Huntsville and Stockton, MO. Cows, at random, are also allocated to each sire for natural service use at one of the ranches. Other Angus sires developed from Circle A purebred operations are tested through the program. Traits measured on steer offspring include calving ease, birth weight, weaning weight, backgrounding starting and ending weight, feedyard starting and ending weights, yearling weight, yearling ultrasound %IMF, yearling ultrasound ribeye area, yearling ultrasound fat thickness, carcass weight, carcass marbling score, carcass %KPH, carcass ribeye area and carcass 12-13th rib fat thickness. Data collected on heifers include calving ease, birth weight, weaning weight and yearling weight. Steer contemporary groups are established at birth and defined by birth pasture. These contemporary groups remain together and are not sorted from that point forward through harvest. At weaning, steers are backgrounded at the ranches for approximately 120 days. They are then shipped to a cooperating feedyard until harvest.

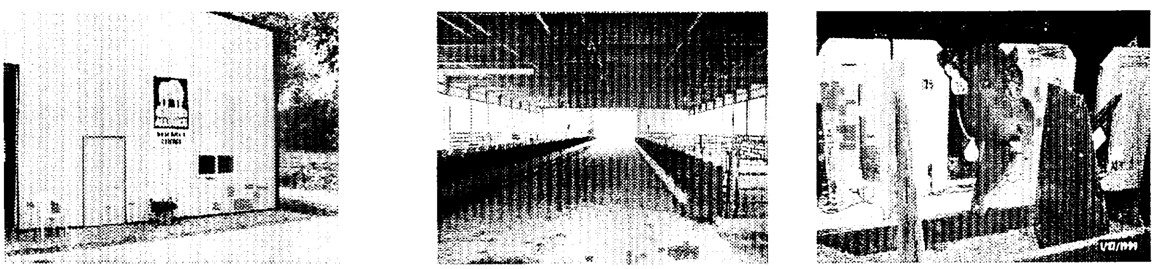


Figure 2. Calan Broadbent Feeding Gates used for measuring intake at Angus Sire Alliance Research Center

Feed efficiency: After the backgrounding period, some of the steer contemporary groups are placed in the Angus Sire Alliance Research Center at Huntsville, MO, to be evaluated for individual daily dry matter intake (figure 2). The research barn houses 96 Calan Broadbent Feeding Gates. Initial weights are taken at the beginning of the test and daily feed intake is recorded from this day to the end of the feeding period. A stepwise series of five finishing rations that are identical to the series of rations fed to the remaining test cattle at the commercial feedyard are used throughout the finishing period. Steers are weighed and ultrasonically scanned midway through the test. The afternoon prior to harvest, steers are weighed and then transported overnight to a commercial facility for slaughter and carcass data collection.

These data have made it possible to provide some preliminary estimates of genetic parameters for feed efficiency traits in Angus steers. Table 6 provides a description of the steers, both with and without intake records, used in this analysis. The deviation of weaning weight from carcass weight (adjusted to a final live weight using an assumed 62% dress) was used to compute average daily gain. Test average daily gain was computed using actual starting and final weight for those steers with intake records. Metabolic mid-weight for steers with intake records was computed using the actual weight collected midway through the feeding trial. Residual intake was computed as the deviation of the observed from predicted values by regressing average daily intake on test average daily gain and metabolic mid-weight.

Table 6. Descriptive statistics for Angus Sire Alliance steers

Trait	N	Mean	Std. Dev.	Min	Max
Slaughter age, d	3960	445	21	364	503
Average daily gain[a], $lbs \cdot d^{-1}$	3937	2.9	.43	1.1	4.5
Test average daily gain[b], $lbs \cdot d^{-1}$	353	3.6	.5	1.8	5.0
Intake, $lbs \cdot d^{-1}$	353	20.3	2.2	12.2	26.2
Mid-weight, $lbs^{.75}$	353	190	16	151	234
Feed conversion	353	5.7	.7	3.9	9.0
Residual intake, $lbs \cdot d^{-1}$	353	0.0	1.1	-2.5	4.0
Carcass weight, lbs	3960	751	73	476	993
Fat thickness, in	3932	.56	.18	.10	1.4
Ribeye area, in^2	3927	11.8	1.4	6.2	8.2
USDA yield grade	3912	3.4	.7	.5	6.4
Marbling score[c]	3941	5.8	1.0	2.1	10.8

[a]Calculated using weaning weight and estimated live slaughter weight (estimated from carcass weight using a 62% dressed weight)
[b]Calculated using initial and final live weights from steers with intake records
[c]4.0=Slight^{00}; 5.0= Small^{00}; etc.

Genetic and environmental (co)variances were estimated with a 6-trait animal model for post-weaning gain, daily dry-matter intake, feed conversion, residual daily intake, fat thickness and marbling score. For steers without intake records, their average daily gain, fat thickness and marbling records were included in the analysis. A fixed effect of contemporary group and a random direct genetic effect were fit for all traits. An additional covariate for slaughter age was included for marbling score and fat thickness. An average information REML algorithm was used to estimate genetic and environmental (co)variances among all traits. Heritabilities and genetic correlations are provided in table 7.

Table 7. Heritability (diagonal) and genetic correlations for feed efficiency and carcass traits in Angus steers

	ADG	Intake	FC	RI	FAT	MAR
Average daily gain (ADG)	.28	.56	.01	.23	.04	-.04
Intake		.44	.55	.92	.46	.20
Feed conversion (FC)			.15	.65	-.09	.14
Residual intake (RI)				.50	.46	.10
Fat thickness (FAT)					.40	.23
Marbling score (MAR)						.45

We emphasize that these results are preliminary (n=353 animals with intake records) and may change as more data become available. Heritabilities for average daily gain, intake and feed conversion are similar to those reported by studies in table 4. However, the heritability for residual intake in the present study of .50 is higher than those reported by Arthur et al. (2001a and 2001b) and Herd and Bishop (2000).

Genetic correlations for average daily gain:intake, feed conversion:intake and residual intake:feed conversion were all moderate and similar to those reported in the earlier referenced studies. While Arthur et al. (2001a and 2001b) and Herd and Bishop (2000) reported large genetic correlations between residual intake and intake, our estimated relationship was even larger (r_g=.92), with all reports indicating that selection for lower residual intake (more efficient cattle) would decrease overall feed consumption.

Different from the same reports is our estimate of no relationship between feed conversion and average daily gain. Because of the strong genetic correlation we report between residual intake and intake, this lack of relationship could be due to intake driving feed conversion rather than gain. We also estimated a small genetic relationship between residual intake and average daily gain. While residual intake is phenotypically independent of average daily gain (r_p=.0), it may need to be estimated using genetic rather than phenotypic regression (Kennedy et al., 1993) as more data become available.

We were also able to estimate genetic relationships with carcass marbling and fat thickness. Of interest was the genetic correlation of .46 between residual intake and fat thickness, indicating that selection for lower residual intake would result in compositionally leaner cattle at harvest. This is a stronger relationship than that reported by Arthur et al. (2001a) and Herd and Bishop (2000).

<u>Multi-trait selection:</u> While feed consumption accounts for a major portion of costs associated with terminal feedlot animals, growth and carcass traits contribute additionally to net return. Maximizing profit for terminal production systems may not necessarily mean using the most biologically efficient genetics for feed consumption. Profit should be maximized, however, if each of the traits that contribute to profit is appropriately weighted by its relative economic value and subsequently used in an economic selection index to rank sires for profit. Herring and Macneil (2001), from these same data, computed Expected progeny Differences (EPD) for birth weight, weaning weight direct, post-weaning gain, intake, marbling score and yield grade. Relative economic weights were then computed from a bio-economic simulation for each of the traits for a terminal Angus production system. The EPD and relative economic values were then combined to rank sires for net return per progeny for the terminal system, resulting in a range of $42 per calf among the sires.

Archer et al. (1999) suggested that while it may be more appropriate to use intake and gain EPD with economic selection index, producers are more acclimated to using individual EPD rather than selection index. Therefore, they suggest that genetic values for residual intake rather than intake or feed conversion are a better alternative. However, we suggest that rather than spend educational efforts on a new trait, those efforts would perhaps be better spent assisting cattlemen with understanding and implementing economic selection indexes that include component traits of feed efficiency.

Efficiency – Future Efforts

Even though the improvement of feed and forage utilization could significantly improve profitability of U.S beef operations, there are no genetic predictions available for improvement of efficiency in growing or adult animals. Inadequacies in current knowledge include a lack of understanding of genetic relationships of efficiency with other economically important traits both within and across growing and adult cattle. Further, very little is understood about the underlying physiological mechanisms that control the utilization of feed and forage.

The most obvious obstacles to providing broadscale genetic predictions for efficiency are the expense of gathering individual feed intake records and the identification of which animals should be the focus of intake collection efforts. Genetic predictions could be generated without intake records based only on relationships with other traits such as growth and fat. However, Expected Progeny Differences computed without intake records and based only on relationships with other traits would not identify animals that defy the norm.

So, what possible solutions exist for genetically improving feed efficiency in feedlot cattle for terminal production systems? Ideally, records would be generated from steer progeny in a feedlot setting and would originate from a structure similar to that used for designed progeny testing for carcass traits. Several breed associations already have ongoing progeny testing programs for carcass traits, and these programs could be expanded to collect individual intake data. This approach would require existing commercial feedyards to install individual intake measuring equipment and designate personnel for day-to-day oversight.

Secondly, there are approximately 58 central bull test stations in the United States that are operated by land grant university extension programs. Historically, these stations were used as genetic testing platforms for growth traits in purebred bulls. Some of these stations already have individual feed intake equipment. If funding were available, other central test stations could be retrofitted with intake measuring equipment. Working with beef cattle breed associations, contemporary groups of bulls that most appropriately represent sires used on a broad scale could be targeted for testing.

Of course, both of these approaches would require significant levels of funding and expertise to implement and maintain. Recent advances in intake measuring equipment are notable, and uses of these technologies for collection of field data may be approaching reasonable costs. Depending on test length, initial equipment costs and depreciable equipment life, test costs over and above normal animal production costs may now be as little as $50 per animal (Alison Sunstrum, Growsafe Systems Ltd., *personal communication*).

It has been demonstrated that feed efficiency in feedlot cattle is moderately heritable, and thus should respond to selection if Expected Progeny Differences were available. There were 28.5 million steers and heifers harvested from U.S. feedlots in 2001. Assuming averages for dry-matter conversion of 6.5, $120/Ton feed costs, and 500 lbs of feedlot gain, a 2% reduction in feed consumption holding all other traits constant would provide an $111 million improvement in net return to U.S. beef producers. To achieve this end, cattlemen will have to assist through direct support or lobbying of federal funding for facilities and operating capital to support research and development of programs to improve feed and forage efficiencies. Feed and forage efficiency improvement will increase ranch profit through reduced input costs and reduce potential environment disruption through reduced animal waste production.

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GENETIC PREDICTION OF EFFICIENCY IN THE FUTURE: *AN AUSTRALIAN PERSPECTIVE*

David Johnston
Animal Genetics and Breeding Unit, University of New England,*
Armidale, NSW 2351, AUSTRALIA

Introduction

The cost of feed is an important variable affecting the profitability of beef production. The cow herd has been estimated to consume 65-85 % of the energy required for beef production and slaughter stock often consume expensive feed, particularly those finished on high concentrate feedlot diets. Manipulation of the environment and cattle management (e.g. age of turn-off) can be used to reduce feed costs and it has also been known for several decades that feed intake and measures of feed efficiency are heritable in beef cattle. However to date, no direct selection based on feed intake data has occurred in the beef industry. Recently there has been a wave of new genetics research on feed intake with particular focus on implementation into industry breeding programs. Research in Australia has been lead by NSW Agriculture's team at Trangie NSW and continued by the Cooperative Research Centre for Cattle and Beef Quality (Beef CRC). Results to date show feed intake and various measures of efficiency are under genetic control and sufficient variation exists, along with the high economic importance of feed, to warrant inclusion of a suitable measure in a genetic evaluation scheme and in the formulation of breeding objectives. Outlined in this paper are results from Australian research and our recent development of an estimated breeding value (EBV) for net feed intake (NFI) for use in the Australian seedstock industry.

Research Projects

Measuring individual feed intake in beef cattle is expensive, requiring sophisticated equipment and considerable labour. Therefore generating sufficient data for genetic studies is difficult and costly. Two major studies in Australia over the past 10 years have measured individual feed intake on over 3000 straightbred cattle with known pedigree and management information. The first project was a comprehensive study on feed efficiency at the Agricultural Research Centre, Trangie, NSW, Australia. Angus bulls and heifers (N =1500) were tested for postweaning feed efficiency between 1993-1999 using an automated feeding system. Each animal was fitted with an electronic ear tag and every feeding event was recorded over a 120 or 70 day period. Animals had *ad lib* access to a pelleted alfalfa and wheat diet with an average energy density of 10.5 MJ ME/kg DM and 15 to 17 % crude protein. In 1994, NFI selection lines were established by dividing the heifers from each test into "Low" (high efficiency) and "High" (low efficiency) lines based on their NFI performance. Each year 3-6 bulls (selection based on their own NFI performance) were used in each line. Progeny were measured for feed intake and NFI using the postweaning test.

* AGBU is a joint venture of NSW Agriculture and The University of New England

The second large project that measured feed intake was conducted by the Beef CRC. It was a very large integrated research program that investigated production and processing factors affecting meat quality (Bindon 2001). The straightbreeding project provided almost 8000 pedigree recorded animals for both quantitative and molecular genetics work. Animals used in the study were from four temperate breeds (Angus, Hereford, Shorthorn and Murray Grey) and three tropically adapted breeds (Brahman, Santa Gertrudis and Belmont Red). A subset of the feedlot finished cattle (N =1590) had individual feed intake measured using computerized automatic feeders and data loggers developed as part of the Beef CRC, in conjunction with the Ruddweigh International Scale Company. A total of sixteen feeders were installed. Each pen was fitted with a single feeder and could hold up to 12 animals. Each animal was fitted with an electronic ear tag and every feeding event was recorded over the test period after an initial warm-up period. Animals had *ad lib* access to a typical feedlot finishing diet of 75% barley with a 12.1 MJ ME/kg DM energy density. Animals (predominantly steers) ranged in age and weight depending on their market weight treatment group (i.e. domestic or export). On average the domestic market group (target carcass weight of 220 kg) consumed 11.6 kg of feed per day and were 377 kg liveweight compared to the export market groups (target carcass weights of 280 or 320 kg) that consumed on average 12.3 kg/d and were 510 kg liveweight. Due to feedlot constraints, animals were only recorded for feed intake for an average of 50 and 65 days for domestic and export groups, respectively.

Defining efficiency traits

The collection of large numbers of individual feed intake records has enabled researchers to investigate the genetics of daily feed intake and also compute several measures of efficiency. Although initially it may seem logical, selection for reduced feed intake alone inevitably results in a correlated reduction in body weight. Therefore various functions of output of beef per unit of feed are used as measures of feed efficiency. The most common index of efficiency is gross efficiency defined as the ratio of output (e.g. gain) over feed inputs (e.g. kg feed eaten). Feed conversion ratio (FCR) is the inverse of gross efficiency. FCR has been used as a measure of efficiency for several decades, particularly in the chicken and swine industries. Many researchers have shown FCR to be strongly negatively correlated with growth rate. It is therefore argued that selection for faster growth rates will achieve improvements in feed efficiency mainly through a reduction in maintenance costs due to less days on feed to the same weight endpoint. Whilst selection for growth rate may negate the need to measure feed intake, it is likely to lead to higher mature weights, which may be undesirable in the cow herd. Conversely, the trait net feed intake (NFI), or residual feed intake (RFI) as is it sometimes called, is computed in such a way as to be phenotypically independent of weight and gain. NFI was first proposed by Bob Koch (Koch et al. 1963) and is the difference between actual feed intake and the expected feed intake requirements for maintenance of body weight and production (e.g. gain). Kennedy et al. (1993) showed that although NFI is phenotypically independent of production it is not necessarily genetically independent. Many other measures and definitions of efficiency exist (e.g.

cow/calf efficiency, maintenance efficiency) and several are discussed in detail in the review of Archer et al. (1999).

Although clear definition of a trait is important in a genetic evaluation program, the key trait that must be measured is feed intake. Selection index methodology can be used to ensure the correct trait emphasis in a multi-trait selection framework. Barwick (2002) discusses the effect of trait definition and presence of other measures on the derivation of economic values and index weightings for costing feed. The choice of which trait to include in a genetic evaluation program will depend on the data being recorded, the model used to compute EBVs and the method used to construct indexes. However, for industry adoption, consideration is required on the definition of a trait such that breeders will be encouraged to take the new measurements. In Australia, researchers in consultation with industry, have decided to use NFI as the trait to be used in genetic evaluation to improve feed efficiency.

Key research Outcomes

Numerous publications exist from the Trangie work (e.g. Arthur et al. 2001a,b; Archer et al. 1998; Herd et al. 1997; Archer and Barwick 1999, 2001; Richardson et al. 2001). In brief, daily feed intake (FI) of young animals measured post-weaning over a 70 day test was heritable (h^2=0.39) as were the measures of efficiency; FCR (h^2= 0.29) and NFI (h^2 = 0.39). The phenotypic correlation between FCR and ADG was -0.74 with a genetic correlation of -0.62. Whereas, NFI had phenotypic correlations of -0.06 and 0.02 with ADG and metabolic weight (MWT) (i.e. mid-test weight raised to the power 0.73), respectively. Although the computation of NFI has removed the phenotypic relationship with weight and gain, the genetic correlations between NFI and weight traits were not zero and tended to be negative (-0.02 ADG, -0.06 MWT, -0.45 weaning wt direct, -0.26 yearling wt direct). NFI was still positively correlated (0.69) genetically with FI. These results suggest that selection for reduced NFI would result in correlated increases in weight and reduction in FI. Hence the efficiency appears to be achieved by the animals being genetically able to eat less whilst not reducing growth. The genetic correlation between NFI and measures of fatness tended to be slightly positive.

Data from the Trangie divergent NFI selection lines, after 5 years of selection (1.73 and 1.96 generations, for the Low and High NFI lines, respectively) showed average selection differentials of -0.32 and 0.39 kg/d per year for the Low and High lines, respectively. An average annual divergence rate in NFI of 0.21 kg/d was achieved between the lines with a realized heritability of 0.33 (Arthur et al. 2001).

The final results from the Beef CRC are being prepared for publication and preliminary results have been presented by Robinson et al. (1999a,b; 2001). Feed intake measurements were taken on predominantly steers being finished under commercial feedlot conditions. As previously mentioned, the animals were finished to different market weights and the length of feeding was shorter than the Trangie tests. The major problem encountered with the analysis of the data was in computing an accurate measure of weight gain. This occurred due to the small numbers of weight records during the test and the relatively short test length. These problems highlighted the shortcomings of using ADG but did however allow us to make changes to all future protocols for testing feed intake and measuring ADG. The problem with the inaccurate estimate of ADG was overcome in the analyses by using all weights of an animal whilst in feedlot and not just those measured during the feed test period. The resulting heritability estimates were 0.24, 0.20 and 0.18 for FI, finishing ADG and NFI. The phenotypic and genetic correlations between the three traits: FI, NFI and ADG were very similar to the Trangie results. However the genetic correlations between NFI and fatness were stronger (i.e. more positive) in magnitude, possibly the result of greater genetic expression of fatness in these cattle due to them being older and on a higher energy diet.

Overall the results from both experiments showed feed intake and measures of efficiency were heritable. The trait NFI has several properties that may be preferred over FCR. The genetic correlations suggest that animals with genetically lower NFI (at the same weight and gain) are eating less, are likely to be leaner, with larger eye muscle areas. Unfortunately the data structure was not sufficient to allow the estimation of the genetic correlation between the Trangie postweaning seedstock measure and the Beef CRC feedlot finishing measure. This will be addressed in a current research project (see below).

Note: A 17 paper special edition of the Australian Journal of Experimental Agriculture on Feed Intake and efficiency is expected by next year and will contain new results, some of which have been referred to in this paper.

Economic analyses and costing feed

The relative importance of a trait in a breeding program is dependent on the economic value (EV) of the trait and the amount of genetic variation that exists for the trait. However unlike many other traits, determining an economic value for feed costs is not a trivial task. Deriving an economic value for feed requires, for each market production system, consideration of the unit cost of additional feed (pasture and feedlot), the amount of time spent on pasture and feedlot for the young animal, and for cows and replacements the period of a year when feed has a cost. Commonly techniques are used to discount the EV of a trait to present day dollars. This is the general approach used by Barwick et al. (1999) to derive EVs for feed costs for different production systems and to quantify the increased profit of a breeding program resulting from measuring feed intake and including it in the selection index. The BreedObject system uses two main methods for costing feed: the cost of bought feed and secondly the cost equivalent to lost profit from the reduction in herd numbers.

Recent simulation research (Barwick et al. 1999) showed that recording NFI can increase the accuracy of selection by up to 40 % particularly for production systems that include a considerable period in a feedlot (+200 days at $210/tonne of feed). Archer and Barwick (1999) also investigated the impact of altering the number of animals in a breeding population tested and the effect of altering the cost of testing and the design of industry breeding programs (e.g. 2 stage selection strategies, individual versus progeny testing) on the gains.

Feed intake at pasture

Both Australian experiments reported measured individual feed intake in a feedlot (although with different diets) and not at pasture. The question that needs to be answered is how does this measure relate genetically to feed intake and efficiency at pasture? Follow-up work has occurred at Trangie where almost 1000 of the heifers tested at postweaning were returned to the testing unit as 4 year old cows. Although still not a pasture measure, the cow feed intake data is providing valuable information on feed intake and efficiency measures of the cow and its relationship to other cow traits (weight, fat and fertility) and importantly with the postweaning measures.

Some small studies have also occurred where steers at pasture have had their feed intake estimated using synthetic alkanes administered using intra-ruminal controlled-release devices (CRD). Results to date are encouraging, steers from the High and Low NFI divergence selection lines from Trangie were estimated to have consumed similar amounts of pasture but the Low NFI line (i.e. more efficient) were tending to gain more weight (R.M. Herd personal communication). Analysis of data from a second study is underway where 160 steers were measured post-weaning for feed intake using the CRD technique at pasture and again during feedlot finishing in the Beef CRC automatic feeders.

It is very unlikely that industry-wide measurements of feed intake will be possible given the current technology. Therefore research projects will be critical in generating data that can be used to determine the genetic relationships between the feedlot measure and pasture intake, and between the young animal and the cow. These estimates (including trait variances) along with correlations with other traits will be essential in developing the framework necessary to include genetic measures of feed intake in the formulation of breeding objectives.

Net Feed Intake EBV

The encouraging results from Trangie and the Beef CRC and the potential economic benefits to commercial producers prompted us at AGBU, through our MLA funded research project, to use the feed intake data to develop an EBV based on the postweaning test. Preceding this decision the group at Trangie developed a Standards Manual for the feed intake testing of cattle. The manual outlines the standards and procedures required to become an accredited testing facility and ensures the quality and consistency of data is suitable for genetic evaluation. Data from Trangie, Beef CRC and several accredited on farm and central testing facilities were pooled and used to develop a database that could be easily merged with the performance/pedigree BREEDPLAN databases of the various breeds. Data extracts, along with complete pedigrees was used to develop a Trial BREEDPLAN single trait NFI EBV. A heritability of 35% was used, and an adjustment was made for higher residual variances for NFI data from the Beef CRC.

The Angus NFI EBVs and accuracies were computed using 5093 animals with 2128 animals having individual feed intake records. The EBVs generated ranged from -1.32 to +1.23 kg/day, with BREEDPLAN accuracies up to 87%. A total of 37 Angus sires had an NFI EBV with a BREEDPLAN accuracy greater than 80%.

Fewer records existed for the Hereford/Poll Hereford breed, EBVs being computed for 2265 animals using 562 animals with individual feed intake records. EBVs generated ranged from -0.81 to +0.89 kg/day, with accuracies up to 77%. A total of 12 Hereford or Poll Hereford sires had an NFI EBV with an accuracy of 60% or greater. EBVs with a minimum accuracy of 50% were published on the BREEDPLAN web site (http://breedplan.une.edu.au) for each breed.

Where to now?

1) Further Research

Several projects are underway that will further our knowledge of feed intake and net feed intake. The research is very diverse but is primarily aimed at reducing the cost of obtaining genetic predictions in a beef breed and their implementation into selection programs.

i) Reducing the cost of testing

Work has been completed on determining the optimal length of test. Installation of weigh scales to the automatic feeder units allows an animal's weight to be measured several times a day. This data, accumulated over the whole test period, allows a more accurate calculation of weight gain. Therefore the length of test may be able to be shortened from 70 days to around 50-60 days. This will increase the potential number of animals tested in a year given the finite number of testing units and also reduce the cost of testing for an individual.

Another CRC project is generating additional progeny that will allow the estimation of the genetic correlation between the postweaning test and the feedlot finishing test. These results will be very important for the further development of the breeding objectives and the correlations will also help determine how to best use data in a genetic evaluation from the different sources. Feed intake data from steer progeny test programs may in the future be an important source of data for the genetic evaluation of NFI. This data will also be very useful for several researchers that are investigating the most effective design of breeding programs to optimize selection for feed efficiency in industry. A two stage selection strategy with recording of feed intake on elite young bulls is one option that looks promising.

ii) Indirect measures

Given the cost of recording feed intake and the limitations on the number of animals that can be tested, research is underway to determine if suitable correlated measures exist. One promising measure being investigated is the circulating concentrations of the hormone insulin-like growth factor 1 (IGF-1). Johnston et al. (2001) showed IGF-1 was heritable (h^2 = 0.31) in young growing beef cattle, and more recently preliminary analyses obtained estimates of 0.39 and 0.56 between IGF-1 and NFI in Trangie and Beef CRC populations, respectively. Genetic correlations between NFI and measures of fatness and certain weights make these traits useful as indirect measures of NFI.

Gene markers for feed efficiency would also be extremely useful in increasing the accuracy of an NFI EBV. A South Australian gene mapping experiment for feed efficiency in Limousin x Jersey crosses was recently completed and results from their work will be released later this year. The Beef CRC is also using the DNA on all feed intake tested animals to do gene mapping and confirmation studies. This will include over the next 3 years approximately 2,000 feed intake tested progeny from the Beef CRC Northern breeding project, representing over 100 Brahman and Red Composite sires.

iii) Incorporating NFI into the breeding objective

To utilize the genetic information on feed efficiency it is important that the trait is included into a multiple selection index for profitability. In Australia, selection index software called BreedObject uses BREEDPLAN EBVs to compute index values ($EBVs) for different production systems. In the absence of genetic information on feed intake BreedObject has included the feed costs in the economic value assessments of traits affected in the breeding objective (both young animal and cow). In each case the cost of increased feed required associated with a unit increase in the trait is used. This method accounts for differences in gross feed efficiency but not for differences in feed use. The next version of BreedObject will include net feed intake in the breeding objective. However to include NFI EBV as selection criteria (and/or in the objective) will require genetic correlations with other traits be known. Some of this estimation work has been done but more will be required. The Beef CRC Northern Breeding project will provide important estimates of the correlation between NFI and female reproduction and adaptability traits for tropically adapted breeds.

2) Industry implementation

Science is rapidly advancing our understanding of the genetics of feed intake and efficiency but the challenge is to gain widespread adoption by industry such that selection decisions on young bulls in seedstock herds can use knowledge of genetic differences in NFI. To date, most of the testing of animals in Australia has been done through research experiments. However with the recent publication of the first Trial BREEDPLAN NFI EBVs for Angus and Hereford/Polled Herefords the incentive exists for innovative seedstock breeders to test their young bulls. Currently, two options exist for testing bulls (and steers). On-farm testing is possible with some breeders purchasing their own units or using mobile testing units that can be transported to a farm. Secondly, several commercial central test facilities exist to measure individual feed intake. It is hoped that in the next 12 months approximately 1000 animals will be measured as part of research projects and an additional 650 individuals will be measured by industry. An important initiative of the Australian Shorthorn and Angus breed societies has been the development of progeny test herds for the testing of elite young sires. Both these programs will include individual feed intake testing of the steer progeny and the data used to compute NFI EBVs for the sires.

Conclusions

Although genetic differences in feed intake and efficiency were estimated over 30 years ago no known direct selection for improvement of these traits has occurred in the beef industry. This is primarily due to restrictions in the number of individuals that can be measured for feed intake and its cost. Recent research into reducing the cost of the test and increasing the accuracy by including indirect measures will hopefully ensure the adoption of this new trait into beef cattle breeding programs.

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GENETIC PREDICTION OF EFFICIENCY IN THE FUTURE: A U.S. PERSPECTIVE

E. John Pollak and David Kirschten
Cornell University

This presentation will focus on the need to establish a program for evaluating efficiency. By program, we mean the complete package of data collection, model development, and routine genetic evaluations. We will refer to using feed consumption information in combination with management or other variables to define an appropriate economically relevant trait (ERT). The ERT could be consumption to an endpoint (for a variety of endpoints), consumption in conjunction with gain (efficiency of gain), consumption in conjunction with production measures to define cow efficiency, or any other definition or measure of "efficiency." We will not dwell on these options as they are addressed in other presentations.

We will focus on the need for a system that provides data for use in selection. For traits that are above the "low hanging fruit," the most difficult component is the system for capturing data. As an example, for decades we held symposium after symposium on the importance of reproductive performance to the economic well-being of the national cowherd. No one questioned the importance, but we struggled to provide genetic evaluations of reproductive performance simply because of the lack of data. The data structure needed was what we now refer to as whole herd reporting. From that base, evaluations for heifer pregnancy developed by the Animal Breeding Group at Colorado State University and applied to Red Angus data could move forward. There are other examples including meat tenderness evaluations (the Carcass Merit Project of the National Cattlemen's Beef Association), which required an industry-wide effort to establish a data-capture system. We are sure no one would debate the value of having good genetic information related to disease and health, but we do not have a system to address that at this time. So if we are to look to the future for genetic predictions of efficiency, we need to look at the industry first and determine how to generate data!

We will start by considering options for feedlot animals and performance-tested animals. The first problem encountered for feedlot animals is that these animals are typically not identified to sires. There are exceptions: for example, commercial herds that use AI or herds in designed progeny test programs for carcass traits. To generate the mass of data needed, however, would require a parent identification system of calves from many commercial herds. The National Beef Cattle Evaluation Consortium (NBCEC) is currently working on a pilot study with the Bell Ranch in New Mexico to evaluate a system for progeny testing commercial bulls. In that project, we are using DNA markers to establish parentage since the calves are produced in multiple sire breeding pastures. This obviously incurs a cost that must be recovered by selection to improve the ERT for that herd. In the selection system we have designed for that herd, each year 200 to 300 sire-identified steers will be available for data collection downstream.

Given we can amass a reasonable number of animals each year that have the requisite pedigree information, we now face the problem of generating useful data. There are programs that are currently being used to address this problem. Feeding sire progeny groups in small units is one such program. Information from this design provides group consumption data but not always individual consumption data. The measure of comparison then is between average progeny consumption. In Canada, Beef Improvement Ontario uses feed efficiency in a computerized sire selection program, which was developed by the University of Guelph. Feed intake is measured in central bull evaluation centers. Then feed efficiency across-breed EPDs are calculated and combined with growth rate and ultrasound backfat-across-breed EPDs to predict carcass weights and feed intakes in steer progeny. From these predictions, along with other traits such as marbling, net economic values of progeny are calculated based on breeds or crosses of cows, feeding programs, and market prices. The predictions are on an actual level such that all sires are compared on an across-breed basis (Wilton et al., 1998). The obvious problems here are the limited number of animals that can be measured annually and the high cost of the procedures. While procedures of this type do contribute some information, the results of these low-output, high-cost systems may prevent them from becoming a part of routine data collection systems in the field.

This brings us to alternative measures (or indicator traits). The industry has used indicator traits in place of traits that are difficult or expensive to measure. Scrotal circumference is an example of using an indicator trait that is easier to measure than heifer pregnancy. We are also now in the process of generating increasingly large numbers of observations on carcass characteristics using ultrasound. Can we also use indicator traits for consumption or efficiency measures? We could investigate traits correlated to consumption or efficiency measures and then transform the EPDs from those analyses to EPDs for the ERT. This may be difficult if the relationship is nonlinear. Also, under this option, we feel we are obligated to report the accuracy in terms of the ERT EPD. As an example, using ultrasound data to evaluate a sire from progeny records can result in a very high accuracy of the predictions for that ultrasound trait. But the accuracy obtained for the ERT is limited by the correlations between ultrasound measures on breeding animals and carcass measures on harvested animals. A second option is to use the phenotypic information on the related traits in a modeling approach to predict a phenotype on the same animal. The genetic evaluation would then be run on the predicted value. This approach would bring the world of models together with the world of genetic evaluators. This is intuitively appealing.

There are many steps required to use predicted phenotypes for genetic evaluation. The first is model validation. Does the predicted variable reflect the actual measure? The second is whether there is a heritable component to the predicting variable. And third is whether there is a genetic correlation between the predicted variable and the ERT. Think again in terms of ultrasound and carcass measures relative to these steps. Validation of ultrasound was done on animals with both ultrasound measures and carcass data. As confidence in ultrasound technology grew, use of ultrasound on breeding animals to predict slaughter animal performance became an accepted component of data collection in the industry. Recent research from Iowa State (Wilson et al., 1999) using Angus records provided estimates of the requisite parameters for using ultrasound measures in genetic evaluation. The genetic correlations were high and positive between associated carcass and ultrasound measures. Hence, selection for EPDs on ultrasound measures will result in a correlated response in slaughter progeny carcass traits. Correlated responses can exceed responses to direct selection under certain conditions. For ultrasound measures on breeding animals these conditions include 1) early capture of information on potential parents, 2) decreased generation interval and 3) increased selection intensity. To use predicted phenotypes, we need to follow the same philosophy that was used to validate ultrasound.

As an example, we will use the Cornell Value Discovery System (CVDS) model for prediction of individual feed consumption (Tedeschi et al., 2002). Models require inputs. In the case of the CVDS, the inputs are gain on test and carcass measures, ration ingredient analysis, and environmental factors (i.e., temperature, windspeed, lot conditions, and description of facilities). This modeling approach can also be used for performance tests of potential breeding bulls using ultrasound in place of carcass measures (see Appendix A). The CVDS model has been validated in experimental environments, (Fox et al., current proceedings), and the NBCEC is now running a pilot study with the American International Charolais Association to collect information on performance-tested bulls (see Appendix B). This pilot will be used to estimate parameters for genetic evaluation. The EPDs produced by the genetic evaluation will then be validated. This would include studies similar to those undertaken to validate EPDs for traits such as maternal milk. This process is potentially iterative. Shortcomings in the models that are identified by the genetic studies could be addressed to improve the predictability of the phenotypic prediction models.

Obviously other technologies will come along that may enhance data capture. It is just difficult to envision those technologies addressing the ERT directly. They will most likely enhance the predictability of the phenotypes.

In conclusion, we believe that the future for genetic prediction of efficiency will necessitate a closer relationship between those working with biologically based models for predicting phenotypes and those implementing genetic evaluation programs. The industry would be required to provide the second basic component, which is pedigree information. For performance-tested breeding males and females, this is not an issue, but if we want to evaluate animals closer to the end product, strategies for parent identification in commercial herds will need to be developed.

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APPENDIX A

DETERMINING FEED EFFICIENCY FOR INDIVIDUAL BULLS FED IN GROUPS

D.G. Fox, D. P. Kirschten, L. O. Tedeschi, and M.J. Baker
Cornell University

Introduction

Feed costs represent 60% of the total cost incurred in the feeding cattle (Baker and Ketchen, 2000). Simulations with our performance prediction computer programs show that a 10% improvement in feed efficiency can result in a 43% improvement in feedlot profit (Fox et al., 2001). Simulation models developed with published research data on cattle requirements that account for biological differences (mature size, growth rate, milk production, pregnancy requirements, environmental effects) (Fox et al., 1992; Tylutki et al., 1994; and National Research Council, 2000) can be used to identify differences among cattle in feed efficiency (Fox et al., 2002). If differences in individual feed efficiency can be detected economically, this information has the potential to be used in the development of selection indexes.

It is cost prohibitive to measure feed consumption on an individual basis in feedlots where most bulls are evaluated. However, recent improvements in predicting the impact of environmental conditions on maintenance requirements and in determining the composition of gain has led to the development of a model that can accurately allocate feed to individuals fed in group pens (Guiroy et al., 2001). This model uses the animals' own growth rate and average body weight during the test to compute feed required for the observed body weight and growth rate. We have developed a computer program called the Cornell Value Discovery System (CVDS) that applies our published models to determine the feed required for the observed performance of individual steers or bulls fed in pens (Fox et al., 2002). The CVDS model is described in these proceedings in the paper by Fox et al., determining post weaning feed efficiency in beef cattle". This section describes the steps used by the CVDS model and the data collection process to obtain the inputs needed by the CVDS model to predict feed required by individuals fed in pens.

Procedures for computing feed required by individual bulls fed in groups

Steps we use for computing feed required for the observed performance

1. The net energy value of the ration for maintenance and gain must be determined. We use feed analysis of the ration ingredients and the ration dry matter formula to predict the net energy value of the ration dry matter for maintenance and growth with the Cornell Net Carbohydrate and Protein System (CNCPS; Fox et al., 2000), as described by Fox et al. (2002).

2. Beginning and ending weight and days on test are used to compute average weight and average daily gain during the test.
3. The animals' average body weight during test is used to predict their average daily maintenance requirement.
4. The average daily maintenance requirement is adjusted for the effect of environment on the energy required for maintenance.
5. This average daily maintenance requirement is divided by the net energy value of the ration for maintenance to compute the feed required for maintenance/day.
6. The animals' expected weight at 28% body fat (average fatness of low choice grade) is predicted from the animals' weight and backfat, rib eye area, and marbling determined by ultrasound.
7. This 28% fat weight is divided into the weight of the animal used to develop the net energy requirement equations (standard reference weight) to get the ratio of the animal to this standard reference weight (standard reference weight ratio).
8. The standard reference weight ratio is multiplied by the average weight during the test to get the weight equivalent to the standard reference animal (Equivalent weight).
9. The average daily gain during the test and the equivalent weight are used to compute the daily net energy required for gain.
10. The net energy required for gain is divided by the ration net energy value for growth to obtain feed dry matter required for growth.
11. The feed required for maintenance and gain are added together to determine dry matter required/day.
12. Feed efficiency is then the dry matter required/day divided by the average daily gain.

The actual feed fed to the pen is allocated to the individual bulls to determine the cost for each individual animal as follows.

1. The dry matter required/day required for each bull in a pen are summed to get the total required/day for the pen.
2. Each bulls' dry matter required/day is divided by the total for the pen to compute the proportional share of the actual feed fed to the pen.
3. The proportional share for each bull is multiplied times the total feed fed to the pen to obtain the amount and cost of the feed for each individual bull.

The above calculations give the feed efficiency and cost for the actual weight gained during the test. However, the bulls will be at different stages of growth at the end of the test, because of differences in initial age and weight, and rate of gain during the test. Therefore the data need to be adjusted to the same final endpoint to evaluate the bulls. To accomplish this, each animals' data is entered into the CVDS and performance is evaluated over a standard growth period, using the feed required to adjust dry matter intake to that observed during the test.

Collecting inputs required

1. Body weights.
    - Beginning of test (minimum 90 day test period)
    - When ultrasound measurements are taken
    - End of test
2. Ultrasound measurements (taken as near the end of test as possible)
    - Fat depth
    - Rib eye area
    - Marbling
3. Age and hip height (taken at time of ultrasound measurements)
4. Ration
    - Dry matter formula (keep as constant as possible during the entire test)
    - Ration ingredient analysis (take as many samples as needed to represent each ration ingredient during the entire test).
        i. Dry matter, NDF, Lignin, CP, protein solubility, NDIP, ADIP.
        ii. Total feed fed to each pen during the test.
5. Environment description (average for each month during the test)
    - For the entire test
        i. Lot type (choose from the list)
        ii. Square feet/head
    - Average for each month during the test
        - Wind speed and temperature the cattle are exposed to, lot conditions (choose from the list)

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Example data input sheets

Pen Space: square feet per head: ____________

Animal Data-IN	Pen No._______			
Date	ID	Breed	Weight	BCS
Animal Data-OUT	Pen No._______			
Date	ID	Breed	Weight	

Date: __________		
Animal ID	Hip Height	Birthdate

Ration		
Date	Ingredient	Lbs/batch
Date	Pen No.	Amount fed

Ultrasound Data					
Date					
	An ID	BF	Rump Fat	IMF	REA

Environmental data							
	Temp. (°F)	RH (%)	Mud (in.)	Wind (MPH)	Hair Coat[1]	Hair Depth (in.)	Min. Temp. (°F)
Month							

[1] 1=No mud; 2=mud on lower body; 3=mud on lower body and sides; 4=heavily covered with mud.

APPENDIX B

CONTEMPORARY GROUPING AND MANAGEMENT PROCEDURES FOR BULLS INVOLVED IN THE CHAROLAIS FEED EFFICIENCY PROJECT

David P. Kirschten
Cornell University

Introduction

The phenotype of an animal may be defined as genotype plus environment (P = G + E). One purpose of genetic evaluation is to accurately remove environment from the equation so that the estimation of the genotypic value of the animal is based on the genetic merit of the animal rather than any outside (environmental) influences. Contemporary grouping is one method that is used to accomplish this. Calves are assigned to a particular contemporary group if they are in the same location (pasture, not ranch), are of the same sex, are of similar age, and have been managed alike. Remember, as the group of calves get older, a contemporary group will decrease in number due to sickness, death, culling or allotment into different pens at weaning. A contemporary group may decrease in numbers, but it will never increase in numbers after calving season is over. Groups cannot be recombined and cattle that have been removed from a pen cannot be put back into a contemporary group.

Contemporary grouping and management procedures

1. Your breed association procedures or BIF guidelines will assist you in contemporary grouping for your breed from birth to yearling.

2. Our recommendation is that in addition to your regular bull feeding pens, set up one more pen that is not included in our trial. This may be a cull pen, or a pen where you feed a few steers or cull heifers. We would like to have you put any bulls from the test pens into this pen and remove them from the trial if they have been in a sick pen away from their group for three or more days. The model to predict feed efficiency can be adjusted to account for animals taken out of a pen, but not for animals put into a pen after the start of the trial period. When an animal is permanently removed from a pen, weigh the animal and decrease the pen feed by the amount of one animals' daily intake. We cannot deal with additions to a pen or animals that are put back into a pen after more than a three-day absence.

3. If you sell a bull before the end of the trial period, weigh the bull when he leaves the pen, and adjust the total ration downward by that bulls percent of the total ration.

Records that will be provided by producers

1. On test weight and off test weight. Contemporary group information and pedigrees will be furnished by the breed association.
2. Ultrasound images. To be processed through CUP Laboratories.
3. Feed analysis on each individual ingredient in the ration. To be processed at Dairy One. Producer will be responsible for the cost of the samples ~$20 each. The cost to the producers will vary depending on the number of ingredients in the ration.
4. Feed records to indicate pounds of fed feed over the feeding period to each pen. This may take the form of daily feed records, weekly records or simply total amount of each ingredient fed to each pen.
5. The wind speed, humidity, and temperature will be drawn from the NWS website by researchers at Cornell University.
6. The predictions will be greatly enhanced by your recording of feedlot conditions, although we will not require it for participation.

Beef Improvement Federation
Live Animal, Carcass and End Product Committee

Robert Williams, Chairman

Agenda for meeting on July 11, 2002

1. Allan Bright, Antioch, Nebraska
   NCBA Animal Identification Sub-Committee Chairman
   NCBA Cattle Identification Standards and Recommendations

SOURCES OF INFORMATION — GATHERING AND SUBMISSION OF INFORMATION — MANAGEMENT OF INFORMATION

These standards will be reviewed on a three year schedule

SOURCES OF INFORMATION

Applying a tag at any stage of production or ownership is not automatic entitlement to any information. Participation and/or agreement between buyers and sellers are necessary to ensure the sharing of information. While these standards are intended to create additional producer value by electronic transfer of individual animal attributes, there is validity for visual identifications, especially as a bridge to a full electronic system.

STANDARDS:

1. ISO - based Electronic ID Tag
   - Entire ISO number must be printed on tag
   - Minimum read range (stationary system) of 30 inches in an active commercial packing environment.
2. Tag must be applied at or before animal leaving herd of origin.
3. Tag must not be removed except at harvest (packer).
4. Tags must be placed in manufacturer recommended position in the animal's left ear.
5. Tags shall be one-time use only and tamperproof/tamper-evident in design.
6. Producer is responsible for cross-referencing any other identification number that they chose to utilize (American ID Number, Breed Association/ Registry number, USDA/government number, etc.).

RECOMMENDATIONS:

1. Failed tags should be replaced with another unique ISO Electronic tag and so noted (and cross-referenced to original tag if possible) in the database.
2. Must be open to adopting other technologies as they become commercially viable.
3. Agreements and Terms of Trade are necessary for sharing and transfer of information from one party to another.
4. If a producer does not choose EID tag at herd of origin, they may use a visual ID based on a nationally accepted standard such as american ID number, Breed Association Registry number, USDA government, etc.

GATHERING AND SUBMISSION OF INFORMATION

For confidentiality purposes, previous ownership(s) identity will not be passed to buyer without agreement or ownership authorization.

STANDARDS:

1. WHEN the information is gathered and submitted
   - Initial data is gathered for all cattle prior to animal leaving herd of origin.
   - Additional data to be added at each change of ownership or premise.
   - Data shall be transferred according to terms of trade or by agreement.
2. WHERE the information is gathered
   - At each stage of production
     - Seedstock
     - Cow Calf
     - Market facilities
     - Stocker
     - Feeder/Feedyard
     - Packer
3. WHAT information is required
   - Basic Information
     - Individual Animal ID #: 15 digits including manufacturer/country code (3 digits) and individual animal number (12 digits);(ISO 11784 Standard)
     - Premises Information (Producer Name, Physical and Mailing Address, Phone Number, 3 character alphanumeric field for single or multiple producer defined locations).

4. HOW the information is gathered
   - All tag readers (stationary and handheld) should be capable of reading tags in accordance with ISO 11785.
     - All readers must be capable of electronically transferring data to an external computing and storage device.

RECOMMENDATIONS:

1. WHEN
   - Data should be electronically transferred whenever possible.
2. WHAT
   - Additional performance or management data may be collected in accordance with terms of trade and agreement between buyers and sellers.
   - Producers may reference other premise codes or identifiers into Premises Information
   - Agreements and Terms of Trade are necessary for sharing and transfer of information from one party to another
3. HOW
   - Reader/data collection systems should also have the ability to enter tag data manually.

MANAGEMENT OF INFORMATION

Data exchange and interfacing among data management and software companies is encouraged.

STANDARDS:

1. Data remains the property of the cattle owners/stakeholders.
2. Information will be formatted for transmission as follows:
   - Producer Name (alphanumeric characters)
     - First Name (22 alphanumeric characters)
     - MI (1 alphanumeric characters)
     - Last Name (15 alpha characters)
   - Ranch Business Name (32 alphanumeric characters)
   - Telephone Number (15 alphanumeric characters)
   - Producer/Ranch Mailing Address, consisting of:
     - Street Address (32 alphanumeric characters)
     - City (18 alphanumeric characters)
     - State (2 alpha characters)
     - Country (3 alpha characters)
     - Zip/Postal Code (9 numeric characters)
   - Producer/Ranch Physical Business Address (same definition as Producer Mailing Address).
   - Producer Phone Number (15 numeric characters)
   - Producer Location Code (3 alphanumeric characters)
   - Animal EID (15 numeric characters)
   - Date Originally Created (8 numeric characters)
   - Transferred by a widely accepted standard such as Comma Separated Variable ASCII or XML file
3. Data would be retained for a minimum of 20 years from the initiation of the individual animal record.

RECOMMENDATIONS:

1. Reasonable data security is expected.
2. Time, date and source stamp of all data entry into system.
   - Databases should have lock-down feature for all data entries.
3. Agreements and Terms of Trade are necessary for sharing and transfer of information from one party to another.

GLOSSARY OF TERMS:

ISO - International Organization for Standardization.

ISO 11784 STANDARD - Internationally recognized standard for the data/numeric structure of electronic animal identification devices.

ISO 11785 STANDARD - Internationally recognized standard for communication protocols between electronic identification devices and reading systems.

EID - Electronic Identification

HERD OF ORIGIN - Herd of birth

TERM OF TRADE - Elements of the negotiated transfer of ownership

PREMISES - Producer defined location or locations, such as ranch, pasture, etc.

ELECTRONIC TRANSFER - Mode of information transfer, such as e-mail, disk transfer, etc.

MANUFACTURER/ COUNTRY CODE - Three-digit code defined by ISO 11784 Standard (USA country code is 840).

EXTERNAL COMPUTING AND STORAGE DEVICE - A device that can store and manage electronic data, such as a computer or electronic scalehead with download capabilities, etc.

3-DIGIT LOCATION NUMBER - Producer-defined location identifier, such as pasture, ranch or feedyard location(s).

ALPHANUMERIC CHARACTER - data consisting of both alphabetic (A, B, C...) and numeric (1, 2, 3...) characters.

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National Cattlemen's Beef Association
9110 East Nichols Avenue
Centennial, CO 80112
Phone: 303-694-0305
Fax: 303-770-7109
www.beef.org
animalid@beef.org

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01/02

2. Bob Hough, Ph.D., Red Angus Association of America
   Update on the Beef Cattle Ultrasound Technician Annual Proficiency Testing and Certification (APTC) Program

3. Dan Moser, Ph.D., Kansas State University
   Update on the NCBA Carcass Merit Project

4. J. R. Tait, Iowa State University
   Predicting Retail Product with Live Animal Measures

5. Keith Bertrand, Ph.D., The University of Georgia
   Use of Live Animal Ultrasound Carcass Measurements in Carcass Genetic Evaluation of Beef Cattle.

PREDICTING PERCENT RETAIL PRODUCT IN BEEF CATTLE

R. G. Tait, Jr., D. E. Wilson, and G. H. Rouse
Iowa State University

Introduction

Retail product determination in beef cattle has been a trait of significant importance for generations. Researchers have spent time, money, and effort working on methods to quantify and predict retail product yield of individual animals. Many retail product studies utilize the measures of yield in terms of pounds of retail product, however this is highly dependent upon the weight of the animal at slaughter. The other method to evaluate retail product yield, is to express the weight of retail product as a percent of carcass weight. Retail product percentage can be computed as a percentage coming from the four major wholesale cuts (which Abraham et al. (1980) found accounts for the majority of the value of a beef carcass), or the whole carcass side.

Carcass value is determined when the carcass is fabricated into saleable end product and priced. The most direct influence of retail product percentage is when pricing carcass beef. This is important because the beef retailer is interested in having an estimate of the retail yield that is to come from a particular carcass before it is purchased and/or fabricated. The relationships between carcass attributes, and the retail yield of the carcass are going to be of utmost importance in determining the profitability of the retailer or packer after purchasing a carcass. Segments of the beef cattle industry which have handled the cattle before slaughter can have an influence on what the final percent retail product of the carcass will be. Even seedstock producers have the opportunity to influence carcass value when they make selection decisions – relative to the predicted retail product yield percent of the harvested offspring. Evaluation of seedstock may not have the direct economic impacts that assessment of the carcass has in today's market. However, seedstock producers who have the consumer and retailer in mind when selecting breeding stock could have a competitive advantage in the future.

Traditional means of determining retail product proportions in seedstock animals has involved long term collection of carcass information from relatives, and then calculating breeding values for the potential seedstock. However, today the technology exists to evaluate body composition of seedstock with real-time ultrasound before selection for breeding. The purpose of this paper is to compare some of the measurements available in the carcass and in the live animal, and how they impact the ability to predict percent retail product.

Carcass Trade

Carcass data has long been used to evaluate the proportion of cuts which are expected to come from a particular carcass (Murphey et al., 1960). The significant traits for predicting percent of boneless retail cuts from the four primals (round, loin, rib, and chuck) are hot carcass weight, 12th rib fat thickness, 12th rib ribeye area, and percent kidney, pelvic, and heart fat (KPH). These are the same four traits utilized today as the industry standard for trading of beef carcasses under the regulations of the United States Department of Agriculture (USDA). The current equation (USDA, 1997) used to trade beef carcasses is:

USDA Yield Grade = 2.50 + 2.50*adjusted fat thickness(in.) + 0.2*kidney, pelvic, and heart fat(%) + 0.0038*hot carcass weight(lbs.) - 0.32*ribeye area(in.^{2})

USDA Yield Grade is calculated such that a lower yield grade (e.g. 1) is expected to have a higher retail yield from the four primals than a higher yield grade carcass (e.g. 5).

Genetic Evaluation

The Angus genetic evaluation for retail product prediction in the carcass database is calculated using an equation to predict percent retail product from the whole side (American Angus Association, 2002). That equation is:

Percent Retail Product (%) = 65.69 - 9.931*fat thickness(in.) + 1.2259* ribeye area(in.^{2}) - 0.013166*carcass weight(lb.) - 1.29*KPH(%)

The Angus breed uses the same equation for retail product prediction in the ultrasound body composition database. However, not all of the necessary measures are available from the ultrasound information (Table 1). Therefore, some assumptions are made about these data. First, there is no measure for % KPH, a trait which was considered for removal from the USDA yield grading equation (Crouse et al., 1986), so all animals are assumed to be the same (2.0 %). The hot carcass weight has to be estimated from the live animal parameters. Hot carcass weight is predicted from scan weight, ribeye area, and age. Currently there are two different regressions being used, with animals gaining less than 2.7 lb./day being in one regression class, and animals gaining more than or equal to 2.7 lb./day in the other class. Also, ultrasound data incorporates two measurements of fat thickness (over the 12th rib, and over the rump of the animal). These measures are weighted (60% 12th rib fat, 40% rump fat) before being incorporated as the fat thickness in the percent retail product equation.

Table 1. Measures used by American Angus Association for genetic evaluation of percent retail product

Trait	Carcass Data Evaluation	Ultrasound Body Composition Evaluation
Hot Carcass Weight	Measured directly	Estimated from scan weight, age, and ribeye area
Fat Thickness	Measured at 12th rib	Weighted average of 12th rib fat thickness (60%) and rump fat thickness (40%)
Ribeye Area	Measured at 12th rib	Measured at 12th rib
Kidney, Pelvic, and Heart Fat	Measured directly	All animals assumed to be 2.0 %

Research for Percent Retail Product

Several researchers have looked at adding measurements which can be determined on the live animal for calculation of percent retail product. The following discussion is summarized in Table 2.

Williams et al. (1997) found that by incorporating the traits of final weight, ultrasound 12th rib fat thickness, ultrasound 12th rib ribeye area, and ultrasound rump fat thickness, 31.8 percent of the variation in percent retail product on the whole side basis was accounted for. Interestingly, this study, which utilized cattle that averaged 0.47 in. for 12th rib fat thickness and 0.61 in. for rump fat thickness, found that rump fat thickness was a better predictor of percent retail product than 12th rib fat thickness. These data were compared to the carcass traits of hot carcass weight, carcass 12th rib fat thickness, carcass 12th rib ribeye area, and carcass percent kidney, pelvic, and heart fat which accounted for 31.2 percent of the variation. This study also looked at incorporating an ultrasound measurement of depth of the *biceps femoris* in the prediction equation. However, this only increased the R^2 of the equation from .318 to .322, and this measurement requires extra time and effort for the collection of an extra image. Therefore, this measurement has not been actively pursued.

Greiner (1997) looked at the possibility of incorporating an ultrasound measurement of body wall thickness below the *longissimus dorsi* muscle. This measurement was found to be a significant predictor of percent retail product. However, it only improved the R^2 of the ultrasound prediction equation from .60 to .61, when added to the measurements of ultrasound 12th rib fat thickness, ultrasound rump fat thickness, and ultrasound 12th rib ribeye area. This study found that ultrasound and carcass measures predicted percent retail product similarly. Ultrasound traits of live weight, ultrasound 12th rib fat thickness, ultrasound 12th rib ribeye area, and ultrasound rump fat thickness had an R^2 = .60. Carcass traits of hot carcass weight, adjusted 12th rib fat thickness, carcass ribeye area, and carcass percent kidney, pelvic, and heart fat had an R^2 = .65.

Ongoing research at Iowa State University (Tait et al., 2002) has been investigating the merits of incorporating a measurement (either depth or area) of the *gluteus medius* from the rump image which is already being collected by field technicians. In this data set, significant ultrasound measures were ultrasound 12th rib fat thickness, ultrasound 12th rib ribeye area, scan weight, and depth of the *gluteus medius*. However, the depth of *gluteus medius* only increased the R^2 by .0064 over the observed R^2 = .39 without depth of *gluteus medius*. Carcass traits utilized to predict percent retail product were carcass 12th rib fat thickness, % kidney, pelvic, and heart fat, and carcass 12th rib ribeye area. The carcass trait based equation had a R^2 of .28. This data suggests that ultrasound measurements can do a better job of evaluating percent retail product than carcass measurements.

Table 2. Summary of percent retail product prediction equation coefficients for carcass and ultrasound derived measurements

Study	USDA (1997)	Williams et al. (1997)		Greiner (1997)		Tait et al. (2002)	
Trait	Carcass YG	Carcass	Ultrasound	Carcass	Ultrasound	Carcass	Ultrasound
Weight (lb.)	0.0038	0.0213	-0.0032	-0.0104	-0.0020	**	-0.0041
12th rib fat (in.)	2.50	-1.3114	-0.5071	-2.1543	-2.4350	-3.0306	-7.0495
12th rib ribeye area (in.^{2})	-0.32	0.0073	0.0181	0.0256	0.0327	0.3444	0.5511
Rump fat (in.)	*	*	-1.1358	*	-1.3831	*	**
Kidney, Pelvic, & Heart Fat (%)	0.2	-1.684	*	-1.417	*	-1.4801	*
Model R^2		0.31	0.32	0.65	0.60	0.28	0.40

*Trait not relevant for this equation
**Trait not significant ($p > 0.10$)

Implications

It is important to realize that both carcass data and ultrasound data can be used to evaluate cattle for percentage retail product. At the same time it is important to know what impact each of the traits is having on percent retail product. Here are some rules of thumb for looking at the changes related to these measurements, when run through the genetic evaluation percent retail product equation:

- For each 0.1 inch of decrease in fat , percent retail product increases ~ 1%
- For each 1.0 square inch increase in ribeye area, percent retail product increases ~ 1.2%
- For each 100 pounds decrease in carcass weight, percent retail product increases ~ 1.3%

In these studies (Williams et al., 1997; Greiner, 1997; and Tait et al., 2002) it is the fat cover which accounts for the largest amount of variation in percent retail product. As an example, Table 3 shows the order of importance, through stepwise regression, of the traits, and their contributions to the predictive ability of the equation (Tait et al., 2002). Management or genetic changes that can decrease fat cover will have tremendous impacts in improving the percent retail product of an animal.

Table 3. Order and partial R^2 contribution to the overall prediction equation for carcass or live animal measurements to predict percent retail product (Tait et al., 2002)

Carcass Trait	Partial R^2	Ultrasound Trait	Partial R^2
12^{th} rib fat	0.14	12^{th} rib fat	0.27
KPH	0.07	12^{th} rib ribeye area	0.09
12^{th} rib ribeye area	0.06	Weight	0.03
Total Equation	0.28	Total Equation	0.40

Producers should realize that percent retail product is a composite trait composed of several contributing parts. It combines the traits which have been shown to have significant relationship to percent retail product. With the tremendous discounts often associated with USDA YG 4 and 5 cattle in today's market place, it may seem that producers should attempt to select for cattle which will have increased percent retail product. However, percent retail product is not a selection index, and there have been no economic weights put with the traits of importance in predicting retail product percentage. This equation is simply a prediction of observed changes in percent retail product from changes in the related traits. In fact, there is some evidence (MacNeil et al., 1984) that females from sires selected for reduced fat trim of steer progeny would be expected to reach puberty later and at a heavier weight, have reduced fertility, and be larger at 7 yr of age. Therefore, producers should know what traits are contributing to the changes in percent retail product (fat thickness, ribeye area, or weight), and what, if any, antagonistic changes may come with this selection decision, which focuses on increasing the percent retail product trait only.

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USE OF LIVE ANIMAL ULTRASOUND CARCASS MEASURES IN CARCASS EVALUATION OF BEEF CATTLE

J. Keith Bertrand
Animal and Dairy Science Department
University of Georgia, Athens 30602-2771

Introduction

Due to the industry's need for genetic information in this era of grid pricing and alliances, many U.S. beef breed associations have either recently developed or are developing carcass genetic evaluation programs. Traditionally, carcass genetic evaluation programs have principally utilized carcass measures from finished slaughter cattle. However, many purebred breeders have been collecting live animal ultrasound measures on their young seedstock and sending this information to the breed associations. As a result, some breed associations are already using live animal seedstock ultrasound measures to predict carcass genetic values, and other breed associations are trying to decide the best ways to utilize ultrasound measures in their genetic evaluation programs. The purpose of this paper is to present some information on the usefulness of ultrasound measures of young seedstock in the prediction of carcass genetic values.

Use of Ultrasound to Predict Carcass Genetic Values

Several studies have shown that ultrasound technology can measure ribeye area, external fat thickness and percent intramuscular fat with acceptable precision (Robinson et al., 1992; Herring et al., 1998; Wilson et al., 1998). However, it is not enough that ultrasound can be used to accurately measure carcass traits, it must also be shown that live animal measures of seedstock can be used to predictably change carcass traits in finished cattle. Table 1 contains heritability estimates for live animal ultrasound measures of ribeye area, external 12-13th rib fat thickness and intramuscular fat percent. The estimates in this table were from data on yearling seedstock, mainly bulls, adjusted to 365 or 400 days of age. The average magnitude of the heritability estimate for all three traits was > .30, which indicates that all three traits should respond well to selection. Table 2 provides genetic correlations between yearling (365 day) seedstock measures of carcass traits and similar traits measured in finished cattle slaughtered at 15-16 months of age. All the traits presented in table 2 were adjusted to an age constant basis. With the exception of the genetic correlation estimate (.23) reported by Crews and Kemp (2001) between ultrasound 12-13th rib fat thickness measured in bulls with the same trait in finished steers, the genetic correlations were $\geq$ .66 for similar traits measured in yearling seedstock and finished cattle across all studies. It is interesting to note that the average 12-13th rib fat thickness of the yearling bulls (.16 in.) in the study by Crews and Kemp (2001) was the lowest observed in any of the studies presented in table 2. In contrast, the yearling heifers in the study of Crews and Kemp (2001) had an average 12-13th rib fat thickness of .22 inches and a genetic correlation estimate of .66. It may be that a minimum amount of external finish is necessary in young seedstock to obtain measures of fat that are highly genetically related to similar fat measures in slaughter cattle.

The correlations presented in table 2 were for traits that were adjusted to an age constant basis. Wilson et al. (1999) adjusted yearling seedstock ultrasound ribeye area and 12-13th rib fat thickness measures for both weight and age. In the same study, carcass measures of slaughter cattle were adjusted to an age endpoint. Genetic correlation estimates between yearling bull and slaughter steer adjusted measures of ribeye area and 13-13th rib fat thickness were .71 and .75, respectively. Reverter et al. (2000) used data from Australian Hereford and Angus cattle to estimate within breed genetic parameters between carcass measures from steers and heifers and ultrasound measures from 15 month old bulls and heifers. All abattoir collected carcass traits, except for carcass weight were adjusted to a carcass weight constant endpoint, while all ultrasound traits were age adjusted . Near-infrared spectroscopy was used to measure percent intramuscular fat in the abbatoir. The genetic correlations between Angus carcass measures and live animal Angus bull ultrasound carcass measures for ribeye area, rump fat thickness, 12-13th rib fat thickness, and percent intramuscular fat were .29, .82, .79, and .47, respectively. The same genetic correlation estimates involving seedstock and slaughter carcass measures were .94, .82, .87, and .28 for Hereford bulls, were .16, .96, 99, and .46 for Angus heifers and were .46, .34, .02, and .93 for Hereford heifers. Devitt and Wilton (2001) estimated genetic correlations between live animal ultrasound measures in yearling bulls and carcass measures in 15-17 month steers using ultrasound and carcass data that were both adjusted to a weight constant basis. They reported genetic correlation estimates between steer carcass and live animal bull ultrasound carcass measures for ribeye area, 12-13th rib fat thickness and marbling score-intramuscular fat percent of .75, .91, and .68, respectively. Although more variable than literature genetic correlation estimates when both ultrasound and carcass traits were age adjusted, estimates when either ultrasound measures, carcass measures or both were adjusted to a weight constant endpoint indicated that the traits measured in seedstock and slaughter cattle were highly genetically related.

One of the potential benefits of using live animal ultrasound measures on young seedstock is the ability to predict useful carcass genetic values on animals at a much younger age than is possible when using carcass progeny information. Since a young bull could have his own individual measure for ribeye area, external fat thickness and intramuscular fat percent, it is possible to predict non-parent carcass merit EPDs on these bulls to use when making yearling bull selection decisions. Sapp et al. (2002) conducted a study in which different pairs of Angus bulls were selected from three cooperator herds in Georgia. The bull pairs were selected to create large differences based on their age adjusted phenotypic yearling intramuscular fat percent performance within the same contemporary group. Each year the bulls were randomly mated to 14 to 30 commercial Angus females, and the resulting steer progeny were backgounded, then sent to a commercial feedlot, and slaughtered at an average of approximately 480 days of age. Steer progeny from sires with high phenotypic intramuscular fat percent measures had higher adjusted marbling scores ($P < .05$) and quality grades ($P < .05$) than steer progeny from sires with low phenotypic intramuscular fat percent measures.

The live animal ultrasound data from all bulls measured in the cooperator herds was combined with other ultrasound records collected by the American Angus Association. Genetic values (EPDs) were then computed using all available information after adjusting bull ultrasound measurements to 365 days, and heifer ultrasound measurements to 390 days and to a bull equivalent. The regression of age adjusted carcass marbling score of the steer progeny on the ultrasound intramuscular fat percent EPD of the sires produced a highly significant regression coefficient of 90.5. This regression coefficient meant that for every 1.0% unit difference in sire intramuscular fat percent EPD, a corresponding difference of a little more than 9/10 of a marbling score was observed in the steer progeny. The information from this study demonstrated that young animal ultrasound intramuscular fat percent measures can be used to provide EPDs on yearling bulls that can be used to as a selection tool to enhance marbling score in future steer offspring.

Conclusions

Bertrand et al. (2001) showed that when genetic correlations between live animal ultrasound measures and finished cattle carcass measures were $\geq .70$, progeny testing programs based solely on ultrasound progeny information would yield similar genetic progress at the same cost as a carcass progeny testing program at the same selection intensities. The actual genetic correlation requirements necessary to provide ultrasound based programs with similar overall genetic progress to actual carcass based programs would probably be lower than .70, since greater selection intensities and individual measures on animals directly available for selection could be realized with the use of live animal ultrasound. There are many examples in the literature where the genetic correlations are very close to or greater than .70, which indicates that live animal ultrasound measures on yearling seedstock should be included in the genetic evaluation of carcass traits on a national basis.

The question then arises as to the best way to include live animal ultrasound information in genetic evaluation programs. The genetic correlations between carcass traits and ultrasound traits appear to be less than unity; therefore as stated by Bertrand et al. (2001), the best opportunity to benefit from these favorable relationships at the present time is for breed associations to collect both live animal and carcass information and then to analyze both types of data via multiple-trait models for the purposes of genetic evaluation. This would provide several benefits. First, use of ultrasound information would allow the prediction of useful carcass EPDs at a much younger age than can be obtain using progeny carcass data only. Since the trait of value to the industry is the finished cattle carcass trait, the accuracy of an EPD for an animal based solely on ultrasound information would never be higher than the correlation between the ultrasound and the carcass trait when it comes to predicting future progeny performance on a finished carcass trait basis. Therefore, a second benefit of using both ultrasound and carcass information is that high accuracies would be possible for sires with a lot of carcass information from finished cattle. As presented by Bertrand et al. (2001), continued research needs to be conducted in order to determine which management regimes and measurement ages produce the highest correlations between seed stock and slaughter cattle. A third benefit of collecting both ultrasound and carcass data by breed associations would be a data base to help quantify the genetic relationships between carcass traits and ultrasound traits across different ages of cattle and at different amounts of finish. Some breed associations are presenting carcass EPDs on a yearling seedstock ultrasound basis. It is difficult to quantify the direct impact these EPDs will have on differences in slaughter progeny; therefore, a fourth benefit of having enough information to accurately estimate the genetic relationships between ultrasound and carcass traits is that ultrasound information can be converted to a carcass trait basis for easy interpretation and use. Eventually genetic evaluation programs will probably be primarily based on ultrasound data since it is so much easier and cheaper to collect; however, because of the reasons stated above, it may be prudent to continue collecting actual carcass data on finished cattle, at least for the immediate future.

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Table 1. Heritability estimates for age-adjusted live animal ultrasound measures on seedstock cattle

Source	Trait		
	Ribeye Area	12-13th Rib Fat Thickness	Intramuscular Fat %
Arnold et al. (1991)	.25	.26	
Johnson et al. (1993)	.40	.14	
Evans et al. (1995)	.42	.51	
Shepard et al. (1996)	.11	.56	
Moser et al. (1998)	.29	.11	
Meyer (1999)[a]	.50	.01	
Meyer (1999)	.19	.27	
Wilson et al. (1999)			.42
Unpub. Anal. of IBBA Ultrasound Data	.30	.35	.19
Unpub. Anal. of AHA Ultrasound Data	.31	.26	.39
Crews and Kemp (2001)	.61	.50	
Devitt and Wilton (2001)	.48	.52	.23
Average	.35	.32	.31

[a]First row of estimates for Meyer (1999) is for Brahman cattle; second row of estimates is for Santa Gertrudis cattle.

Table 2. Genetic correlation estimates between 365-day seedstock live animal ultrasound and 15-16 month carcass traits in slaughter cattle

	Trait Combination		
Source	UREA-CREA	UFAT-CFAT	IMF%-MARB
Unpub. Anal. of IBBA Ultrasound-Carcass Data	.89	.69	.70
Wilson et al. (1999)			.77
Crews and Kemp (2001)[a]	.71	.23	
Crews and Kemp (2001)	.73	.66	
Devitt and Wilton (2001)	.66	.88	.80

[a]First row of estimates for Crews and Kemp (2001) are from ultrasound measures from yearling bulls; second row of estimates are from ultrasound measures from yearling heifers.

TRAITS AND MEAN EPDs REPORTED BY 15 BREEDS

Larry V. Cundiff

For selection of breeding stock it is important to know how expected progeny differences (EPDs) for an individual animal compare to the current breed average. Mean non-parent EPDs are useful for making comparisons within breeds. They cannot be used to compare different breeds because EPDs are estimated from separate analyses for each breed. The mean EPDs are shown for certain growth traits in Table1, for reproduction and other production traits in Table 2, and for carcass traits in Table 3. These estimates are from the most recent (2002) genetic evaluations conducted by each breed.

Table 1. Mean EPDs for eighteen breeds for weight traits (Spring, 2002)

Breed	BWT	WNWT	YRWT	MILK
Angus	+2.6	+32.0	+60.0	+16.0
Hereford	+3.9	+33.5	+56.4	+12.0
Red Angus	+.6	+26.3	+44.3	+12.7
Shorthorn	+1.9	+13.0	+20.4	+2.5
S. Devon	+.1	+14.1	+19.6	+6.1
Brahman	+1.9	+14.1	+23.3	+7.4
Brangus	+1.9	+21.2	+34.1	+18.9
Beefmaster	+1.1	+5.0	+5.0	+8.3
Limousin	+1.4	+11.7	+22.0	+4.3
Simmental	+2.4	+33.6	+56.5	+6.1
Charolais	+1.6	+14.1	+23.9	+8.9
Gelbvieh	+1.3	+34.0	+61.0	+17.0
Maine Anjou	+3.3	+16.8	+31.9	+4.9
Salers	-1.3	+12.6	+20.9	+8.0
S. Devon	+.0	+15.6	+21.7	+6.4
Tarentaise	+2.2	+12.0	+23.0	+1.5
Pinzgauer	-.1	+.6	+.7	-1.0
Braunvieh	+1.1	+5.0	+5.0	0.0

Table 2. Mean EPDs for several breeds for some production traits (Spring, 2002)

Breed	Scrot Circ	Calving ease YRWT	Calving ease MILK	Stay-ability	Gest Lnth	DOC
Angus	.14					
Hereford	.50					
Red Angus	.10			8.0		
Beefmaster	.06					
Brangus	.47					
Limousin	.13			15.2	-.4	10.6
Simmental		4.9	2.1			
Charolais	.28					
Gelbvieh	.30	104	104	4	-.9	
Salers	.10					4.7
Tarentaise		-.8	0			

Table 3. Mean EPDs for several breeds for some carcass traits (Spring, 2002)

Breed	Carc Wt	Marb	Fat thick	Rea	Ret prod
Angus	8	-.02	.003	.05	.01
Red Angus		.04	-.01	-.04	
Shorthorn	-2	-.03	.00	-.03	.36
Brangus		-.001			
Simmental	0	.00	.00		.00
Gelbvieh	2	.00	.00		
Salers	9	-.01	.00		

ACROSS-BREED EPD TABLES FOR THE YEAR 2002 ADJUSTED TO BREED DIFFERENCES FOR BIRTH YEAR OF 2000

L. D. Van Vleck and L. V. Cundiff
Roman L. Hruska U.S. Meat Animal Research Center, ARS, USDA, Lincoln and Clay Center, NE 68933

Introduction

This report is the year 2002 update of estimates of sire breed means from data of the Germplasm Evaluation (GPE) project at the U.S. Meat Animal Research Center (MARC) adjusted to a year 2000 base using EPDs from the most recent national cattle evaluations. Factors to adjust EPD of 15 breeds to a common birth year of 2000 were calculated and reported in Tables 1-4.

Changes from the 2001 update (Van Vleck and Cundiff, 2001) are as follows:

1) Braunvieh data were added for the first time with 132 calves and 5 sires used in Cycle I of GPE. Weaning weights of 328 grandprogeny of 60 daughters were used in the maternal analysis.
2) Maternal data were available for the first time on 34 grandprogeny of 34 daughters of 15 Red Angus sires.
3) No EPDs were reported this year for 7 Hereford sires used in Cycles I and II of GPE, resulting in deletion of weaning weight records of 296 of their progeny and 532 grandprogeny by 117 daughters. A more recent sample of Hereford bulls (1 born in 1983, and 8 born in 2000) added 63 progeny with weaning weights.
4) The most recent sample of Angus bulls (9 born in 2000) added 59 progeny with weaning weights.
5) New sires of Angus (13), Hereford (13), Simmental (15), Limousin (14), Charolais (15), and Gelbvieh (15) breeds had grandprogeny with weaning weights for the maternal analysis for the first time.

The across-breed table adjustments apply **only** to EPD for most recent (in most cases; spring, 2002) national cattle evaluations. Serious biases can occur if the table adjustments are used with earlier EPD which may have been calculated with a different within-breed base.

Materials and Methods

Adjustment for heterosis

The philosophy underlying the calculations has been that bulls compared using the across-breed adjustment factors will be used in a crossbreeding situation. Thus calves and cows would generally exhibit 100% of direct and maternal heterozygosity for MILK analysis and 100% of direct heterozygosity for BWT, WWT, and YWT analyses. The use of the MARC III composite (1/4 each of Pinzgauer, Red Poll, Hereford, and Angus) as a dam breed for Angus, Brahman, Hereford and Red Angus sires requires a small adjustment for level of heterozygosity for analyses of calves for BWT, WWT and YWT and for cows for maternal weaning weight. Some sires (all multiple sire pasture mated) mated to the F1 cows are also crossbred so that adjustment for direct heterozygosity for the maternal analysis is required. Two approaches for accounting for differences in breed heterozygosity were tried which resulted in similar final table adjustments. One approach is to include level of heterozygosity in the statistical models which essentially adjusts to a basis of no heterozygosity. The other approach is based on the original logic that bulls will be mated to another breed or line of dam so that progeny will exhibit 100% heterozygosity. Most of the lack of heterozygosity in the data results from homozygosity of Hereford or Angus genes from pure Hereford or Angus matings and also from Red Angus by Angus and from Hereford, Angus or Red Angus sires mated with MARC III composite dams (1/4 each, Pinzgauer, Red Poll, Hereford, and Angus). Consequently, the second approach was followed with estimates of heterosis obtained from analyses of BWT, WWT, YWT, and MWWT using only records from the imbedded diallel experiments with Hereford and Angus. Red Angus by Angus matings were assumed not to result in heterosis.

The steps were:

1) Analyze records from H-A diallel experiments to estimate direct heterosis effects for BWT, WWT, YWT (1,140, 1,073, and 1,049 records for BWT, WWT, and YWT, respectively, representing 145 sires). The H-A diallel experiments were conducted as part of Cycle I (1970-1972 calf crops), Cycle II (1973-1974), Cycle IV (1986-1990) and Cycle VII (1999-2000) of the GPE program at MARC.
2) Adjust maternal weaning weight (MWWT) records of calves of the H-A cows from the diallel for estimates of direct heterosis from 1) and then estimate maternal heterosis effects from 2,465 weaning weight records of 602 daughters representing 151 Hereford and Angus maternal grandsires.
3) Adjust all records used for analyses of BWT, WWT and YWT for lack of direct heterozygosity using estimates from 1), and
4) Adjust all records used for analysis of MWWT for lack of both direct and maternal heterozygosity using estimates from 1) and 2).

Models for the analyses to estimate heterosis were the same as for the across-breed analyses with the obvious changes in breed of sire and breed of dam effects. Estimates of direct heterosis were 3.30, 15.40, and 31.70 lb for BWT, WWT and YWT, respectively. The estimate of maternal heterosis was 25.76 lb for MWWT. As an example of step 3), birth weight of a H by H calf would have 3.30 added. A Red Angus by MARC III calf would have (1/4) (3.30) added to its birth weight. A Red Poll sired calf of an Angus by MARC III cow would have (1/8) (15.40) plus (1/4) (25.76) added to its weaning weight record to adjust to 100% heterozygosity for both direct and maternal components of weaning weight.

After these adjustments, all calculations were as outlined in the 1996 BIF Guidelines. The basic steps were given by Notter and Cundiff (1991) with refinements by Núñez-Dominguez et al. (1993), Cundiff (1993, 1994), Barkhouse et al. (1994, 1995), and Van Vleck and Cundiff (1997, 1998, 1999, 2000, 2001). All calculations were done with programs written in Fortran language with estimates of variance components, regression coefficients, and breed effects obtained with the MTDFREML package (Boldman et al., 1995). All breed solutions are reported as differences from Angus. The table values to add to within-breed EPDs are relative to Angus.

For completeness, the basic steps in the calculations will be repeated.

Models for Analysis of MARC Records

Fixed effects in the models for birth weight, weaning weight (205-d) and yearling weight (365-d) were: breed of sire (15), dam line (Hereford, Angus, MARC III composite) by sex (female, male) by age of dam (2, 3, 4, 5-9, ≥10 yr) combination (49), year of birth (20) of birth (1970-76, 86-90, 92-94 and 97-99, 2000-01) by damline combination (99) and a separate covariate for day of year at birth of calf for each of the three breeds of dam. Cows from the Hereford selection lines have been used in GPE. To account for differences from the original Hereford cows, Hereford dams were subdivided into the selection lines and others. That refinement of the model had little effect on breed of sire solutions. Dam of calf was included as a random effect to account for correlated maternal effects for cows with more than one calf (4291 dams for BWT, 4049 for WWT, 3933 for YWT). For estimation of variance components and to estimate breed of sire effects, sire of calf was also used as a random effect (591).

Variance components were estimated with a derivative-free REML algorithm. At convergence, the breed of sire solutions were obtained as were the sampling variances of the estimates to use in constructing prediction error variance for pairs of bulls of different breeds.

For estimation of coefficients of regression of progeny performance on EPD of sire, the random sire effect was dropped from the model. Pooled regression coefficients, and regression coefficients by sire breed, by dam line, and by sex of calf were obtained. These regression coefficients are monitored as accuracy checks and for possible genetic by environment interactions. The pooled regression coefficients were used as described later to adjust for genetic trend and bulls used at MARC.

The fixed effects for the analyses of maternal effects included breed of maternal grandsire (15), maternal grand dam line (Hereford, Angus, MARC III), breed of natural service mating sire (16), sex of calf (2), birth year-GPE cycle-age of dam subclass (71), and mating sire breed by GPE cycle by age of dam subclass (38) with a covariate for day of year of birth. The subclasses are used to account for confounding of years, mating sire breeds, and ages of dams. Ages of dams were (2, 3, 4, 5-9, ≥10 yr). For estimation of variance components and estimation of breed of maternal grandsire effects, random effects were maternal grandsire (509) and dam (2,455 daughters of the maternal grandsires). Sires were unknown within breed. For estimation of regression coefficients of grandprogeny weaning weight on maternal grandsire EPD for weaning weight and milk, random effects of both maternal grandsire and dam (daughter of MGS) were dropped from the model.

Adjustment of MARC Solutions

The calculations of across-breed adjustment factors rely on solutions for breed of sire or breed of maternal grandsire from records at MARC and on averages of within-breed EPDs. The records from MARC are not included in calculation of within-breed EPD. The basic calculations for BWT, WWT, and YWT are as follows:

MARC breed of sire solution adjusted for genetic trend (as if bulls born in the base year had been used rather than the bulls actually used).

$$M_i = MARC(i) + b[EPD(i)_{YY} - EPD(i)_{MARC}].$$

Breed table factor to add to the EPD for a bull of breed i:

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

where,

MARC(i) is solution from mixed model equations with MARC data for sire breed i,

$EPD(i)_{YY}$ is the average within-breed EPD for breed i for animals born in the base year (YY, which is two years before the update; e.g., YY = 2000 for 2002 update),

$EPD(i)_{MARC}$ is the weighted (by number of progeny at MARC)

average of EPD of bulls of breed i having progeny with records at MARC,

b is the pooled coefficient of regression of progeny performance at MARC on

EPD of sire (for 2002: 1.01, 0.90, and 1.19 for BWT, WWT, YWT),

i denotes breed i, and

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

The calculations to arrive at the Breed Table Factor for milk are more complicated because of the need to separate the direct effect of the maternal grandsire breed from the maternal (milk) effect of the breed.

MARC breed of maternal grandsire solution for WWT adjusted for genetic trend:

$$MWWT(i) = MARC(i)_{MGS} + b_{wwt}[EPD(i)_{YYWWT} - EPD(i)_{MARCWWT}] + b_{MLK}[EPD(i)_{YYMLK} - EPD(i)_{MARCMLK}]$$

MARC breed of maternal grandsire solution adjusted for genetic trend and direct genetic effect:

$$MILK(i) = [MWWT(i) - 0.5\ M(i)] - [\overline{MWWT} - 0.5\ \overline{M}\,]$$

Breed table factor to add to EPD for MILK for bull of breed i:

$$A_i = [MILK(i) - MILK(x)] - [EPD(i)_{YYMLK} - EPD(i)_{MARCMLK}]$$

where,

$MARC(i)_{MGS}$ is solution from mixed model equations with MARC data for MGS breed i for WWT,

$EPD(i)_{YYWWT}$ is the average within-breed EPD for WWT for breed i for animals born in base year (YY),

$EPD(i)_{MARCWWT}$ is the weighted (by number of grandprogeny at MARC) average of EPD for WWT of MGS of breed i having grandprogeny with records at MARC,

$EPD(i)_{YYMLK}$ is the average within-breed EPD for MILK for breed i for animals born in base year (YY),

$EPD(i)_{MARCMLK}$ is the weighted (by number of grandprogeny at MARC) average of EPD for MILK of MGS of breed i having grandprogeny with records at MARC,

b_{WWT}, b_{MLK} are the coefficients of regression of performance of MARC grandprogeny on MGS EPD for WWT and MILK (for 2002: 0.51 and 1.18),

$M(i) = M_i$ is the MARC breed of sire solution from the first analysis of direct breed of sire effects for WWT adjusted for genetic trend,

$\overline{MWWT}$ and $\overline{M}$ are unneeded constants corresponding to unweighted averages of MWWT(i) and M(i) for i = 1,..., n, the number of sire (maternal grandsire) breeds included in the analysis.

Results

Tables 1, 2, and 3 (for BWT, WWT and YWT) summarize the data from, and results of, MARC analyses to estimate breed of sire differences and the adjustments to the breed of sire effects to a year 2000 base. The last column of each table corresponds to the "breed table" factor for that trait.
The general result shown in Tables 1-4 is that many breeds are continuing to become

more similar to the arbitrary base breed, Angus. Most of the other breeds have not changed much relative to each other. Column 7 of Tables 1-3 and column 10 of Table 4 represent the best estimates of breed differences for calves born in 2000. These pairs of differences minus the corresponding differences in average EPD for animals born in 2000 result in the last column of the tables to be used as adjustments for pairs of within-breed EPD.

Birth Weight

The range in estimated breed of sire difference for BWT relative to Angus are large and range from 1.2 lb for Red Angus to 9.3 lb for Charolais and 12.1 lb for Brahman. The relatively heavy birth weights of Brahman sired progeny would be expected to be completely offset by favorable maternal effects reducing birth weight if progeny were from Brahman or Brahman cross dams which would be an important consideration in crossbreeding programs involving Brahman cross females. In general, the changes from the 2001 update were slightly smaller differences from Angus with most changes of less than a pound. Changes in differences between other breeds were smaller. The smaller differences from Angus may be due to Angus calves becoming bigger or other calves becoming smaller at birth. In any case, the breeds seem to be becoming more similar, although still quite different for BWT.

Suppose the EPD for birth weight for a Charolais bull is +2.0 (which is above the year 2000 average of 1.6 for Charolais), and for a Hereford bull is also +2.0 (which is below the year 2000 average of 3.9 for Herefords). Then the adjusted EPD for the Charolais bull is 10.3 + 2.0 = 12.3 and for the Hereford bull is 3.0 + 2.0 = 5.0. The expected birth weight difference when both are mated to another breed of cow, e.g., Angus would be 12.3 - 5.0 = 7.3 lb.

Weaning Weight

Weaning weights also seem to be becoming more similar for the breeds when used as sire breeds. Most of the changes between the year 2001 and 2002 updates were about 2 lb or less. Most sire breed means for WWT adjusted to year of birth of 2000 are within 10 lb of the Angus mean. The only large change from Angus from the update for 2001 to the 2002 update was a decrease of nearly 9 lb for Herefords.

Yearling Weight

The only large change from the year 2001 update was a decrease of 19 lb for Herefords compared to Angus for the base year of 2000. Nine breeds decreased in yearling weight relative to Angus but by relatively small amounts since the year 2001 update. The three breeds that increased relative to Angus did so by 1.5 to 3.7 lb. Adjusted to a base year of 2000, Angus have heavier yearling weights than 10 breeds (1.1 to 45.7 lb) and lighter yearling weights than 3 breeds (0.2 to 17.0 lb).

MILK

Maternal milk adjusted to a 2000 year of birth was second highest for Braunvieh (based on limited numbers of daughters of Braunvieh sires). The Red Angus had, for the first time, a milk evaluation which, with few Red Angus daughters, was similar to that for Angus. Nine breeds decreased relative to Angus (1.8 to 5.8 lb) and three increased (0.3 to 3.1 lb) since the year 2001 update. The largest decreases were for Simmental (5.8 lb) and Gelbvieh (5.8 lb). Herefords also declined relative to Angus by 3.6 lb, which follows the pattern for all traits.

The largest changes between the year 2001 and year 2002 updates were for the differences in WWT and YWT between Hereford and Angus. The new records were from 57 progeny of 8 Hereford sires with moderate accuracy (range of 0.53 to 0.83) and from 59 progeny of 9 Angus sires with high accuracy (0.87 to 0.99; six with 0.99). Failure to report EPD of seven old Hereford sires resulted in loss of 288 progeny of five of these, all of which had low accuracy (0.12 to 0.43) and a limited range of current EPD (for WWT; 0 to 11 lb). Thus, the changes in Hereford vs Angus may reflect recent trends in Angus and Herefords or sampling variation in the early and/or late Herefords. In fact, calculations ignoring the Cycle 8 Angus and Hereford matings show that most of the change in difference between Hereford and Angus from the year 2001 to the year 2002 updates was due to the failure to report the EPD for the seven older low accuracy Hereford sires which excluded progeny of those sires from the year 2002 update. The regressions of progeny performance at MARC on breed association EPD have regularly been similar for Herefords and Angus. The changes for Hereford relative to Angus are generally in the same direction as for other breeds relative to Angus except somewhat larger. What is apparent is that the breeds are changing.

Table 5 summarizes the average BIF accuracy for bulls with progeny at MARC weighted appropriately by number of progeny or grandprogeny. South Devon bulls had relatively small accuracy for all traits as did Hereford, Brahman and Maine-Anjou bulls. Braunvieh bulls had low accuracy for milk. Table 6 reports the estimates of variance components from the records that were used in the mixed model equations to obtain breed of sire and breed of MGS solutions. Neither Table 5 nor Table 6 changed much from the 2001 report.

Table 7 updates the coefficients of regression of records of MARC progeny on sire EPD for BWT, WWT and YWT which have theoretical expected values of 1.00. The standard errors of the specific breed regression coefficients are large relative to the regression coefficients. Large differences from the theoretical regressions, however, may indicate problems with genetic evaluations, identification, or sampling. The pooled (overall) regression coefficients of 1.01 for BWT, 0.90 for WWT, and 1.19 for YWT were used to estimate breed solutions as of the 2000 birth year. These regression coefficients are reasonably close to expected values of 1.0. Deviations from 1.0 are believed to be due to scaling differences between performance of progeny in the MARC herd and of progeny in herds contributing to the national genetic evaluations of the 15 breeds.

The regressions by sex for YWT EPD changed in 1998 so that the female regression (1.13) was smaller than the male regression (1.23) whereas in 1997 the reverse was found (1.29 and 1.19). For YWT in 1999, the female regression decreased to 1.02 and the male regression increased to 1.32 which are similar to the 1.02 and 1.36 in the year 2002 analysis. This pattern of the regression coefficients by sex changing over years has not yet been explained. The change in 1998 was thought to be due to joint adjustment of records for sex, age of dam and dam breed.

The coefficients of regression of records of grandprogeny on MGS EPD for WWT and MILK are shown in Table 8. Several sire (MGS) breeds have regression coefficients considerably different from the theoretical expected values of 0.50 for WWT and 1.00 for MILK. The standard errors for the regression coefficients by breed are large except for Angus and Hereford. The standard errors for regression coefficients overall all breeds of grandsires associated with heifers and steers overlap for milk EPD. Again, the pooled regression coefficients of 0.51 for MWWT and 1.18 for MILK are reasonably close to the expected regression coefficients of 0.50 and 1.00, respectively.

Prediction Error Variances of Across-Breed EPD

The standard errors of differences in the solutions for breed of sire and breed of MGS differences from the MARC records can be adjusted by theoretical approximations to obtain variances of adjusted breed differences (Van Vleck, 1994: Van Vleck and Cundiff, 1994). These variances of estimated breed differences can be added to prediction error variances of within-breed EPDs to obtain prediction error variances (PEV) or equivalently standard errors of prediction (SEP) for across-breed EPDs (Van Vleck and Cundiff 1994, 1995). The variances of adjusted breed differences are given in the upper triangular part of Table 9 for BWT, lower triangular part of Table 9 for YWT, upper triangular part of Table 10 for direct WWT, and lower triangular part of Table 10 for MILK. How to use these to calculate standard errors of prediction for expected progeny differences of pairs of bulls of the same or different breeds was discussed in the 1995 BIF proceedings (Van Vleck and Cundiff, 1995).

Even though the variances of estimates of adjusted breed differences look large, especially for YWT and MILK, they generally contribute a relatively small amount to standard errors of predicted differences. For example, suppose for WWT a Salers bull has an EPD of 15.0 with prediction error variance of 75 and a Hereford bull has an EPD of 30.0 with PEV of 50. The difference in predicted progeny performance is (Salers adjustment + Salers bull's EPD) - (Hereford adjustment + Hereford bull's EPD):

$$(26.1 + 15.0) - (-6.9 + 30.0) = 41.1 - 23.1 = 18.0.$$

The prediction error variance for this difference is (use the 19.0 in the upper part of Table 10 at intersection of row for HE and column for SA):

V(Salers breed - Hereford breed) + PEV(Salers bull) + PEV(Hereford bull):

$$19 + 75 + 50 = 144$$

with

standard error of prediction $\sqrt{144} = 12$.

If the difference between the Salers and Hereford breeds in the year 2000 could be estimated perfectly, the variance of the estimate of the breed difference would be 0 and the standard error of prediction between the two bulls would be:

$\sqrt{0 + 75 + 50} = 11.2$ which is only slightly smaller than 12.0.

Implications

Bulls of different breeds can be compared on a common EPD scale by adding the appropriate table factor to expected progeny differences (EPDs) produced in the most recent genetic evaluations for each of the 15 breeds. The AB-EPDs are most useful to commercial producers purchasing bulls of two or more breeds to use in systematic crossbreeding programs. Uniformity in AB-EPDs should be emphasized for rotational crossing. Divergence in AB-EPDs for direct weaning weight and yearling weight should be emphasized in selection of bulls for terminal crossing. Divergence favoring lighter birth weight may be helpful in selection of bulls for use on first calf heifers. Accuracy of AB-EPDs depend primarily upon the accuracy of the within-breed EPDs of individual bulls being compared.

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Table 1. Breed of sire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2000 base and factors to adjust within breed EPDs to Angus equivalent - BIRTH WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw MARC Mean (1)	Ave. Base EPD Breed 2000 (2)	Ave. Base EPD MARC Bulls (3)	Breed Soln at MARC + Ang (4)	Breed Soln at MARC vs Ang (5)	Adjust to 2000 Base + Ang (6)	Adjust to 2000 Base vs Ang (7)	Factor to adjust EPD to Angus (8)
Hereford	103	1454	88	3.9	3.1	88	3.9	89	4.3	3.0
Angus	102	1308	84	2.6	2.1	84	0.0	85	0.0	0.0
Shorthorn	25	181	87	1.9	0.9	90	6.4	91	6.9	7.6
South Devon	15	153	80	0.1	-0.2	88	4.3	89	4.0	6.5
Brahman	40	589	98	1.9	0.7	95	11.4	97	12.1	12.8
Simmental	48	623	87	2.4	2.8	91	7.1	91	6.1	6.3
Limousin	40	589	83	1.4	-0.5	87	3.0	89	4.4	5.6
Charolais	75	675	89	1.6	0.5	93	8.7	94	9.3	10.3
Maine-Anjou	18	218	94	3.3	6.1	94	10.0	91	6.6	5.9
Gelbvieh	48	595	89	1.3	0.6	88	4.0	89	4.2	5.5
Pinzgauer	16	435	84	-0.1	-0.4	89	4.5	89	4.3	7.0
Tarentaise	7	199	80	2.2	1.8	86	2.4	87	2.3	2.7
Salers	27	189	85	-1.3	1.3	88	4.4	86	1.3	5.2
Red Angus	21	206	85	0.6	-0.5	85	0.6	86	1.2	3.2
Braunvieh	5	136	87	1.1	0.1	88	3.9	89	4.4	5.9

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) - (3)] with b = 1.01
(7) = (6) - (6, Angus)
(8) = (7) - (7, Angus) - [(2) - (2, Angus)]

Table 2. Breed of sire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2000 base and factors to adjust within breed EPDs to Angus equivalent - WEANING WEIGHT (lb)

	Number		Raw MARC Mean	Ave. Base EPD		Breed Soln at MARC		Adjust to 2000 Base		Factor to adjust EPD to Angus
				Breed 2000	MARC Bulls	+ Ang	vs Ang	+ Ang	vs Ang	
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hereford	101	1319	511	33.5	28.0	499	-1.3	504	-5.4	-6.9
Angus	103	1204	500	32.0	22.0	500	0.0	509	0.0	0.0
Shorthorn	25	170	521	13.0	7.4	513	12.6	518	8.6	27.6
South Devon	15	134	443	15.6	0.4	501	0.9	515	5.5	21.9
Brahman	40	509	532	14.1	4.7	517	16.8	525	16.2	34.1
Simmental	47	564	505	33.6	23.8	523	23.3	532	23.1	21.5
Limousin	40	533	477	11.7	-1.0	500	0.3	512	2.7	23.0
Charolais	74	600	514	14.1	6.4	523	23.1	530	21.1	39.0
Maine-Anjou	18	197	459	16.8	22.8	514	14.4	509	0.0	15.2
Gelbvieh	48	559	507	34.0	27.7	514	13.7	519	10.4	8.4
Pinzgauer	16	415	478	0.6	-4.1	498	-1.6	503	-6.4	25.0
Tarentaise	7	191	476	12.0	-4.8	502	1.7	517	7.9	27.9
Salers	27	176	525	12.6	7.4	511	11.0	516	6.7	26.1
Red Angus	21	199	535	26.3	28.0	502	1.8	500	-8.7	-3.0
Braunvieh	5	132	450	5.0	6.2	508	8.5	507	-1.6	25.4

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) - (3)] with b = 0.90
(7) = (6) - (6, Angus)
(8) = (7) - (7, Angus) - [(2) - (2, Angus)]

Table 3. Breed of sire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2000 base and factors to adjust within breed EPDs to Angus equivalent - YEARLING WEIGHT (lb)

Breed	Number Sires	Number Progeny	Raw MARC Mean (1)	Ave. Base EPD Breed 2000 (2)	Ave. Base EPD MARC Bulls (3)	Breed Soln at MARC + Ang (4)	Breed Soln at MARC vs Ang (5)	Adjust to 2000 Base + Ang (6)	Adjust to 2000 Base vs Ang (7)	Factor to adjust EPD to Angus (8)
Hereford	101	1257	860	56.4	46.6	849	-17.5	860	-27.5	-23.9
Angus	103	1148	866	60.0	41.9	866	0.0	888	0.0	0.0
Shorthorn	25	168	918	20.4	14.5	880	13.5	887	-1.1	38.5
South Devon	15	134	744	21.7	0.0	864	-1.9	890	2.3	40.6
Brahman	40	438	838	23.3	8.5	824	-41.7	842	-45.7	-9.0
Simmental	47	528	852	56.5	39.2	884	17.9	905	16.9	20.4
Limousin	40	527	797	22.0	1.2	844	-21.9	869	-18.7	19.3
Charolais	74	566	882	23.9	12.0	890	24.5	905	17.0	53.1
Maine-Anjou	18	196	787	31.9	45.2	878	12.0	862	-25.5	2.6
Gelbvieh	48	555	849	61.0	50.0	857	-8.9	870	17.4	-18.4
Pinzgauer	16	347	838	0.7	-8.0	835	-30.8	846	-42.1	17.2
Tarentaise	7	189	807	23.0	-3.4	824	-41.8	856	-31.9	5.1
Salers	27	173	899	20.9	8.3	873	6.8	888	0.2	39.3
Red Angus	21	194	916	44.3	48.5	872	6.4	867	-20.3	-4.6
Braunvieh	5	131	733	5.0	7.9	835	-31.4	831	-56.5	1.5

Calculations:
(4) = (5) + (1, Angus)
(6) = (4) + b[(2) - (3)] with b = 1.19
(7) = (6) - (6, Angus)
(8) = (7) - (7, Angus) - [(2) - (2, Angus)]

Table 4. Breed of maternal grandsire solutions from MARC, mean breed and MARC EPDs used to adjust for genetic trend to 2000 base and factors to adjust within-breed EPDs to Angus equivalent - MILK (lb)

					Mean EPD				Breed Soln at MARC MWWT		Adjust to 2000 Base MWWT			Factor to Adjust MILK EPD to Angus
		Number		Raw MARC Mean	Breed		MARC						MILK	
Breed	Sr	Gpr	Daughters	(1)	WWT (2)	MILK (3)	WWT (4)	MILK (5)	+ Ang (6)	vs Ang (7)	+ Ang (8)	vs Ang (9)	(10)	(11)
Hereford	85	1743	471	474	33.5	12.0	24.4	5.9	471	-16.0	483	-24.3	-21.5	-17.6
Angus	87	1544	412	487	32.0	16.0	15.1	6.2	487	0.0	507	0.0	0.2	0.0
Shorthorn	22	251	69	527	13.0	2.5	7.6	6.3	512	24.6	510	2.8	-1.4	11.9
South Devon	14	347	69	488	15.6	6.4	0.3	5.6	493	5.5	501	-5.8	-8.4	1.1
Brahman	40	880	216	522	14.1	7.4	4.9	2.6	522	34.7	532	25.0	17.1	25.5
Simmental	42	830	186	510	33.6	6.1	16.8	8.9	515	27.7	520	12.8	1.4	11.2
Limousin	34	800	186	474	11.7	4.3	-9.9	-0.4	480	-7.2	496	-10.8	-12.0	-0.5
Charolais	61	746	187	498	14.1	8.9	0.6	2.8	500	13.1	514	7.0	-3.4	3.5
Maine-Anjou	17	485	86	533	16.8	4.9	22.2	4.9	510	23.2	507	0.4	0.5	11.5
Gelbvieh	40	691	181	531	34.0	17.0	25.2	15.3	517	29.8	523	16.2	11.1	10.0
Pinzgauer	15	545	133	504	0.6	-1.0	-1.7	6.4	501	13.8	493	-13.9	-10.5	6.3
Tarentaise	6	341	78	513	12.0	1.5	-6.0	4.7	508	21.1	513	6.4	2.6	16.9
Salers	25	351	87	534	12.6	8.0	5.7	4.4	511	24.0	519	11.6	8.4	16.3
Red Angus	15	34	34	423	26.3	12.7	26.0	15.2	509	22.4	507	-0.5	4.0	7.2
Braunvieh	5	328	60	538	5.0	0.0	6.8	-1.6	517	30.0	518	10.9	11.8	27.7

Calculations:
(6) = (7) + (1, Angus)
(8) = (6) + b_{WWT} [(2) - (4)] + b_{MLK} [(3) - (5)] with $b_{WWT} = 0.51$ and $b_{MLK} = 1.18$
(9) = (8) - (8, Angus)
(10) = [(9) - Average (9)] - 0.5[(7, Table 2) - Average (7, Table 2)]
(11) = [(10) - (10, Angus)] - [(3) - (3, Angus)]

Table 5. Mean weighted[a] accuracies for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), maternal weaning weight (MWWT) and milk (MILK) for bulls used at MARC

Breed	BWT	WWT	YWT	MWWT	MILK
Hereford	0.62	0.59	0.53	0.55	0.53
Angus	0.89	0.87	0.84	0.83	0.81
Shorthorn	0.82	0.80	0.74	0.82	0.76
South Devon	0.37	0.39	0.37	0.41	0.42
Brahman	0.50	0.54	0.37	0.54	0.41
Simmental	0.93	0.92	0.92	0.96	0.95
Limousin	0.94	0.92	0.88	0.95	0.91
Charolais	0.80	0.78	0.68	0.76	0.67
Maine-Anjou	0.69	0.68	0.68	0.68	0.67
Gelbvieh	0.74	0.69	0.62	0.69	0.64
Pinzgauer	0.85	0.68	0.62	0.70	0.64
Tarentaise	0.95	0.95	0.94	0.95	0.95
Salers	0.83	0.77	0.72	0.77	0.76
Red Angus	0.82	0.79	0.78	0.79	0.75
Braunvieh	0.77	0.70	0.69	0.70	0.48

[a]Weighted by number of progeny at MARC for BWT, WWT, and YWT and by number of grand progeny for MWWT and MILK.

Table 6. REML estimates of variance components (lb^2) for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), and maternal weaning weight (MWWT) from mixed model analyses

	Direct			Maternal
Analysis[a]	BWT	WWT	YWT	MWWT
Direct				
Sires (591) within breed (15)	11.0	150	643	
Dams (4049) within breed (3)	27.3	874	1176	
Residual	67.6	1511	4141	
Maternal				
MGS (509) within MGS breed (15)				183
Daughters within MGS (2455)				882
Residual				1264

[a]Numbers for weaning weight.

Table 7. Pooled regression coefficients (lb/lb) for weights at birth (BWT), 205 days (WWT), and 365 days (YWT) of F_1 progeny on sire expected progeny difference and by sire breed, dam breed, and sex of calf

	BWT	WWT	YWT
Pooled	1.01 ± 0.05	0.90 ± 0.06	1.19 ± 0.05
Sire breed			
Hereford	1.10 ± 0.09	0.96 ± 0.10	1.30 ± 0.09
Angus	1.03 ± 0.12	0.78 ± 0.10	1.17 ± 0.08
Shorthorn	0.77 ± 0.47	0.79 ± 0.43	1.32 ± 0.37
South Devon	0.81 ± 0.59	-0.28 ± 0.37	-0.14 ± 0.43
Brahman	1.86 ± 0.26	1.09 ± 0.27	0.72 ± 0.24
Simmental	1.08 ± 0.22	1.24 ± 0.17	1.34 ± 0.15
Limousin	0.73 ± 0.17	0.56 ± 0.15	1.14 ± 0.14
Charolais	0.99 ± 0.14	0.94 ± 0.14	1.02 ± 0.14
Maine-Anjou	1.23 ± 0.38	0.55 ± 0.46	0.35 ± 0.48
Gelbvieh	1.04 ± 0.16	1.28 ± 0.27	1.28 ± 0.23
Pinzgauer	1.25 ± 0.17	1.47 ± 0.21	1.66 ± 0.16
Tarentaise	0.85 ± 0.90	0.88 ± 0.56	1.34 ± 0.62
Salers	1.17 ± 0.37	1.17 ± 0.49	0.78 ± 0.44
Red Angus	0.59 ± 0.20	0.64 ± 0.35	0.75 ± 0.32
Braunvieh	-0.13 ± 0.52	0.70 ± 0.85	1.02 ± 0.60
Dam breed			
Hereford	0.96 ± 0.08	0.81 ± 0.09	1.05 ± 0.08
Angus	1.08 ± 0.07	0.93 ± 0.07	1.26 ± 0.07
MARC III	0.96 ± 0.08	0.95 ± 0.10	1.24 ± 0.09
Sex of calf			
Heifers	0.99 ± 0.06	1.03 ± 0.07	1.02 ± 0.06
Steers	1.04 ± 0.06	0.78 ± 0.07	1.36 ±.0 06

Table 8. Pooled regression coefficients (lb/lb) for progeny performance on maternal grandsire EPD for weaning weight (MWWT) and milk (MILK) and by breed of maternal grandsire, breed of maternal grandam, and sex of calf

Type of regression	MWWT	MILK
Pooled	0.51 ± 0.05	1.18 ± 0.07
Breed of maternal grandsire		
Hereford	0.47 ± 0.09	1.17 ± 0.13
Angus	0.56 ± 0.10	1.01 ± 0.15
Shorthorn	0.23 ± 0.36	0.74 ± 0.44
South Devon	0.32 ± 0.25	-1.23 ± 0.82
Brahman	0.38 ± 0.21	0.72 ± 0.36
Simmental	0.70 ± 0.22	1.30 ± 0.56
Limousin	0.79 ± 0.19	2.48 ± 0.30
Charolais	0.39 ± 0.16	1.45 ± 0.25
Maine-Anjou	-0.02 ± 0.32	0.38 ± 0.37
Gelbvieh	0.60 ± 0.28	1.38 ± 0.36
Pinzgauer	0.70 ± 0.20	0.38 ± 0.58
Tarentaise	0.22 ± 0.66	0.73 ± 0.80
Salers	0.77 ± 0.33	1.86 ± 0.32
Red Angus	0.70 ± 0.77	1.44 ± 0.95
Braunvieh	0.00 ± –	2.21 ± –
Breed of maternal grandam		
Hereford	0.44 ± 0.07	1.49 ± 0.12
Angus	0.59 ± 0.06	1.10 ± 0.11
MARC III	0.43 ± 0.10	0.84 ± 0.15
Sex of calf		
Heifers	0.53 ± 0.06	1.07 ± 0.10
Steers	0.50 ± 0.06	1.16 ± 0.10

Table 9. Variances (lb^2) of adjusted breed differences to add to sum of within breed prediction error variances to obtain variance of differences of across breed EPDs for bulls of two different breeds[a]. Birth weight above diagonal and yearling weight below diagonal

Breed	HE	AN	SH	SD	BR	SI	LI	CH	MA	GE	PI	TA	SA	RA	BV
HE	0.0	0.3	0.9	1.4	0.5	0.5	0.5	0.4	1.2	0.5	0.9	2.6	0.8	0.8	1.5
AN	17	0.0	0.9	1.4	0.5	0.5	0.5	0.4	1.2	0.5	0.9	2.6	0.8	0.8	1.6
SH	57	58	0.0	2.0	1.2	1.2	1.2	1.0	1.7	1.0	1.4	3.2	1.1	1.5	2.1
SD	88	88	130	0.0	1.8	1.3	1.4	1.3	2.2	1.6	2.1	3.8	2.0	1.9	2.6
BR	40	40	84	118	0.0	0.9	0.9	0.8	1.4	0.8	0.9	2.6	1.2	1.2	1.8
SI	32	32	75	82	61	0.0	0.5	0.5	1.4	0.7	1.2	2.9	1.1	0.9	1.8
LI	34	33	77	85	63	31	0.0	0.5	1.4	0.7	1.2	3.0	1.2	0.9	1.8
CJ	26	26	64	84	55	29	32	0.0	1.3	0.5	1.0	2.8	0.9	0.8	1.7
MA	74	74	110	141	97	87	89	82	0.0	1.1	1.6	3.3	1.6	1.7	1.4
GE	30	31	67	99	57	40	41	35	69	0.0	1.0	2.8	1.0	0.9	1.5
PI	60	62	94	134	68	78	80	71	108	70	0.0	2.6	1.3	1.5	2.0
TA	167	168	205	239	166	184	186	178	212	178	161	0.0	3.2	3.2	3.7
SA	53	54	74	126	80	72	74	61	106	63	91	201	0.0	1.4	2.0
RA	50	49	94	116	81	52	54	51	107	54	98	204	90	0.0	2.1
BV	102	103	139	170	126	115	117	110	94	97	137	241	135	135	0.0

[a]For example, a Hereford bull has within breed PEV of 300 for YWT and that for a Shorthorn bull is 200. Then the PEV for the difference in EPDs for the two bulls is 57 + 300 + 200 = 557 with SEP $= \sqrt{557} = 23.6$.

Table 10. Variances (lb^2) of adjusted breed differences to add to sum of within breed prediction error variances to obtain variance of difference of across breed EPDs for bulls of two different breeds. Weaning weight direct above diagonal and MILK below the diagonal

Breed	HE	AN	SH	SD	BR	SI	LI	CH	MA	GE	PI	TA	SA	RA	BV
HE	0	5	20	29	12	11	11	9	26	10	18	45	19	18	34
AN	17	0	21	29	12	11	11	9	26	10	18	46	19	18	34
SH	51	53	0	45	29	27	27	23	40	24	30	60	27	34	48
SD	61	61	97	0	38	27	28	28	49	33	43	70	44	40	57
BR	27	28	66	76	0	19	20	17	33	18	19	44	27	27	41
SI	36	36	73	62	51	0	10	10	30	13	24	52	25	19	38
LI	38	39	75	65	54	42	0	10	31	14	24	52	26	19	39
CJ	27	28	61	60	42	36	39	0	29	12	22	50	22	18	37
MA	59	60	93	103	72	78	81	70	0	24	36	63	38	38	32
GE	31	32	62	75	45	49	51	39	60	0	21	50	23	20	32
PI	53	55	86	101	57	76	78	66	95	67	0	42	30	32	44
TA	127	128	162	174	125	149	152	140	167	142	136	0	59	60	71
SA	42	45	67	89	57	64	67	52	85	54	78	154	0	33	47
RA	103	104	140	142	119	113	115	107	146	112	144	217	132	0	46
BV	105	107	140	150	119	125	127	116	112	106	141	214	131	192	0

FRANK H. BAKER

May 2, 1923	Stroud, Oklahoma
February 15, 1993	Little Rock, Arkansas

(Photograph of portrait in Saddle and Sirloin Club Gallery:
Everett Raymond Kinstler, Artist)

FRANK BAKER MEMORIAL SCHOLARSHIP AWARD ESSAYS

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

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

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

Frank served on advisory committees for the Angus, Hereford, and Polled Hereford beef breed associations, the National Cattlemen's Association, Performance Registry International, and the Livestock Conservation, Inc. His service and leadership to the American Society of Animal Science (ASAS) included many committees, election as vice-president and as president, 1973-74. Frank was elected an ASAS Honorary Fellow in 1977, he was a Fellow of the American Association for the Advancement of Science, and served the Council for Agricultural Science and Technology (CAST) as president in 1979.

Frank Baker received many awards in his career, crowned by having his portrait hung in the Saddle and Sirloin Club Gallery at the International Livestock Exposition, Louisville, Kentucky, on November 16, 1986. His ability as a statesman and diplomat for the livestock industry was to use his vision to call forth the collective best from all those around him. Frank was a "mover and shaker" who was skillful in turning "Ideas into Action" in the beef cattle performance movement. His unique leadership abilities earned him great respect among breeders and scientists alike. Frank died February 15, 1993, in Little Rock, Arkansas.

GENETIC EVALUATION OF FEMALE REPRODUCTIVE PERFORMANCE

Katherine A. Donoghue
The University of Georgia
Athens, GA

INTRODUCTION

Fertility or reproductive performance is one of the most important components of production efficiency and genetic gain in beef production systems. It has been reported to be at least twice as important, economically, as production traits under a conventional cow-calf operation (Melton, 1995). A delay in conception due to poor fertility prolongs the calving interval, and causes a shift in calving pattern, which can lead to culling. However, reproductive traits in cattle are difficult to measure, report and interpret. This is particularly true for pasture mating situations, where information on females in extremely limited. In these situations, the only information readily available is whether or not a cow produces a calf, and when she calves.

Breeding value estimation for reproductive traits is difficult, in part because the expression of reproductive potential is often constrained by the management system. Reproductive data is of a complex nature, and is the culmination of many events that occur throughout the breeding season. Evaluation of genetic merit for reproduction requires information on the complete reproductive history of each animal, which is often unavailable. Thus, while genetic values for growth and carcass traits are reported in national genetic evaluations for most breeds, very few breeds report genetic values for fertility. In the past, correlated traits (such as scrotal circumference) have been used to indirectly select for female fertility. Currently, genetic values for three measures of female fertility are being reported in national genetic evaluations; days to calving, stayability and heifer pregnancy. The purpose of this paper is to review the suitability of these traits as measures of female reproductive performance, and to suggest improvements or modifications that could enhance the evaluation of fertility in national genetic evaluations.

REVIEW OF LITERATURE

Calving date/Days to calving

Calving interval has been used as the preferred measure of reproduction in dairy cattle. However, because a fixed breeding season is generally used in beef herds, calving interval has limited value as a selection criterion. Calving dates are generally available in field data, and their use requires minimal modification of existing performance programs. It is defined as the day of the year on which the cow calves, and allows comparison between cows when breeding is of the same duration, and starts on the same date. In early studies, calving date was found to be preferable to the alternative measure of calving interval. Later studies, which included the records of open cows in analyses, found calving date to be heritable, as well as having a clear economic interpretation.

In an early study, Bourdon and Brinks (1983) demonstrated the superiority of calving date over calving interval. In their study, calving interval was more susceptible to the bias caused by the use of a fixed breeding season, due to its strong dependence on previous calving date. In general, cows that calve early in the season will experience an ample postpartum period before the breeding season. As a rule, they will rebreed early, but are unable to register a subsequent calving interval of less than 365 days (Bourdon and Brinks, 1983). Cows that calve later in the season, however, have a shorter period between calving and breeding, and, therefore, the opportunity to record a shorter calving interval. In their study, calving interval decreased 0.86 days and calving date was delayed 0.11 days for each 1-day delay in previous calving date. The authors also noted that an additional advantage of calving date was its clearly identifiable economic value; calves born earlier in the calving season weigh more at weaning; while the economic interpretation of calving interval is difficult.

Numerous studies have addressed the issue of which parity should be used to measure calving date. Meacham and Notter (1987) used a sire model to estimate genetic parameters for calving date, calving interval and percent return using first and second calving records. All traits had a highly significant relationship with calving ease score recorded at first calving. Heritability estimates pooled across herds for calving interval, first and second calving dates and percent return were 0.04, 0.17, 0.07 and 0.11, respectively, and the estimated genetic correlation between first and second calving dates was 0.66. The authors noted that the lower heritability estimate for second calving date might reflect culling of open cows before the second calving, or real changes in the magnitude of genetic and environmental variation. The authors concluded that useful levels of genetic variation existed for first calving date, and that this trait could be used in sire selection as a measure of daughter's reproductive ability.

In order to make the best use of the data available for reproductive performance, information for open cows must be included in the evaluation. Notter (1988) noted that if data on open cows is ignored, the most genetically inferior, and possibly most informative, animals are ignored. Therefore, if sires differ markedly in the frequency of open daughters, consideration of open cows may be required to accurately estimate true sire difference in daughter's fertility.

Notter and Johnson (1988) obtained genetic parameter estimates for calving date with records for open cows included in the analysis using simulated data. They proposed a procedure using threshold theory to calculate penalties for open cows. Observed calving dates (CD) for cows that calved were transformed as $W = \ln(CD+1)$ to normalize the data, and calving dates for open cows were projected by considering cows that didn't calve to represent the upper tail of a truncated normal distribution of the transformed calving date. The authors found no carryover effects of prior calving date in cows calving within the first 21 days of the breeding season, but for cows calving after day 21, each 1-day increase in calving date was associated with an increase of 0.69

days in the next calving date. Adjustment for previous calving performance in this study reduced repeatability estimates of calving date from 0.26 to 0.24, while heritability estimates remained constant at 0.125, and the correlation between actual and adjusted calving date was 0.95. The authors suggested these results indicate that even though significant transient environmental effects existed between adjacent calving dates, adjustment for these effects didn't greatly affect overall rankings of females. Correlations between mean calving date and ability to conceive were found to be consistently higher for actual calving date than for the transformed data. The authors also found that selection against late calving was more effective than selection for early calving in identifying cows with genetic potential to conceive. The authors concluded that under pasture mating, unbiased estimates of ability to conceive cannot be obtained, but selection based on observed calving date yielded acceptable estimates, provided that open cows were included in the evaluation.

Buddenberg et al. (1990) compared estimates of variance components obtained from excluding and including records of open cows. Open cows were assigned a value based on the projected mean calving date of the open cows in an unrestricted breeding season, as described by Notter and Johnson (1988). Data were transformed as outlined by Notter and Johnson (1988), and the projected mean calving date for open cows was then obtained separately for each year based on the actual data and percentages of open cows for that year. Heritability estimates were obtained as paternal half-sib correlations. In general, the proportion of variance due to service sire and sire of dam increased when open cows were included in the analysis. Heritability estimates (open records excluded) for first-calf, second-calf and mature animals were 0.20, 0.04 and 0.03, respectively. The corresponding estimates for open records included were 0.39, 0.13 and 0.00, respectively, and confirmed that estimates from data excluding open cows are biased downward. The authors suggested that the lower heritability estimates for older animals was most likely the result of culling open cows each year. Service sire was the largest source of variation in calving date in both data sets, and sire of dam accounted for only a small portion (<10%) of variation. As a result of culling open cows, variation associated with service sire and sires of dams generally decreased with age. The authors concluded that attention should be given to selection against late calving date of first-calf heifers, and that the advantages of this selection would be lower birth weights, less dystocia and more recovery time between calving and breeding.

Days to calving has been investigated by researchers in Australia, and gives the same information as calving date when the cows to be compared went into breeding on the same day. Meyer et al. (1990) compared calving rate, number of calves, calving success and days to calving as measures of reproductive performance in Australian beef cattle. Calving rate was defined as the number of calves a cow produced divided by the number of opportunities to do so; calving success was scored as 0 (non-calver) and 1(calver); and days to calving was calculated as the difference in days between the beginning of the breeding season and calving date, for each breeding season. Cows not calving were assigned a predicted value, derived from threshold theory, as suggested by Notter and Johnson (1988). Days to calving was analyzed both as observed, and transformed to logarithmic values, while calving success was analyzed without adjustment for the categorical nature of the trait. Heritability estimates for calving rate for Zebu crosses, Herefords and Angus were 0.17, 0.07 and 0.02, respectively. Heritability estimates for days to calving for Zebu crosses, Herefords and Angus were 0.09, 0.05 and 0.08, respectively. Transformation to log scale had practically no effect on estimates or on the predicted difference between calvers and non-calvers. Heritability estimates for calving success for Zebu crosses, Herefords and Angus were 0.08, 0.08 and 0.02, respectively. The authors concluded that days to calving appeared the most suitable trait for incorporation into genetic evaluation, as it is readily measurable under pasture conditions, and allows information on all cows to be included in the analysis. As well, the authors noted that the expected deviation of the distribution from normality for this trait would be considerably less than for other traits considered, which would allow the application of standard methods of genetic evaluation for analyses.

Johnston and Bunter (1996) demonstrated that days to calving, as defined by Meyer et al. (1990), was also a suitable measure of reproductive performance in a large field data set. Cows with open records were assigned a projected value on a within breeding management group basis. The highest days to calving record within each breeding management group was identified, and a constant number of days (21 days) were added to this record to generate the projected value for all non-calvers. The procedure proposed by Notter and Johnson (1988) to create penalty records was also considered. However, the procedure was deemed unsuitable because some of the predicted days to calving records for non-calvers were less than actual days to calving records. Calving success, scored as 0 (non-calvers) and 1 (calvers), was included in a bivariate analysis with days to calving, and was analyzed without any adjustment for the categorical nature of the trait. The genetic correlation estimate between the traits was –0.97, and the authors concluded that selecting for days to calving would be the same as selecting for calving success, with the added benefit of being able to distinguish between early and late calvers. Heritability estimates for days to calving in the first and second parities were 0.10 and 0.11, respectively, while repeatability and heritability estimates of 0.25 and 0.12 were obtained for a repeatability model. The genetic correlation between days to calving in the first and second parities was 0.85, supporting the use of a repeatability model. Genetic correlations between days to calving in the first parity and growth traits were generally unfavorable but not significantly different from zero, and thus the authors concluded that direct selection on reduced days to calving would be required to improve the trait.

Once a trait has been deemed suitable for incorporation into national genetic evaluations, the nature of the relationship between the trait and other traits is of primary interest. Meyer et al. (1991) used a subset of the data used by Meyer et al. (1990) to investigate covariances between days to calving, growth traits and male fertility traits. A weak but consistently favorable association (-0.30) was found between scrotal circumference and days to calving, while serving capacity and days to calving were found to be unrelated in this study. There seemed to be little favorable genetic association between growth and female fertility in the temperate breeds. Estimates of the genetic correlations were larger in Zebu crosses for yearling (-0.36) and weaning weight (-0.66). The authors failed to find any unfavorable genetic correlations between growth and days to calving, and concluded that joint selection for fertility and growth should improve genetic potential in both.

Rege and Famula (1993) studied factors affecting calving date in USA field data. They found that animals which as heifers calved in the first 21 days of the calving season had lower average subsequent calving dates, and gave birth to calves which were weaned earlier and had significantly heavier yearling weights than those that calved after the 42^{nd} day of the season. Also, animals that calved late as heifers proceeded to calve later than initial early calvers in subsequent parities. Repeatability of calving date was estimated at 0.23, and heritability at 0.16. Genetic correlations between calving date and birth weight (-0.30), weaning weight (-0.05), postweaning gain (-0.64) and yearling weight (-0.60) were generally favorable. The nature of the relationship between calving date and maternal breeding value (BV) was also studied, with an increase in maternal BV associated with a delay in calving date. The authors suggested that there is an optimum level of milk production above which reproduction is jeopardized. Moreover, calving date of younger cows was more adversely affected by high maternal BV than was calving date of older cows, and late calving was associated more with high than with low milk production potential. The authors found that early initial calvers were superior to their late counterparts in subsequent reproductive performance. They concluded that since heifer calvings aren't constrained by a previous calving; most heifers are bred and have the opportunity to calve early; differences in heifer performance are good indicators of genetic differences in calving date.

The study by Johnston and Bunter (1996) investigated the relationship between calving success and days to calving, but was unable to account for the categorical nature of calving success, due to computational limitations. Johnston et al. (2001) estimated the nature of the relationship between days to calving and calving success, using a new analytical procedure that accounted for the categorical nature of calving success. Days to calving and calving success were defined as described by Johnston and Bunter (1996), and only records from the first parity were retained for analysis for both traits. In addition, calving success records were only used from breeding management groups where variation existed, so that calving success records were removed for all animals in breeding management groups where all cows calved. Variance components were estimated using the Bayesian approach via the Gibbs sampler. Heritability estimates for days to calving and calving success (on the underlying scale) were 0.12 and 0.04, respectively, and the genetic correlation estimate between the two traits was –0.66. The authors suggested that, based on these results, selection for reduced days to calving would result in correlated increases in calving success. The correlation between estimated breeding values (EBV) for both traits was –0.96, indicating that shorter days to calving was favorably associated with an increased probability of a successful calving. The regression coefficient for days to calving EBV was –0.6 percent success/day. Thus, for each 1-day shorter days to calving EBV, there was a 0.6% increase in calving success EBV. The authors concluded that, from a selection point of view, days to calving and calving success are genetically similar, with the former having a higher heritability.

Various methods have been used to incorporate records of open cows in the analysis of calving date and days to calving (Notter and Johnson, 1988; Johnston and Bunter, 1996). An alternative approach would be to use survival analysis to evaluate reproductive traits. Such analyses could model days to calving with a hazard rate or probability of calving past time t, given the individual has not calved prior to t. Studies in dairy cattle have shown that survival analysis is useful for evaluating longevity (Ducrocq, 1994) and fertility traits such as days open (Eicker et al., 1996) but little research has been undertaken using the survival model for analysis of beef fertility traits. Although survival analyses offer several advantages over the linear model, e.g., better statistical modeling of censored data, the high computational requirements associated with applying these non-linear analyses hinders their use with an animal model and large data sets. Despite this drawback, survival analysis offers the potential for better evaluation of fertility traits in beef cattle in the future.

Stayability

Another trait of primary interest to the beef industry is the length of the productive life of females, sometimes termed "stayability". Snelling et al. (1995) conducted within-herd genetic analyses of stayability, where traits considered were probabilities of a female having 2,5,8 and 11 calves, given that she calved once. The number of calves born to each dam was used to assign binary stayability observations to dams old enough to have had the required number of calves, coded as 1 (success) and 0 (failure). Observations of failure on culled cows not yet old enough to have had the required number of calves were not used. Three variations of nonlinear procedures for mixed-model analysis of binary data were used to estimate variances and predict genetic merit; animal and sire model marginal maximum likelihood, and animal model Method R, with only the former yielding heritability estimates for all traits in all herds. The heritability estimates for probability of having 2,5,8 and 11 calves, given that she calved once, were 0.09, 0.11, 0.07 and 0.20, respectively, for herd one, and 0.02, 0.14, 0.09 and 0.07, respectively, for herd two. Comparing accuracies of the 4 traits, the predictions for probability of having 5 calves, given that she calved once, had the highest mean accuracy in both herds. The authors concluded that this result, along with higher heritability estimates, offset the greater number of records available at earlier ages.

Van der Westhuizen et al. (2001) estimated variance components for stayability, longevity and calving success, and investigated the nature of the relationship between the traits using a sire model. Stayability was defined as the probability of an animal surviving to a specific age (36, 48, 60, 72 and 84 months), given the opportunity to reach that age, and coded as 1 (cow survived) and 0 (last record). Calving success was coded as 1 (successful calving) and 0 (otherwise), and longevity was calculated from the age at which the last data set was recorded. Variance components and genetic values were obtained using GFCAT, a set of programs for the analysis of "mixed" model threshold models. Heritability estimates for stayability at 36, 48, 60, 72 and 84 months of age were 0.06, 0.10, 0.06, 0.03 and 0.11, respectively. Heritability estimates for calving success and longevity were 0.03 and 0.08, respectively. Product-moment correlations between stayability at different ages were found to be low, and the authors concluded that there would be little to no improvement in level of stayability when selection was applied at another level. In general, they concluded that heritability estimates and correlations between traits were of such a low magnitude that selection for these characteristics would result in limited genetic improvement, and also indicated that sires had little influence on the stayability, longevity or calving success of their daughters. However, the authors did not address whether these results would hold for evaluation under the animal model.

Heifer pregnancy

Evans et al. (1999) evaluated the feasibility of producing expected progeny differences (EPD) for heifer pregnancy using yearling bull scrotal circumference and yearling heifer pregnancy observations. Heifer pregnancy was defined as the observation that a heifer conceives and remains pregnant to palpation, given that she was exposed at breeding, and scored as 1 (successful pregnancy) and 0 (failure to maintain pregnancy up to 120 days). Heifer pregnancy was analyzed using a maximum *a posteriori* probit threshold model to predict BV on the underlying scale, while variance components were estimated using Method R. Age of dam and age of heifer had significant effects on heifer pregnancy; heifers from 2-year-old dams were 10% less likely to conceive and remain pregnant than heifers born from mature dams, and for every 20-day increase in heifer age, there was a corresponding 10% increase in the probability a heifer will conceive and remain pregnant. The heritability estimate for heifer pregnancy was 0.138, and the estimate of the genetic correlation between heifer pregnancy and scrotal circumference was not significantly different from zero. The authors concluded that heifer pregnancy data could be used to develop BV for heifer pregnancy.

Doyle et al. (2000) investigated the nature of additive genetic relationships between heifer pregnancy, subsequent rebreeding and stayability. Heifer pregnancy was defined as described by Evans et al. (1999), and stayability as described by Snelling et al. (1995). Subsequent rebreeding was defined as the observation of a 2-year-old conceiving and remaining pregnant to palpation, given pregnancy as a yearling and exposure during the breeding season, and was coded as 1 (rebred animals) and 0 (non-pregnant females). All traits were analyzed using a maximum *a posteriori* probit threshold model to predict genetic merit on the underlying scale, while Method R was used to estimate variance components. The average heritability estimates for heifer pregnancy, subsequent rebreeding and stayability were 0.21, 0.19 and 0.15, respectively. The authors noted that, for the trait of subsequent rebreeding, only 87 of the 162 sub-samples produced point estimates within the parameter space, which they attributed in part to the small number of observations available, and the 50% repeated sub-sampling procedure of Method R. Three additive genetic groups formed on heifer pregnancy estimated BV (low, intermediate and high) were used in the analysis of stayability. The authors found differences between these groups, providing evidence for the existence of a nonlinear relationship between heifer pregnancy and stayability. The authors concluded that the difference found between the middle and high heifer pregnancy genetic groups suggested higher heifer fertility appeared favorably related to higher sustained fertility. In conclusion, the authors noted that heifer pregnancy and stayability were heritable and should respond favorably to selection, however subsequent rebreeding did not appear to be heritable. It should be noted, however, that variance components were estimated using Method R, which is not recommended for use with small data sets, as in this study. Thus, no conclusions regarding heritability of the traits can be made, and further research in this area is necessary

Other measures

Calving rate is an alternative measure of reproductive performance that has received attention by researchers. Ponzoni (1992) compared the merits of calving rate and calving day in the context of a comprehensive breeding objective. Calving day in this study was analogous to calving date, and calving rate was defined as the number of calves born per cow present in the herd. In this study, reproductive rate made the greatest contribution to genetic gain in economic units, regardless of which of the 2 traits was in the breeding objective. Genetic gain in reproductive rate and total gain in economic units were greater when calving rate was included in the breeding objective. This result was attributed to the greater phenotypic variance of calving rate under the economic and genetic assumptions made in this study. However, Ponzoni (1992) concluded that from a genetic point of view, the difference between using calving rate or calving day would be small, compared with the effect of completely ignoring reproduction.

While from a genetic point of view, calving rate, as defined by Ponzoni (1992), may be superior to calving date, from a production perspective, calving rate and calving success have some of the same deficiencies as calving interval. Both measures are historic, and do not indicate when cows calve in the calving season. Calving rate as defined by Meyer et al. (1990), can only be used after a number of calvings have taken place, and, thus, can't be used directly on heifers as a measure of future production.

Another potential trait for selection is pregnancy rate, as it has been shown that pregnancy rate measured in the first parity is the same trait as lifetime pregnancy rate. Morris and Cullen (1994) estimated genetic correlations between pubertal traits of males or females and lifetime pregnancy rate. Yearling pregnancy rate was considered normal, and coded as 1 (success) and 0 (failure). Lifetime pregnancy rate was calculated as the number of pregnancies divided by number of mating years, up to the fifth mating year. Heritability estimates for yearling and lifetime pregnancy rate and calving date were 0.04, 0.04 and 0.04, respectively. The phenotypic and genetic correlations between yearling and lifetime pregnancy rate were 0.84 and 0.92, respectively, indicating that they are the same trait. Genetic correlations of standardized age at first estrus with yearling or lifetime pregnancy rate were all negative and, hence, desirable in direction. For scrotal circumference, genetic correlation estimates with yearling and lifetime pregnancy rate were 0.53 and 0.34, respectively. From this study it appears that pubertal traits are favorably correlated with lifetime pregnancy rate.

Morris et al. (2000) estimated genetic parameters for age at first estrus, calving date and pregnancy rates using experimental data. Heritabilities for standardized age at first estrus and calving date were 0.27 and 0.09, respectively. Genetic correlations of standardized age at first estrus with calving date and pregnancy rate were 0.57 and –0.36, respectively. The pregnancy rate for the line selected for reduced age at puberty was 5% higher than the line selected for increased age at puberty, and the mean calving date was 3 days earlier. Thus, the authors concluded that selecting for reduced age at puberty leads to earlier calving dates and higher pregnancy rates in beef females.

Researchers have also attempted to identify physiological parameters, such as endocrine factors, that are related to fertility, and are heritable. Mialon et al. (2000) found a favorable genetic correlation between age at puberty and postpartum intervals in experimental data. The length of postpartum anoestrus was estimated based on weekly blood progesterone assays and on twice daily detection of estrus behavior. Estimates of heritability and repeatability for the interval from calving to first observed estrus were 0.12 and 0.38, respectively. Corresponding values for the interval from calving to the first positive progesterone test were 0.35 and 0.60, respectively. The genetic and phenotypic correlations between the two measures of postpartum interval were 0.98 and 0.65, respectively. The genetic relationships between postpartum intervals and body weight and body condition score at time of calving were negative; cows that were genetically heavier at calving with more body reserves had shorter postpartum intervals. A favorable positive genetic correlation between age at puberty and postpartum intervals was found, in that heifers which were younger at puberty also had shorter postpartum intervals. While the favorable relationships of the postpartum intervals with weight at calving and age at puberty may benefit beef producers, it is unlikely that direct selection on either trait will be possible, due to the difficulty in measuring both traits outside of experimental populations.

Age at first calving has also been studied as a potential measure of reproductive performance. A reduced age at first calving would increase the number of calves born in the herd. An advantage of this measure is that it can be computed without the need for additional data, as the birth date of the cow and her first calving are generally known. The biggest disadvantages are that it only represents one component in the reproductive life of a cow, and that it is only recorded in heifers. Furthermore, in a variable seasonal environment, age at first calving reflects management decisions to a greater extent than genetic merit. Bourdon and Brinks (1982) reported a low heritability estimate (0.07) for age at first calving, and favorable correlations with growth traits.

CONCLUSIONS AND IMPLICATIONS TO GENETIC IMPROVEMENT OF BEEF CATTLE

Reproduction is a complex trait, and, hence, there are many different measures of reproductive performance. Some of the more popular alternative measures include age at first estrus, age at first breeding, calving rate and pregnancy rate. While many researchers have identified these measures to be heritable, they are not widely used for several reasons. Some measures are historic, and fail to provide an indication of when cows calve in the calving season (calving and pregnancy rates), while others are heavily influenced by management (age at first calving). Other measurements cannot be measured feasibly in field data (postpartum intervals).

The traits of calving date and days to calving have been identified as suitable measures of reproductive performance. They are heritable traits, and allow producers to distinguish between early and late calvers in their herds. However, past studies have generally used records from the first and second parities. Thus further research to ascertain whether these results can be extrapolated for the entire reproductive life of the female is needed. As well, the method of prediction of records for open cows needs further refinement. The alternative approach of using survival analysis should be investigated in the future.

The trait of heifer pregnancy is currently used in genetic evaluation. However, it fails to identify when an individual will calve in the calving season, thus should be included along with some measure of calving date. As well, the relationship between heifer pregnancy and lifetime productivity, or stayability, has not been clearly defined. Further research to properly quantify this relationship is needed.

While several measures of reproductive performance are currently being incorporated into national genetic evaluation, further refinement is still needed. Given the nature of reproductive records, it is unlikely that one individual measure will be able to completely predict reproductive performance. Most likely several measures will need to be used together. The main limitations to genetic evaluation of fertility in the past, and currently, are the lack of records available from field data. The adoption of whole-herd reporting schemes by herds will help to alleviate this problem. In conclusion, there is much potential to make improvements to the evaluation of female reproductive performance of beef cattle in the future.

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TWINNING IN BEEF CATTLE: AN OPPORTUNITY TO IMPROVE REPRODUCTIVE AND ECONOMIC EFFICIENCY OF BEEF PRODUCTION?

K.A. Nephawe
A218 Animal Sciences, University of Nebraska,
Lincoln, NE 68583

Introduction

The possibility of improving the rate of reproduction in beef cattle by selection for an increased rate of twinning has been debated with both pessimism and optimism since the early days of animal breeding. The success of selection for multiple births in sheep lifted hopes that a similar program for cattle would also be successful. Pearl (1912) wrote, "From the standpoint of practical breeder it is slightly important that the phenomenon of multiple gestation in normally uniparous animals be carefully studied. Any definite and heritable increase in the fecundity and fertility of the domestic animals, if it can be gained without loss of other desirable qualities, is greatly to be desired. Cases of multiple gestation are the 'favorable variations', which must serve as the foundations for the creation of more fertile breeds and races."

Pearl (1912) cited three cases of extraordinary fecundity in cattle. One cow of "the black polled breed" produced a total of 25 calves in eight calvings between 1842 and 1848, another cow calved four times and produced three sets of twins and one set of triplets between 1876 and 1878, whereas another cow produced 14 calves between 1902 and 1910. Other examples of exceptional fecundity in cattle have also been documented (Wentworth, 1912; Hayden, 1922).

Beef producers, however, are commonly opposed to twin births because of the number of problems associated with the trait. These include greater incidence of calf mortality, dystocia, stillbirths, abortions, calf abandonment, and retained placenta as well as longer rebreeding intervals and occurrence of freemartin heifers. Cady and Van Vleck (1978) pointed out that the question that should be answered before attempting to increase twinning in cattle, whether through genetic selection or the administration of hormones, is whether the advantages can profitably overcome the problems associated with the trait.

Another concern was whether selection experiments for twinning would be successful in markedly altering the twinning rate in cattle because of low heritability, low repeatability and small amount of variation associated with reproductive traits and long generation intervals needed for progeny testing for a trait with low heritability. The time and money costs of increasing twinning rate would make attainment of a profitable high-incidence twinning herd a difficult undertaking (Cady and Van Vleck, 1978).

If selection experiments for multiple births in cattle were successful, what use could be made of such animals? Obviously, a beef cow can wean more total calf weight by raising twins. Reproductive performance is known to be a major determinant of profitability for beef cattle producers. Melton (1995) reported that reproductive traits are twice as important economically as production traits for commercial cow-calf producers. Gregory et al. (1997) indicated that more than 50% of the feed units used by beef cattle in the United States are needed to meet maintenance requirements of reproducing females, considerably higher than the 3% needed in meat chickens (Gregory and Dickerson, 1989). Results from experimentation (twins produced by embryo transfer) and simulation of production systems have suggested the potential of a 24% increase in efficiency of producing beef by twinning (Guerra-Martinez et al., 1990).

Because selection for twinning would appear to be difficult and time consuming, the development of a population with a high twinning frequency (≥ 40%) that is competitive in both reproductive and economic efficiency would likely be required for consideration of a twinning technology by the beef cattle industry (Gregory et al., 1997). Results from the Twinning Project at the US Meat Animal Research Center (USMARC), Clay Center, Nebraska suggest that it could be feasible to increase twinning rate in cattle to an economically viable level (Echternkamp et al., 1990; Van Vleck and Gregory, 1996; Gregory at al., 1996; Echternkamp and Gregory, 2002). In that experimental herd, the frequency of fraternal twin births has increased from 3.1% per year to an annual rate of 50 to 55% in about 20 years (Echternkamp and Gregory, 2002). Gregory et al. (1996) stated that "If twinning technology is to be implemented it will require the use of cattle from this population (USMARC Twinning herd) because they are the only known source of germplasm available with high breeding value for twinning".

The primary objective of this paper is to review reports on twinning in cattle and discuss some of the biological and management factors relevant to a twinning technology in cattle. The paper will also discuss the implications of a twinning technology to the genetic improvement of beef cattle although with the limitation that a thorough economic assessment of twinning technology in beef cattle is not yet available.

Review of Literature

The biology and diagnosis of twin pregnancy

Twins are classified as fraternal or identical twins, based on their origin, the most common being fraternal or dizygotic twins. Since fraternal twins originate from two separate ova or eggs, multiple ovulations from the same ovary or one from each ovary must therefore precede dizygotic twinning. Identical or monozygotic twins result from dividing or splitting of an embryo during early development (i.e., within 8 to 10-d after conception). Generally, about 10% of the twin births in national cattle populations are identical twins (Echternkamp and Gregory, 2002).

Kirkpatrick (2002) reported that one of the most important changes in management that should accompany efforts to exploit twinning is determination of pregnancy status with regard to single vs twin pregnancies. Cows gestating twins need to be provided with a higher plane of nutrition and increased obstetrical care before and after calving. Ovulation rate can be measured by counting the number of corpus luteum (CL) observable on the surface of the ovaries several days after ovulation. Methods for diagnosing pregnancy status include transrectal palpation of the reproductive tract or transrectal ultrasonography to visualize the reproductive tract. Although ultrasonography seems to be the most reliable method available, constraints to the application of this technology for many producers is the availability of the equipment at a justifiable cost (Kirkpatrick, 2002). Alternative approaches for determining pregnancy status include evaluation of hormone or protein levels associated with luteal, fetal or placental tissues (Dobson et al., 1993; Takahashi et al., 1997; Patel et al., 1998; Chauvin et al., 1999).

Breed differences in twinning rate

In typical beef herds, most twin births are unanticipated events occurring naturally at low frequencies (Kirkpatrick, 2002). Reviews of the genetics of twinning (Rutledge, 1975; Morris and Day, 1986) suggest that the twinning rate in beef breeds is typically less than 5%. The twinning rate in cattle that were used to initiate the Twinning Project at the USMARC in 1981, ranged from about 0.5% in British beef breeds, 1 to 2% in Continental breeds and 4% in some dairy breeds (Echternkamp and Gregory, 2002).

Genetic selection for twinning in cattle

Most of early literature reports direct one towards pessimism rather than optimism for the success of selection in markedly altering twinning rate in cattle (Rutledge, 1975). As with many other reproductive traits, heritability, repeatability and variance of the trait are low. Literature estimates of heritability for twinning in cattle are around 0.10 (Van Vleck and Gregory, 1996; Gregory et al., 1997; Karlsen et al., 2000). However, one should not immediately dismiss such a trait from being a candidate for selection. Rutledge (1975) proposed that twinning rate in cattle could be increased to an economically viable level through genetic selection when multiple observations of ovulation rate are the primary selection criterion for replacement heifers and sires (i.e., ovulation rate of daughters and female siblings). His hypothesis was soon confirmed by the results of the Twinning Project at the USMARC (Echternkamp et al., 1990; Van Vleck and Gregory, 1996; Gregory at al., 1996; Echternkamp and Gregory, 2002). The rationale for using ovulation rate is that multiple ovulations must precede twinning. Because of the high genetic correlation ($r_g > 0.75$) between ovulation and twinning rates, and because the mean of six ovulation rates is moderate to highly heritable ($h^2 = 0.35$) repeated measurement of ovulation rate is effective as an indirect selection criterion for twinning rate (Gregory et al., 1997).

Problems associated with twinning in cattle

Fetal survival

One of the problems associated with multiple fetuses in cattle is caused by the fusion of the chorionic blood vessels between the fetuses so that fetuses share a common blood supply (Echternkamp, 1992). The consequences are increased fetal mortality and the freemartin syndrome in females born with a male. If a twinning technology is implemented, theoretically nearly one half of the females born as twins will be freemartin. Freemartins exhibit development of male's primary and secondary sex characteristics. Gregory et al. (1996) reported that more than 95% of females born co-twin to a male are freemartin and, thus, sterile. Kirkpatrick (2002), however, pointed out that freemartinism is more a perceived than a real problem because the number of fertile females produced from a twinning system will differ only a little from the number from a single-birth system. Placental fusion also increases fetal mortality because if one fetus in the placenta dies, the other fetus(es) also dies (Echternkamp, 1992).

Shorter gestation length

Studies on twinning have reported that shorter gestation periods and lighter birth weights can be expected from gestations with twins rather than singles. Gestation length for twin births in cattle is approximately 5 to 7-d shorter than for cattle bearing singles (Turman et al., 1971; Bellows et al., 1974; Anderson et al., 1982, Echternkamp and Gregory, 1999a). Differences in gestation length between twin and single births likely contribute to some of the differences in calf birth weight in twin vs single pregnancies (Gregory et al., 1996).

Retained Placenta

The incidence of retention of placental membranes is increased after a twin birth (Turman et al., 1971; Bellows et al., 1974) and is also increased after a twin birth with dystocia (Echternkamp and Gregory, 2002). Echternkamp et al. (1987) reported that premature induction of parturition in cattle will also increase the incidence of placental retention for singles. Since gestation length is about a week shorter for twin, this may account for part of the increase in incidence of retained placenta with twins (Echternkamp and Gregory, 2002). Placental retention associated with malpresentation dystocia, however, is substantially greater than the effect of gestation length. Echternkamp and Gregory (2002) further indicated that retention of placental membranes reduced subsequent conception rates by 7 to 8% after either a single birth or twin births.

Dystocia

Reports on twinning have been generally consistent in identification of problems associated with twinning with one exception, that being dystocia. Kirkpatrick (2002) indicated that the inconsistency could be a reflection of two competing dynamics: "twinning reduces incidence of dystocia attributable to large calf size but increases incidence of dystocia attributable to malpresentation". The incidence of dystocia (no assistance vs assistance) is higher with twin births and differs in cause between single and twin births (Cady and Van Vleck, 1978; Gregory et al., 1996). The smaller twin calves have a lower incidence of births requiring traction but a higher incidence of malpresentations due to abnormal positioning of one or both calves in the birth canal (Echternkamp and Gregory, 2002). Dystocia reduces perinatal calf survival, especially for twins (Gregory et al., 1996; Echternkamp and Gregory, 2002). Kirkpatrick (2002), however, suggested that in the event of potential malpresentation with twin calves, the cow should be penned and the calves repositioned prior to delivery.

Increased interval from parturition to conception

A longer interval from parturition to conception in dams of twins is well documented (Turman et al., 1971; Cady and Van Vleck, 1978, Guerra-Martinez et al., 1990; Kirkpatrick, 2002). Echternkamp and Gregory (1999b) reported a 12-d longer interval from parturition to the next conception for cows after giving birth to twins as compared to cows that carried only one calf. Kirkpatrick (2002) indicated that early weaning of calves (i.e., at 6 to 8 weeks of age or younger) has been well documented to improve postpartum reproductive performance, which could also be done with cows having twins.

Effects of twinning on productivity

Twinning might be reasonable to emphasize if the economic benefits from such research, if successful, might be very great. For example, Turman et al. (1971) reported that cows producing twins weaned an additional 171 kg of calf as compared to those weaning singles. Although twinning reduced calf survival, dams producing twins at birth weaned 70.8% more calves than dams with a single birth, which resulted in a 48.1% increase (335.7 vs 226.6 kg) in total weaning weight (Echternkamp and Gregory, 2002).

Gregory at al. (1996) compared growth traits of single and twin born calves and reported than twin calves were about 20% lighter at birth and about 10% lighter at weaning. They also pointed out that twin calves were lighter at slaughter, even though they were 3-wk older than single-born calves. Single born calves also had greater ADG both before (1.08 vs 1.01 kg/d) and after weaning (1.44 vs 1.39 kg/d) compared with twins. They postulated that the greater ADG reflects both pre- and postnatal maternal effects on calf growth.

Echternkamp and Gregory (2002) compared carcass traits of single- and twin-born steers. Although twins had less carcass weight (a reflection of their lighter slaughter weight), smaller rib eye area (REA) and smaller retail product percentage (RPP), both dressing percentage and estimated kidney, heart and fat percentage (KPH) were similar for the two groups. However, marbling was increased in the older twin carcasses with 6% ($P < 0.05$) more of the twin carcasses achieving a USDA grade of Choice or above. Echternkamp and Gregory (2002) postulated that the increased marbling in twins could be a result of being fed the high-energy diet 3 wk longer and (or) from twins being less mature with less testicular growth and androgen production prior to castration. Hallford et al. (1976) indicated that carcass composition in cattle from multiple births is not deleteriously affected but that a longer time in the feedlot may be required before a desirable slaughter weight is reached.

Gregory et al. (1996) compared growth and carcass traits among single- and twin-born normal females and freemartin females. Freemartins were similar to normal females for growth traits, but freemartins had higher marbling scores and lower percentages of retail product.

Gregory et al. (1997) obtained positive but small estimates of genetic correlations in the range of 0.15 to 0.39 between growth traits (birth weight, 474-d weight, 566-d weight, and 4-yr-old weight) and both ovulation and twinning rates. Positive genetic correlations between fecundity and growth in cattle of such magnitudes tend to suggest that the beef industry would require little compromise when the selection goal is to increase twinning rate with little or no change in growth and mature size, especially in the cow herd.

Gregory et al. (1997) reported favorable estimates of genetic correlations between ovulation and twinning rates and scrotal circumference (0.29 and 0.38, respectively). The basis for their analyses was that scrotal circumference in males is genetically associated with age at puberty in heifers. Age at puberty seems to be associated with subsequent reproductive performance.

In general, twinning technology could be implemented without compromise of growth rate or carcass merit. The MARC twinning population was equal to or superior to a high performance reference population for growth and carcass traits (Gregory et al., 1996). Despite lower conception rates for dams of twins, the increased prolificacy provides an opportunity to increase total beef production with a twinning technology.

Summary and Implications

Although production of twin calves presents a potentially new paradigm for beef cattle management and production and provides an opportunity to increase both reproductive and economic efficiency, some part of the potential economic gain is compromised by negative factors associated with the trait. These disadvantages include reduced calf survival, increased incidence of dystocia (due to malpresentations) and of retained placentas and longer intervals between conceptions. Kirkpatrick (2002) pointed out that some of these problems could be overcome with changes in management, that other problems lack an obvious management fix, and that still other problems are of little practical importance. Changes in management that may facilitate successful exploitation of twin births include pregnancy status checks to determine twin vs single gestations, adequate nutrition for twin gestations, adequate calving facilities, and early weaning of calves to facilitate rebreeding of the dam. Preparturient diagnosis of twin pregnancies would facilitate management at calving time to provide for timely administration of obstetrical assistance to facilitate delivery of twin calves and to increase their neonatal survival (Echternkamp and Gregory, 1999).

In recent years, new genetic technologies such as quantitative trait loci (QTL) identification, which may have application through marker-assisted selection (MAS) in livestock improvement programs, have been developed. Since selection response for reproductive performance has been quite limited because of the long generation interval needed for progeny testing and because of low heritability, these new approaches may lead to potential genetic benefits for beef producers. If loci affecting traits related to reproductive performance can be identified, then DNA markers might be used to select genetically superior animals and, thus, improve selection response.

Kirkpatrick (2002) hypothesized that different individuals or genetic lines of cattle may have varying predisposition to carry multiple fetuses successfully to term. Successful efforts to identify specific genetic loci controlling ovulation rate (Blattman et al., 1996; Kappes et al., 2000) may facilitate introgression of specific genes into different populations to test such hypotheses. Kappes et al. (2000), for example, suggested that a region in bovine chromosome 5 contains a gene or genes which are involved in the follicular recruitment and development process and thus would affect ovulation rate. However, as only a few important QTL have thus far been identified and sequenced, such innovative approaches have not yet had an impact on animal breeding. In the future, QTL may be identified which control critical components of ovulation, conception, and embryo/fetal survival associated with twinning.

In conclusion, twinning presents a potential means of dramatically improving efficiency of beef production. A high level of intensive management, however, is required for a twinning technology in cattle to increase economic productivity. Improvements in genetics and/or management for dystocia, calf survival and rebreeding rate will be required to make a production system based on twinning economically feasible. A complete economic assessment of twinning in beef cattle has not yet been conducted which is needed to determine if the economic returns from the production of two calves per cow crop could offset the costs of labor, feed and herd health (i.e., intensive management of twin-producing dams and their calves) as well as other disadvantages associated with the trait. Although the likelihood of achieving a workable system of twinning could be low because intensive management systems for beef cattle would seem to be unpractical in much of the U.S., there are regions where farmers have abundant feed resources and would be able to devote enough of their time to calving out cows prior to spring planting.

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2001 BIF
AWARDS PRESENTATIONS
SEEDSTOCK PRODUCER HONOR ROLL OF EXCELLENCE

John Crowe	CA	1972
Dale H. Davis	MT	1972
Elliot Humphrey	AZ	1972
Jerry Moore	OH	1972
James D. Bennett	VA	1972
Harold A. Demorest	OH	1972
Marshall A. Mohler	IN	1972
Billy L. Easley	KY	1972
Messersmith Herefords	NE	1973
Robert Miller	MN	1973
James D. Hemmingsen	IA	1973
Clyde Barks	ND	1973
C. Scott Holden	MT	1973
William F. Borror	CA	1973
Raymond Meyer	SD	1973
Heathman Herefords	WA	1973
Albert West III	TX	1973
Mrs. R. W. Jones, Jr.	GA	1973
Carlton Corbin	OK	1973
Wilfred Dugan	MO	1974
Bert Sackman	ND	1974
Dover Sindelar	MT	1974
Jorgensen Brothers	SD	1974
J. David Nichols	IA	1974
Bobby Lawrence	GA	1974
Marvin Bohmont	NE	1974
Charles Descheemacker	MT	1974
Bert Crame	CA	1974
Burwell M. Bates	OK	1974
Maurice Mitchell	MN	1974
Robert Arbuthnot	KS	1975
Glenn Burrows	NM	1975
Louis Chestnut	WA	1975
George Chiga	OK	1975
Howard Collins	MO	1975
Jack Cooper	MT	1975
Joseph P. Dittmer	IA	1975
Dale Engler	KS	1975
Leslie J. Holden	MT	1975
Robert D. Keefer	MT	1975
Frank Kubik, Jr.	ND	1975
Licking Angus Ranch	NE	1975
Walter S. Markham	CA	1975
Gerhard Mittnes	KS	1976
Ancel Armstrong	VA	1976
Jackie Davis	CA	1976
Sam Friend	MO	1976
Healey Brothers	OK	1976
Stan Lund	MT	1976
Jay Pearson	ID	1976
L. Dale Porter	IA	1976
Robert Sallstrom	MN	1976

M.D. Shepherd	ND	1976
Lowellyn Tewksbury	ND	1976
Robert Brown	TX	1977
Glen Burrows	NM	1977
Henry, Jeanette Chitty	NM	1977
Tom Dashiell	WA	1977
Lloyd DeBruycker	MT	1977
Wayne Eshelman	WA	1977
Hubert R. Freise	ND	1977
Floyd Hawkins	MO	1977
Marshall A. Mohler	IN	1977
Clair Percel	KS	1977
Frank Ramackers, Jr.	NE	1977
Loren Schlipf	IL	1977
Tom & Mary Shaw	ID	1977
Bob Sitz	MT	1977
Bill Wolfe	OR	1977
James Volz	MN	1977
A. L. Frau		1978
George Becker	ND	1978
Jack Delaney	MN	1978
L. C. Chestnut	WA	1978
James D. Bennett	VA	1978
Healey Brothers	OK	1978
Frank Harpster	MO	1978
Bill Womack, Jr.	AL	1978
Larry Berg	IA	1978
Buddy Cobb	MT	1978
Bill Wolfe	OR	1978
Roy Hunt	PA	1978
Harold Anderson	SD	1977
William Borror	CA	1977
Del Krumwied	ND	1979
Jim Wolf	NE	1979
Rex & Joann James	IA	1979
Leo Schuster Family	MN	1979
Bill Wolfe	OR	1979
Jack Ragsdale	KY	1979
Floyd Mette	MO	1979
Glenn & David Gibb	IL	1979
Peg Allen	MT	1979
Frank & Jim Wilson	SD	1979
Donald Barton	UT	1980
Frank Felton	MO	1980
Frank Hay	CAN	1980
Mark Keffeler	SD	1980
Bob Laflin	KS	1980
Paul Mydland	MT	1980
Richard Tokach	ND	1980
Roy & Don Udelhoven	WI	1980
Bill Wolfe	OR	1980
John Masters	KY	1980
Floyd Dominy	VA	1980
James Bryany	MN	1980
Charlie Richards	IA	1980
Blythe Gardner	UT	1980
Richard McLaughlin	IL	1980
Bob Dickinson	KS	1981
Clarence Burch	OK	1981
Lynn Frey	ND	1981

Harold Thompson	WA	1981
James Leachman	MT	1981
J. Morgan Donelson	MO	1981
Clayton Canning	CAN	1981
Russ Denowh	MT	1981
Dwight Houff	VA	1981
G. W. Cronwell	IA	1981
Bob & Gloria Thomas	OR	1981
Roy Beeby	OK	1981
Herman Schaefer	IL	1981
Myron Aultfathr	MN	1981
Jack Ragsdale	KY	1981
W. B. Williams	IL	1982
Garold Parks	IA	1982
David A. Breiner	KS	1982
Joseph S. Bray	KY	1982
Clare Geddes	CAN	1982
Howard Krog	MN	1982
Harlin Hecht	MN	1982
William Kottwitz	MO	1982
Larry Leonhardt	MT	1982
Frankie Flint	NM	1982
Gary & Gerald Carlson	NS	1982
Bob Thomas	OR	1982
Orville Stangl	SD	1982
C. Ancel Armstrong	KS	1983
Bill Borror	CA	1983
Charles E. Boyd	KY	1983
John Bruner	SD	1983
Leness Hall	WA	1983
Ric Hoyt	OR	1983
E. A. Keithley	MO	1983
J. Earl Kindig	MO	1983
Jake Larson	ND	1983
Harvey Lemmon	GA	1983
Frank Myatt	IA	1983
Stanley Nesemeier	IL	1983
Russ Pepper	MT	1983
Robert H. Schafer	MN	1983
Alex Stauffer	WI	1983
D. John & Lebert Shultz	MO	1983
Phillip A. Abrahamson	MN	1984
Ron Beiber	SD	1984
Jerry Chappel	VA	1984
Charles W. Druin	KY	1984
Jack Farmer	CA	1984
John B. Green	LA	1984
Ric Hoyt	OR	1984
Fred H. Johnson	OH	1984
Earl Kindig	VA	1984
Glen Klippenstein	MO	1984
A. Harvey Lemmon	GA	1984
Lawrence Meyer	IL	1984
Donn & Sylvia Mitchell	CAN	1984
Lee Nichols	IA	1984
Clair K. Parcel	KS	1984
Joe C. Powell	NC	1984
Floyd Richard	ND	1984
Robert L. Sitz	MT	1984
Ric Hoyt	OR	1984

J. Newbill Miller	VA	1985
George B. Halterman	WV	1985
David McGehee	KY	1985
Glenn L. Brinkman	TX	1985
Gordon Booth	WY	1985
Earl Schafer	MN	1985
Marvin Knowles	CA	1985
Fred Killam	IL	1985
Tom Perrier	KS	1985
Don W. Schoene	MO	1985
Everett & Ron Batho	CAN	1985
Bernard F. Pedretti	WI	1985
Arnold Wienk	SD	1985
R. C. Price	AL	1985
Clifford & Bruce Betzold	IL	1986
Gerald Hoffman	SD	1986
Delton W. Hubert	KS	1986
Dick & Ellie Larson	WI	1986
Leonard Lodden	ND	1986
Ralph McDanolds	VA	1986
W.D. Morris/James Pipkin	MO	1986
Roy D. McPhee	CA	1986
Clarence VanDyke	MT	1986
John H. Wood	SC	1986
Evin & Verne Dunn	CAN	1986
Glenn L. Brinkman	TX	1986
Jack & Gini Chase	WY	1986
Henry & Jeanette Chitty	FL	1986
Lawrence H. Graham	KY	1986
A. Lloyd Grau	NM	1986
Matthew Warren Hall	AL	1986
Richard J. Putnam	NC	1986
R.J. Steward/P.C. Morrissey	PA	1986
Leonard Wulf	MN	1986
Charles & Wynder Smith	GA	1987
Lyall Edgerton	CAN	1987
Tommy Branderberger	TX	1987
Henry Gardiner	KS	1987
Gary Klein	ND	1987
Ivan & Frank Rincker	IL	1987
Larry D. Leonhardt	WY	1987
Harold E. Pate	IL	1987
Forrest Byergo	MO	1987
Clayton Canning	CAN	1987
James Bush	SD	1987
R.J. Steward/P.C. Morrissey	MN	1987
Eldon & Richard Wiese	MN	1987
Douglas D. Bennett	TX	1988
Don & Diane Guilford & David & Carol Guilford	CAN	1988
Kenneth Gillig	MO	1988
Bill Bennett	WA	1988
Hansell Pile	KY	1988
Gino Pedretti	CA	1988
Leonard Lorenzen	OR	1988
George Schlickau	KS	1988
Hans Ulrich	CAN	1988
Donn & Sylvia Mitchell	CAN	1988
Darold Bauman	WY	1988
Glynn Debter	AL	1988

William Glanz	WY	1988
Jay P. Book	IL	1988
David Luhman	MN	1988
Scott Burtner	VA	1988
Robert E. Walton	WA	1988
Harry Airey	CAN	1989
Ed Albaugh	CA	1989
Jack & Nancy Baker	MO	1989
Ron Bowman	ND	1989
Jerry Allen Burner	VA	1989
Glynn Debter	AL	1989
Sherm & Charlie Ewing	CAN	1989
Donald Fawcett	SD	1989
Orrin Hart	CAN	1989
Leonard A. Lorenzen	OR	1989
Kenneth D. Lowe	KY	1989
Tom Mercer	WY	1989
Lynn Pelton	KS	1989
Lester H. Schafer	MN	1989
Bob R. Whitmire	GA	1989
Dr. Burleigh Anderson	PA	1990
Boyd Broyles	KY	1990
Larry Earhart	WY	1990
Steven Forrester	MI	1990
Doug Fraser	CAN	1990
Gerhard Gueggenberger	CA	1990
Douglas & Molly Hoff	SD	1990
Richard Janssen	KS	1990
Paul E. Keffaber	IN	1990
John & Chris Oltman	WI	1990
John Ragsdale	KY	1990
Otto & Otis Rincker	IL	1990
Charles & Rudy Simpson	CAN	1990
T.D. & Roger Steele	VA	1990
Bob Thomas Family	OR	1990
Ann Upchurch	AL	1991
N. Wehrmann/R. McClung	VA	1991
John Bruner	SD	1991
Ralph Bridges	GA	1991
Dave & Carol Guilford	CAN	1991
Richard/Sharon Beitelspacher	SD	1991
Tom Sonderup	NE	1991
Steve & Bill Florshcuetz	IL	1991
R. A. Brown	TX	1991
Jim Taylor	KS	1991
R.M. Felts & Son Farm	TN	1991
Jack Cowley	CA	1991
Rob & Gloria Thomas	OR	1991
James Burns & Sons	WI	1991
Jack & Gini Chase	WY	1991
Summitcrest Farms	OH	1991
Larry Wakefield	MN	1991
James R. O'Neill	IA	1991
Francis & Karol Bormann	IA	1992
Glenn Brinkman	TX	1992
Bob Buchanan Family	OR	1992
Tom & Ruth Clark	VA	1992
A. W. Compton, Jr.	AL	1992
Harold Dickson	MO	1992
Tom Drake	OK	1992

Robert Elliott & Sons	TN	1992
Dennis, David, Danny Geffert	WI	1992
Eugene B. Hook	MN	1992
Dick Montague	CA	1992
Bill Rea	PA	1992
Calvin & Gary Sandmeier	SD	1992
Leonard Wulf & Sons	MN	1992
R. A. Brown	TX	1993
Norman Bruce	IL	1993
Wes & Fran Cook	NC	1993
Clarence/Elaine/Adam Dean	SC	1993
D. Eldridge & Y. Adcock	OK	1993
Joseph Freund	CO	1993
R. B. Jarrell	TN	1993
Rueben, Leroy, Bob Littau	SD	1993
J. Newbill Miller	VA	1993
J. David Nichols	IA	1993
Miles P. "Buck" Pangburn	IA	1993
Lynn Pelton	KS	1993
Ted Seely	WY	1993
Collin Sander	SD	1993
Harrell Watts	AL	1993
Bob Zarn	MN	1993
Ken & Bonnie Bieber	SD	1994
John Blankers	MN	1994
Jere Caldwell	KY	1994
Mary Howe di'Zerega	VA	1994
Ron & Wayne Hanson	CAN	1994
Bobby F. Hayes	AL	1994
Buell Jackson	IA	1994
Richard Janssen	KS	1994
Bruce Orvis	CA	1994
John Pfeiffer Family	OK	1994
Calvin & Gary Sandmeier	SD	1994
Dave Taylor / Gary Parker	WY	1994
Bobby Aldridge	NC	1995
Gene Bedwell	IA	1995
Gordon & Mary Ann Booth	WY	1995
Ward Burroughs	CA	1995
Chris & John Christensen	SD	1995
Mary Howe de'Zerega	VA	1995
Maurice Grogan	MN	1995
Donald J. Hargrave	CAN	1995
Howard & JoAnne Hillman	SD	1995
Mack, Billy, Tom Maples	AL	1995
Mike McDowell	VA	1995
Tom Perrier	KS	1995
John Robbins	MT	1995
Thomas Simmons	VA	1995
D. Borgen & B. McCulloh	WI	1996
Chris & John Christensen	SD	1996
Frank Felton	MO	1996
Galen & Lori Fink	KS	1996
Cam, Spike, Sally Forbes	WY	1996
Mose & Dave Hebbert	NE	1996
C. Knight & B. Jacobs	OK	1996
Robert C. Miller	MN	1996
Gerald & Lois Neher	IL	1996
C. W. Pratt	VA	1996
Frank Schiefelbein	MN	1996

Ingrid & Willy Volk	NC	1996
William A. Womack, Jr.	AL	1996
Alan Albers	KS	1997
Gregg & Diane Butman	MN	1997
Blaine & Pauline Canning	CAN	1997
Jim & JoAnn Enos	IL	1997
Harold Pate	AL	1997
E. David Pease	CAN	1997
Juan Reyes	WY	1997
James I. Smith	NC	1997
Darrel Spader	SD	1997
Bob & Gloria Thomas	OR	1997
Nicholas Wehrmann & Richard McClung	VA	1997
James D. Bennett Family	VA	1998
Dick & Bonnie Helms	NE	1998
Dallis & Tammy Basel	SD	1998
Duane L. Kruse Family	IL	1998
Abigail & Mark Nelson	CA	1998
Airey Family	MB	1998
Dave & Cindy Judd	KS	1998
Earl & Nedra McKarns	OH	1998
Tom Shaw	ID	1998
Wilbur & Melva Stewart	AB	1998
Adrian Weaver & Family	CO	1998
Kelly & Lori Darr	WY	1999
Kent Klineman & Steve Munger	SD	1999
John Kluge	VA	1999
Kramer Farms	IL	1999
Noller & Frank Charolais	IA	1999
Lynn & Gary Pelton	KS	1999
Rausch Herefords	SD	1999
Duane Schieffer & Terry O'Neill	MT	1999
Tony Walden	AL	1999
Ralph Blalock, Sr., Blalock, Jr. & David Blalock	NC	2000
Larry & Jean Croissant	CO	2000
John C. Curtin	IL	2000
Galen, Lori & Megan Fink	KS	2000
Harlin & Susan Hecht	MN	2000
Banks & Margo Herndon	AL	2000
Kent Klineman & Steve Munger	SD	2000
Jim & Janet Listen	WY	2000
Mike & T.K. McDowell	VA	2000
Vaughn Meyer & Family	SD	2000
Blane & Cindy Nagel	SD	2000
John & Betty Rotert	MO	2000
Alan & Deb Vedvei	SD	2000
Bob & Nedra Funk	OK	2001
Steve Hillman & Family	IL	2001
Tom Lovell	AL	2001
McAllen Ranch	TX	2001
Kevin, Jessica, & Emily Moore	TX	2001
Blane & Cindy Nagel	SD	2001
Don & Priscilla Nielsen	CO	2001

George W. Lemm, Marvin & Katheryn Robertson	VA	2001
Dale, Don & Mike Spencer	NE	2001
Ken Stielow & Family	KS	2001
Eddie L. Sydenstricker	MO	2001

SEEDSTOCK PRODUCER OF THE YEAR

John Crowe	CA	1972
Mrs. R. W. Jones	GA	1973
Carlton Corbin	OK	1974
Leslie J. Holden	MT	1975
Jack Cooper	MT	1975
Jorgensen Brothers	SD	1976
Glenn Burrows	NM	1977
James D. Bennett	VA	1978
Jim Wolfe	NE	1979
Bill Wolfe	OR	1980
Bob Dickinson	KS	1981
A.F. "Frankie" Flint	NM	1982
Bill Borror	CA	1983
Lee Nichols	IA	1984
Ric Hoyt	OR	1985
Leonard Lodoen	ND	1986
Henry Gardiner	KS	1987
W.T. "Bill" Bennett	WA	1988
Glynn Debter	AL	1989
Doug & Molly Hoff	SD	1990
Summitcrest Farms	OH	1991
Leonard Wulf & Sons	MN	1992
R. A. "Rob" Brown	TX	1993
J. David Nichols	IA	1993
Richard Janssen	KS	1994
Tom & Carolyn Perrier	KS	1995
Frank Felton	MO	1996
Bob & Gloria Thomas	OR	1997
Wehrmann Angus Ranch	VA	1997
Flying H Genetics	NE	1998
Knoll Crest Farms	VA	1998
Morven Farms	VA	1999
Fink Beef Genetics	KS	2000
Sydenstricker Angus Farms	MO	2001

2002 SEEDSTOCK PRODUCER AWARD NOMINEES

Circle A Ranch
Dave Gust, Sr. & Family, Missouri

The Circle A Ranch is headquartered in Iberia, Missouri with satellite operations in Stockton, and Huntsville, Missouri and Lineville, Iowa. The ranch headquarters was established 12 years ago and is home to 700 registered Angus and Red Angus females, in addition to 1,800 commercial Angus cows. Circle A's second ranch, near Huntsville, Missouri was acquired eight years ago and is home to approximately 2,000 head of commercial Angus cows and the third location at Stockton, Missouri has another 2,200 head of commercial Angus cows. The fourth ranch in Lineville, Iowa serves as the main heifer development facility for the three other ranches. Approximately 2,100 head of fall and spring replacement heifers are developed and bred at the Lineville facility before being shipped back to the respective cow/calf operation. The Lineville operation has been in the system for nearly four years. Red Angus were added to Circle A's seedstock operation to provide additional customer options. The ranches maintain both fall (September and October) and spring calving herds (December 10th - March 10th). The Dave Gust family started Circle A Ranch with two main goals: 1) Produce the best possible genetics in the beef industry, and 2) Provide service to customers in the best way possible. In their efforts to produce superior genetics, Circle A has contributed over 4,000 carcass records to AHIR from their designed progeny testing programs; established the Angus Sire Alliance; implemented economic selection indexing into their breeding program; constructed a feed efficiency research center; established a DNA repository of approximately 3,500 steer samples; produced seven clonemate families from proven sire and dam cell donors; constructed their own internet-based data collection system that ties together all of the four ranches; computed within-herd EPD's twice each year for the commercial operations; and are continually investigating new technologies that may be implemented into their breeding programs. To better service customers, Circle A has held seedstock female and bull sales for ten and eight years respectively; hosted an annual Customer Appreciation Sale; hosted four feeder-calf sales each year that highlight genetics from their customers; and employ a full-time staff member with commercial marketing responsibilities.

DeBruycker Charolais
Lloyd, Mark, Brett, Joe and Cathy DeBruycker, Montana

DeBruycker Charolais has ranched in the Choteau Montana area for 38 years. The ranch consists of approximately 56,000 acres including both owned and private leased land and is home to 1600 purebred spring and fall calving cows, a small herd of commercial cows for evaluating herd sires, approximately 5000 head of stocker calves and a feedlot with a one time capacity of 7500 head. Approximately 13000 acres that includes irrigated barley and dry-land spring wheat are harvested on an annual basis. The entire family is involved to one extent or another in the management decisions of the herd. Mark, Brett, Joe and Cathy are second generation in the Charolais and third generation farmers and ranchers. Breeding bulls and females are marketed private treaty and through auction. This year was the 18th Annual Bull Sale in which 458 Charolais bulls were sold. The DeBruycker's have been collecting performance records for economically important traits since the beginning and it has become part of the daily routine at the ranch. In the most current Charolais Sire Summary 74 bulls carry the DeBruycker prefix and 42 sires are listed with Carcass EPD, ranking number two among Charolais breeders. A small commercial herd and a customer buy-back program allows for the ranch to evaluate the performance of the DeBruycker bred bulls from the perspective of their customers. Active contributors, Lloyd, Mark, Brett, Joe and Cathy have all been directors or officers of the Montana Charolais Association while Lloyd and Mark have been national directors of the American-International Charolais Association.

Ellis Farms
Phil and Joyce Ellis, Matt and Lisa Ellis, Joe and Lauri Ellis; Illinois

Ellis Farm originated as R.H. Ellis & Sons in 1948 with the purchase of Polled Hereford females and a bull to replace a commercial cowherd that had been in existence. These cows became the nucleus of a registered venture that has continued for 52 years, in the same location since 1964, just one mile from the original Ellis homestead. Today, it is still a family-owned operation with Phil & Joyce Ellis and sons Matt and Lisa Ellis and Joe and Lauri Ellis. In addition, son-in-law Joe Seward serves as veterinarian, while daughter Cathy assists in PR. The operation includes 1300 acres of row crop corn and soybeans, 200 acres of hay and 400 acres of pasture.

Initially Ellis Farms was strictly a single breed operation. However, with the construction of a feedlot and the need to diversify during the 1980's to a more complete supply of genetics for the commercial cattleman, two additional breeds were added. The first Angus cow was purchased in 1978 and the first Salers genetics were introduced in 1983. The decision of adding Angus genetics was based on the need to supply the commercial cattlemen with outcross genetics for the large proportion of Continental bred cattle that were beginning to influence the herds in our region. Coincidentally, the entire Angus cowherd descends from a single cow, and is line bred to that cow. The decision to add Salers genetics was based on carcass data observed at the Denver Stock Show, the maternal efficiencies of the Salers breed, and the desire to utilize a three-way cross of performance cattle.

The cowherd consists of a spring calving herd of approximately 100 Polled Herefords, 60 Salers and percentage-Salers, and 20 Angus females. Ellis Farms sells 60% of their offspring as seed stock replacements or commercial bulls. The 40 % of cattle not selected for replacements are fed out and merchandised through our feed yard, typically sold on an incentive-based premium grid. With this birth to harvest data collection and merchandising method we are able to collect; birth, weaning, yearling weights frame score, scrotal measurements, ultrasound data at yearling time; and carcass data at harvest.

This is a fifth-generation cattle operation and we plan to leave it in good hands for the next generation. We are constantly on the lookout for innovative ides and technologies to further enhance the lives of our customers, cattle, and the environment.

Holly Hill Farm
Dwight Houff, Virginia

Holly Hill Farms has grown from a commercial cow herd initiated in 1953 by Dwight Houff and his family, to the recognized Angus seedstock operation that it is today. In the 1970's Holly Hill Farms consisted of a prominent Polled Hereford herd. Through early adaptation of performance testing – including participation in the VA BCIA Bull Test Program, artificial insemination, and National Sire Evaluation data, the herd built a strong reputation as a source of predictable genetics.

In 1982 the first Angus cattle were added at Holly Hill. Today, the herd consists of 130 registered Angus cows, and an additional 70 commercial cows that are maintained as embryo recipients. Both fall and spring calving seasons are utilized. Although the breeds have changed over the years, the focus of the breeding program at Holly Hill remains constant: designing genetics that work for their commercial customers. Holly Hill strives with intensity to analyze the tools made available by the American Angus Association and/or major bull studs, in order to select proven, high accuracy bulls meeting stringent criteria for economically important traits that will benefit the needs of their customers. Priority selection criteria for sires and their daughters include moderate birth weights, optimum milk, and accelerated growth to year of age. Holly Hill was an early adapter of ultrasound technology to make genetic improvement in carcass merit, as evidenced by the 800+ cattle measured on recent years.

Holly Hill has been a long-time supporter of the Virginia BCIA bull test program. Today, Holly Hill markets genetics through an annual bull sale held the last Monday in November. Approximately 50 bulls sell, mostly fall yearlings with a few spring yearlings. The majority of the spring bulls are marketed through a February open house and by private treaty. The bulls are developed on the farm with comprehensive performance information collected over a 100-day test. For the last six years, Holly Hill has hosted an annual female sale featuring their elite cow families and proven dams.

Isa Cattle Co., Inc.
Laurence, Annette and Laurence M. Lasater; Texas

Laurence Matthews Lasater (Laurie), his wife Annette, and son, Laurence, Jr. (Lorenzo) are the management team of Isa Cattle Co., Inc., based in San Angelo, Texas.

The family's roots go deep in the cattle industry, and this plays a paramount role in how they approach their ranching enterprise. The Lasater and the Matthews families began ranching in Texas before The Civil War. Their brand, the L Bar, was first registered in 1893 by Laurie's grandfather Ed C. Lasater. Laurie's father, Tom founded the Beefmaster breed in 1931. Laurie's' book, **The Lasater Philosophy of Cattle Raising** was first published in 1972, and has enjoyed 10 printings, in both Spanish and English.

Laurie and Annette spent 10 years ranching in Coahuila, Mexico beginning in 1964. They established the Beefmaster breed there, and it is now Mexico's largest breed registry. They are involved in establishing the breed in Brazil today.

The Lasaters moved to Texas in 1972, and today conduct a worldwide genetics business based on quality cattle and customer service. They run a high powered, performance operation in a hostile environment, almost exclusively on leased land. Isa Cattle Co. runs 400 Beefmaster females, 150 Charolais females and 250 sale bulls. All cows calve in a 60-day season, all heifers calve by their second birthday, and every female who fails to breed every 365 days in sold. The operation spans nine locations around Texas and the cattle are owned by three different partnerships. The family hosts an annual bull sale each October and a female sale each January.

Lyons Ranch
Jan and Frank Lyons and Family, Kansas

For the past 25 years, Lyons Ranch has been an Angus seedstock enterprise located in the Flint Hills native grassland area of East Central Kansas and headquartered near Manhattan. Our operation expanded to three locations after our daughters graduated from the College of Agriculture at Kansas State University and, together with their husbands, chose to return to ranching. Daughter Debbie, husband Duane Blythe and family ranch southwest of Manhattan near White City. Daughter Amy, husband Karl Langvardt and family ranch south of Manhattan near Alta Vista. Both daughters selected their cows from the nucleus of their 4-H herds. Today, the cows at all operations trace to the original Lyons Ranch foundation females selected in the late 1970's and early 1980's.

When we started our seedstock business we marketed all cattle by private treaty and through state and local sponsored sales such as the Kansas Beef Expo and the

Kansas Angus Futurity. We held our first production sale at the ranch in 1984 where we sold 110 females.

We believe strongly in performance testing our bulls. During the 1980's we tested them through the Kansas Bull Test at Beloit. Our bulls continued to grow in demand and, in an effort to offer all customers the same opportunity to purchase bulls, in 1989 we began testing the bulls at the ranch on 100-day feed trial, followed by an auction. In our 2002 production sale we sold 140 bulls and 50 females.

Approximately 500 registered females and commercial ET recipients are maintained at the three ranch locations. Our ET is program under the direction of Dr. Kirk Gray of Cross Country Genetics. We have partnered with cooperator herds in Kansas and Montana since 1995 to raise embryo offspring.

To provide an array of marketing options for our genetics customers, we have feeding and marketing arrangements with several feedyards and alliances. Our marketing partners include Harris Ranch, California; several Kansas feedyards; two local auction markets used for Lyons Ranch genetic influence sales; and many of the major alliances, including U.S. Premium Beef, Decatur Beef Alliance, Angus Gen-Net and Frontier Beef.

Our motto is "Your Source for Superior Genetics." Our mission is to produce predictable Angus genetics to meet the needs of our customers and to satisfy the eating quality demands of the consumer and the beef industry. Our operating principles are to maintain the highest level of integrity in all dealings and interactions with customers and data reporting.

Noller and Frank Charolais
David E. Noller, Wayne S. and Judy A. Frank; Iowa

The Noller & Frank Charolais operation is a classic example of the "American Dream" come true. David Noller's Grandfather started farming two miles west of the southeast Iowa town of Sigourney in the early 1890's.

The farm was passed down to his son Glen in 1918 and then on to his son David in 1946, after his stint in the Air Force during WW II. David fed cattle and raised hogs, and the farm grew to over 1500 acres of owned and rented land by 1969. Although David and his wife Jean had raised a son and a daughter, neither of them chose to follow those who had gone before them in the farming and livestock business.

In 1969 David had six employees and by that time had helped three young couples start farming. The Franks were one of those employees and from the beginning showed enthusiasm toward the farm and especially the livestock business.

By 1972 the Nollers and the Franks had formed a farming partnership which has grown to the present 1130 acres of Iowa land which includes approximately 900 acres of crop land and 230 acres of permanent pasture and woods. Wayne and Judy Frank presently own 470 acres of the farm and Noller owns the rest.

Although Noller had kept commercial cows since the early 50's and had added a few Charolais in the mid 60's, the Franks didn't get in until 1975. By 1983 the Noller & Frank Charolais program was started with the purchase of breeding stock from the Garst Company and Marvin Nichols. We had increased the herd to the point that 180 cows were bred for spring calves in 1999 within a 70-day breeding season. In November of 2000 we down sized the herd and will maintain a herd of around 50 head of mother cows in the foreseeable future.

In 1999 Noller and Frank were privileged to be the recipient of the American International Charolais Association "Seedstock Producer of the Year" award and in 2002 was awarded the Iowa Seedstock Producer of the Year by the Iowa Beef Breeds Council.

Rishel Angus
Bill and Barb Rishel, Nebraska

Rishel Angus is a family-owned purebred Angus operation that has been in business since 1966. Our mission is to produce superior Angus genetics based on economically important traits that provide profit for the customers, create value for all segments of the beef industry, and ensure a satisfying eating experience for the consumer.

We were one of the very first breeders of Angus cattle to make a substantial commitment to identifying and improving carcass merit. Our belief then and now is that the real focus of Rishel Angus should be the directed toward the acceptance of our end product by the consuming public. Because of these efforts, many of the leading sires for carcass merit in the Angus breed now carry the Rishel Angus, B/R prefix. Currently, 27 proven sires and 13 young sires listed in the National Angus Sire Evaluation Summary are Rishel bred bulls.

Rishel Angus has collected and used complete performance records on all cattle since the inception of the herd. These records have allowed us to not only identify many outstanding sires, but also to identify and perpetuate numerous outstanding cow families and individual cows. The Rishel Angus herd consists of 280 Angus cows and 100 Angus heifers. For the last 20 years a female sale has been held the first Saturday in November. Rishel Angus operates on a combination of deeded and leased land with wintering and calving at the headquarters located 10 miles south of North Platte, Nebraska.

Running Creek Ranch
Joseph D. Freund, Colorado

Running Creek Ranch has been in the cow-calf business for the past 31 years near Elizabeth, Colorado; the last 22 years of which as a producer of registered Limousin Seedstock. Due to their commercial ranching foundation, Running Creek Ranch genetics reflect practical, functional, cattle emphasizing reproductive efficiency. Mature cow size must be synergistic with the environment in which the cattle are expected to perform and excel.

Running Creek markets 225-250 registered, performance-tested bulls on an annual basis by private treaty. Repeat commercial clientele are the backbone of the Running Creek Program. Sale bulls will have undergone a stringent culling process at both weaning and yearling age, and lastly at the conclusion of the performance testing as coming 2-year olds.

Running Creek Ranch has grown steadily to become the largest Limousin producer with the North American Limousin Foundation. Running Creek currently has 1,600 mature cows in production, grazed over 27,000 acres of deeded and leased land.

Running Creek is heavily involved in customer assistance, with specific emphasis on management and marketing. Running Creek markets 6500-7000 fed-cattle annually through natural beef programs. Running Creek provides feeding performance and carcass data back to our commercial customers, and evaluate this data jointly to determine future genetic emphasis in an ongoing effort to improve commercial users productivity and profitability.

Running Creek Ranch's commitment to commercial cattlemen is illustrated through our cooperative efforts with Colorado State University and NALF on several research projects, studying the relationships between reproductive, calving ease, growth and carcass traits.

Shamrock Angus
Gary and Gloria Parker, Wyoming

Shamrock Angus is located 25 miles west of Laramie, right at the base of the Snowy Range Mountains. After transplanting from central Montana in 1988 we have been at our present location since 1994. We are strictly a registered Angus Seedstock producer, operating on a 3,000-acre base ranch and lease another 15,000 acres of hay and pasture ground in the Laramie high plains. Our range is dry short prairie grass at 7200 ft to high mountain grass at 8500 ft. This elevation has an extremely harsh environment for cattle and can cause high pulmonary aerial pressure (High Mountain Disease or Dropsy) due to the shortage of oxygen. This has led us into developing a 650 head mother cow unit that is environmentally adapted to this elevation and climate.

We have an 80-day calving period starting the 1st of February with the majority of our calves born in the first two cycles. We make two-year-old bulls out of the later bull calves and run all our heifers over to breeding the following spring. This allows us to raise and sell bulls for our high country commercial cattleman.

Stewart Angus
Tom Stewart, Jim Stewart, Steve Gunn, and Gilman Stewart; Indiana

Stewart Angus began in 1955 as a division of family-owned Stewart Seeds, Inc. in order to have cattle utilize the offal from the seed business that began in 1918. Beginning with the entire herd of 35 cows purchased from a reputable breeder, Stewart Angus has grown to 160 registered Angus cows with a three-month calving season, January through March, mainly to have somewhat older bulls to sell. The top-end of the heifer crop is synchronized for replacements while the bull calves are fed to maximize their gain potential to meet the requirements of performance conscious bull customers. A strict herd health program is followed with the herd being certified and accredited free of brucellosis and tuberculosis. Also, two years of Johnes testing has resulted in whole herd negative test. Performance records have been kept since 1962 beginning with the Purdue University performance program and moving to Angus Herd Improvement Records in 1973. Females are merchandised through joint production sales such as the Showcase Sale in Ohio and the Hoosier Heartland Classic. Bulls are advertised under the "Bulls 'R' Us' logo with sixty to seventy of them being merchandised annually, mostly through private treaty, but a few are tested and sold in the Indiana and Kentucky bull testing programs. Approximately 300 acres are used for rotational grazing and forage production. Stewart Angus is striving to produce registered Angus seedstock that will improve the quality and consistency of our nation's beef supply and thereby enhance the world's food resources.

Triple "M" Farm
William, Terri, and Cameron Mayfield, Alabama

Triple "M" Farms, located near Brent in Bibb County, Alabama has been in the cattle business for 25 years. The first Simmental calves born there in the fall of 1983, and today, that size has grown to 100 purebred Simmental brood cows. A 75-day calving period is strived for with calves being born from September 15th through the end of November. In the breeding program, A.I. is utilized for one service with leased performance proven clean-up bulls. Embryo transfer is also utilized to advance their Simmental genetics. Triple "M" Farms actively participates in BCIA Tests and Sales, and has in the past, produced some of the top indexing Simmental bulls in the North Alabama, Auburn, and West Central tests. Bulls are also marketed through Sunshine Bull Development Program and by private treaty. Females are marketed in Simmental consignment sales throughout the southeast. Carcass ultrasound is a vital piece of genetic information collected at Triple "M" Farms, with the bulls having been scanned for the past 4 years and the heifers for the past year. Triple "M" is also an active participant in the Total Herd Enrollment (THE) program through the American Simmental Association to collect total performance data for all cattle. Future production goals at Triple "M" Farms are to produce easy fleshing, black Simmental females with good dispositions and to continue to produce bulls with adequate growth, high maternal, and carcass values that will fit into today's marketplace.

COMMERCIAL PRODUCER HONOR ROLL OF EXCELLENCE

Chan Cooper	MT	1972
Alfred B. Cobb, Jr.	MT	1972
Lyle Eivens	IA	1972
Broadbent Brothers	KY	1972
Jess Kilgore	MT	1972
Clifford Ouse	MN	1973
Pat Wilson	FL	1973
John Glaus	SD	1973
Sig Peterson	ND	1973
Max Kiner	WA	1973
Donald Schott	MT	1973
Stephen Garst	IA	1973
J.K. Sexton	CA	1973
Elmer Maddox	OK	1973
Marshall McGregor	MO	1974
Lloyd Mygard	MD	1974
Dave Matti	MT	1974
Eldon Wiese	MN	1974
Lloyd DeBruycker	MT	1974
Gene Rambo	CA	1974
Jim Wolf	NE	1974
Henry Gardiner	KS	1974
Johnson Brothers	SD	1974
John Blankers	MN	1975
Paul Burdett	MT	1975
Oscar Burroughs	CA	1975
John R. Dahl	ND	1975
Eugene Duckworth	MO	1975
Gene Gates	KS	1975
V. A. Hills	KS	1975
Robert D. Keefer	MT	1975
Kenneth E. Leistritz	NE	1975
Ron Baker	OR	1976
Dick Boyle	ID	1976
James D. Hackworth	MO	1976
John Hilgendorf	MN	1976
Kahau Ranch	HI	1976
Milton Mallery	CA	1976
Robert Rawson	IA	1976
William A. Stegner	ND	1976
U.S. Range Exp. Station	MT	1976
John Blankers	MN	1976
Maynard Crees	KS	1977
Ray Franz	MT	1977
Forrest H. Ireland	SD	1977
John A. Jameson	IL	1977
Leo Knoblauch	MN	1977
Jack Pierce	ID	1977
Mary & Stephen Garst	IA	1977
Todd Osteross	ND	1978
Charles M. Jarecki	MT	1978
Jimmy G. McDonnal	NC	1978
Victor Arnaud	MO	1978
Ron & Malcolm McGregor	IA	1978
Otto Uhrig	NE	1978
Arnold Wyffels	MN	1978
Bert Hawkins	OR	1978
Mose Tucker	AL	1978
Dean Haddock	KS	1978
Myron Hoeckle	ND	1979
Harold & Wesley Arnold	SD	1979
Ralph Neill	IA	1979
Morris Kuschel	MN	1979

Bert Hawkins	OR	1979
Dick Coon	WA	1979
Jerry Northcutt	MO	1979
Steve McDonnell	MT	1979
Doug Vandermyde	IL	1979
Norman, Denton, & Calvin Thompson	SD	1979
Jess Kilgore	MT	1980
Robert & Lloyd Simon	IL	1980
Lee Eaton	MT	1980
Leo & Eddie Grubl	SD	1980
Roger Winn, Jr.	VA	1980
Gordon McLean	ND	1980
Ed Disterhaupt	MN	1980
Thad Snow	CAN	1980
Oren & Jerry Raburn	OR	1980
Bill Lee	KS	1980
Paul Moyer	MO	1980
G. W. Campbell	IL	1981
J. J. Feldmann	IA	1981
Henry Gardiner	KS	1981
Dan L. Weppler	MT	1981
Harvey P. Wehri	ND	1981
Dannie O'Connell	SD	1981
Wesley & Harold Arnold	SD	1981
Jim Russell & Rick Turner	MO	1981
Oren & Jerry Raburn	OR	1981
Orin Lamport	SD	1981
Leonard Wulf	MN	1981
Wm. H. Romersberger	IL	1982
Milton Krueger	MO	1982
Carl Odegard	MT	1982
Marvin & Donald Stoker	IA	1982
Sam Hands	KS	1982
Larry Campbell	KY	1982
Lloyd Atchison	CAN	1982
Earl Schmidt	MN	1982
Raymond Josephson	ND	1982
Clarence Reutter	SD	1982
Leonard Bergen	CAN	1982
Kent Brunner	KS	1983
Tom Chrystal	IA	1983
John Freitag	WI	1983
Eddie Hamilton	KY	1983
Bill Jones	MT	1983
Harry & Rick Kline	IL	1983
Charlie Kopp	OR	1983
Duwayne Olson	SD	1983
Ralph Pederson	SD	1983
Ernest & Helen Schaller	MO	1983
Al Smith	VA	1983
John Spencer	CA	1983
Bud Wishard	MN	1983
Bob & Sharon Beck	OR	1984
Leonard Fawcett	SD	1984
Fred & Lee Kummerfeld	WY	1984
Norman Coyner & Sons	VA	1984
Franklyn Esser	MO	1984
Edgar Lewis	MT	1984
Boyd Mahrt	CA	1984
Neil Moffat	CAN	1984
William H. Moss, Jr.	GA	1984
Dennis P. Solvie	MN	1984
Robert P. Stewart	KS	1984
Charlie Stokes	NC	1984
Milton Wendland	AL	1985
Bob & Sheri Schmidt	MN	1985
Delmer & Joyce Nelson	IL	1985

Harley Brockel	SD	1985
Kent Brunner	KS	1985
Glenn Harvery	OR	1985
John Maino	CA	1985
Ernie Reeves	VA	1985
John R. Rouse	WY	1985
George & Thelma Boucher	CAN	1985
Kenneth Bentz	OR	1986
Gary Johnson	KS	1986
Ralph G. Lovelady	AL	1986
Ramon H. Oliver	KY	1986
Kay Richardson	FL	1986
Mr. & Mrs. Clyde Watts	NC	1986
David & Bev Lischka	CAN	1986
Dennis & Nancy Daly	WY	1986
Carl & Fran Dobitz	SD	1986
Charles Fariss	VA	1986
David J. Forster	CA	1986
Danny Geersen	SD	1986
Oscar Bradford	AL	1987
R. J. Mawer	CAN	1987
Rodney G. Oliphant	KS	1987
David A. Reed	OR	1987
Jerry Adamson	NE	1987
Gene Adams	GA	1987
Hugh & Pauline Maize	SD	1987
P. T. McIntire & Sons	VA	1987
Frank Disterhaupt	MN	1987
Mac, Don & Joe Griffith	GA	1988
Jerry Adamson	NE	1988
Ken/Wayne/Bruce Gardiner	CAN	1988
C. L. Cook	MO	1988
C. J. & D. A. McGee	IL	1988
William E. White	KY	1988
Frederick M. Mallory	CA	1988
Stevenson Family	OR	1988
Gary Johnson	KS	1988
John McDaniel	AL	1988
William A. Stegner	ND	1988
Lee Eaton	MT	1988
Larry D. Cundall	WY	1988
Dick & Phyllis Henze	MN	1988
Jerry Adamson	NE	1989
J. W. Aylor	VA	1989
Jerry Bailey	ND	1989
James G. Guyton	WY	1989
Kent Koostra	KY	1989
Ralph G. Lovelady	AL	1989
Thomas McAvoy, Jr.	GA	1989
Bill Salton	IA	1989
Lauren & Mel Schuman	CA	1989
Jim Tesher	ND	1989
Joe Thielen	KS	1989
Eugene & Ylene Williams	MO	1989
Phillip, Patty & Greg Bartz	MO	1990
John J. Chrisman	WY	1990
Les Herbst	KY	1990
Jon C. Ferguson	KS	1990
Mike & Diana Hooper	OR	1990
James & Joan McKinlay	CAN	1990
Gilbert Meyer	SD	1990
DuWayne Olson	SD	1990
Raymond R. Peugh	IL	1990
Lewis T. Pratt	VA	1990
Ken & Wendy Sweetland	CAN	1990
Swen R. Swenson Cattle	TX	1990
Robert A. Nixon & Son	VA	1991
Murray A. Greaves	CAN	1991

James Hauff	ND	1991
J. R. Anderson	WI	1991
Ed & Rich Blair	SD	1991
Reuben & Connee Quinn	SD	1991
Dave & Sandy Umbarger	OR	1991
James A. Theeck	TX	1991
Ken Stielow	KS	1991
John E. Hanson, Jr.	CA	1991
Charles & Clyde Henderson	MO	1991
Russ Green	WY	1991
Bollman Farms	IL	1991
Craig Utesch	IA	1991
Mark Barenthsen	ND	1991
Rary Boyd	AL	1992
Charles Daniel	MO	1992
Jed Dillard	FL	1992
John & Ingrid Fairhead	NE	1992
Dale J. Fischer	IA	1992
E. Allen Grimes Family	ND	1992
Kopp Family	OR	1992
Harold/Barbara/Jeff Marshall	PA	1992
Clinton E. Martin & Sons	VA	1992
Lloyd & Pat Mitchell	CAN	1992
William Van Tassel	CAN	1992
James A. Theeck	TX	1992
Aquilla M. Ward	WV	1992
Albert Wiggins	KS	1992
Ron Wiltshire	CAN	1992
Andy Bailey	WY	1993
Leroy Beitelspacher	SD	1993
Glenn Calbaugh	WY	1993
Oscho Deal	NC	1993
Jed Dillard	FL	1993
Art Farley	IL	1993
Jon Ferguson	KS	1993
Walter Hunsuker	CA	1993
Nola & Steve Kleiboeker	MO	1993
Jim Maier	SD	1993
Bill & Jim Martin	WV	1993
Ian & Alan McKillop	ON	1993
George & Robert Pingetzer	WY	1993
Timothy D. Sutphin	VA	1993
James A. Theeck	TX	1993
Gene Thiry	MB	1993
Fran & Beth Dobitz	SD	1994
Bruce Hall	SD	1994
Lamar Ivey	AL	1994
Gordon Mau	IA	1994
Randy Mills	KS	1994
W. W. Oliver	VA	1994
Clint Reed	WY	1994
Stan Sears	CA	1994
Walter Carlee	AL	1995
Nicholas Lee Carter	KY	1995
Charles C. Clark, Jr.	VA	1995
Greg & Mary Cunningham	WY	1995
Robert & Cindy Hine	SD	1995
Walter Jr. & Evidean Major	KY	1995
Delhert Ohnemus	IA	1995
Olafson Brothers	ND	1995
Henry Stone	CA	1995
Joe Thielen	KS	1995
Jack Turnell	WY	1995
Tom Woodard	TX	1995
Jerry & Linda Bailey	ND	1996
Kory M. Bierle	SD	1996
Mavis Dummermuth	IA	1996
Terry Stuart Forst	OK	1996

Don W. Freeman	AL	1996
Lois & Frank Herbst	WY	1996
M/M George A. Horkan, Jr.	VA	1996
David Howard	IL	1996
Virgil & Mary Jo Huseman	KS	1996
Q. S. Leonard	NC	1996
Ken & Rosemary Mitchell	CAN	1996
James Sr/Jerry/James Petik	SD	1996
Ken Risler	WI	1996
Merlin Anderson	KS	1997
Joe C. Bailey	ND	1997
William R. "Bill" Brockett	VA	1997
Arnie Hansen	MT	1997
Howard McAdams, Sr & Howard McAdams, Jr.	NC	1997
Rob Orchard	WY	1997
Bill Peters	CA	1997
David Petty	IA	1997
Rosemary Rounds & Marc & Pam Scarborough	SD	1997
Morey & Pat Van Hoecke	MN	1997
Randy & Judy Mills	KS	1998
Mike & Priscilla Kasten	MO	1998
Amana Farms Inc.	IA	1998
Terry & Dianne Crisp	AB	1998
Jim & Carol Faulstich	SD	1998
James Gordon Fitzhugh	WY	1998
John B. Mitchell	VA	1998
Holzapfel Family	CA	1998
Mike Kitley	IL	1998
Wallace & Donald Schilke	ND	1998
Doug & Ann Deane and Patricia R. Spearman	CO	1998
Glenn Baumann	ND	1999
Bill Boston	IL	1999
C-J-R Christensen Ranches	WY	1999
Ken Fear, Jr.	WY	1999
Giles Family	KS	1999
Burt Guerrieri	CO	1999
Karlen Family	SD	1999
Deseret Ranches of Alberta	CAN	1999
Nick & Mary Klintworth	NE	1999
MW Hereford Ranch	NE	1999
Mossy Creek Farm	VA	1999
Iris, Bill & Linda Lipscomb	AL	1999
Amana Farms, Inc.	IA	2000
Tony Boothe	AL	2000
Glenn Clabaugh	WY	2000
Connie, John & Terri Griffith	KS	2000
Frank B. Labato	CO	2000
Roger & Sharon Lamont & Doug & Shawn Lamont	SD	2000
Bill & Claudia Tucker	VA	2000
Wayne & Chip Unsicker	IL	2000
Billy H. Bolding	AL	2001
Mike & Tom Endress	IL	2001
Henry & Hank Maxey	VA	2001
Paul McKie	KS	2001

COMMERCIAL PRODUCER OF THE YEAR

Chan Cooper	MT	1972
Pat Wilson	FL	1973
Lloyd Nygard	ND	1974
Gene Gates	KS	1975
Ron Blake	OR	1976
Steve & Mary Garst	IA	1977
Mose Tucker	AL	1978
Bert Hawkins	OR	1979
Jess Kilgore	MT	1980
Henry Gardiner	KS	1981
Sam Hands	KS	1982
Al Smith	VA	1983
Bob & Sharon Beck	OR	1984
Glenn Harvey	OR	1985
Charles Fariss	VA	1986
Rodney G. Oliphant	KS	1987
Gary Johnson	KS	1988
Jerry Adamson	NE	1989
Mike & Diana Hopper	OR	1990
Dave & Sandy Umbarger	OR	1991
Kopp Family	OR	1992
Jon Ferguson	KS	1993
Fran & Beth Dobitz	SD	1994
Joe & Susan Thielen	KS	1995
Virgil & Mary Jo Huseman	KS	1996
Merlin & Bonnie Anderson	KS	1997
Randy & Judy Mills	KS	1998
Mike & Priscilla Kasten	MO	1998
Giles Ranch	KS	1999
Mossy Creek Farm	VA	1999
Bill Tucker	VA	2000
Maxey Farms	TX	2001

2002 COMMERCIAL PRODUCER AWARD NOMINEES

3R Ranch
Reeves and Betsy Brown, Colorado

Our operation is rooted in generations of pride and passion for the lifestyle and challenges of the livestock business. Progressive family attitudes toward research and natural resource management, coupled with studies in Animal Science and Ag Business at Texas Tech University helped steer us to this point of achievement. Observation of our family's registered and commercial Hereford operation during the 1940's and 1950's, seeing them remain dedicated to the principles of economic return rather than to follow popular fashion in selecting herd genetics; along with another father successful in the feedlot business, were valuable examples in establishing our rules and priorities for success in the cattle business. Our present operation is located on 10,000 plus acres in western Pueblo County, Colorado in the foothills of the Wet Mountain Range of the Rocky Mountains. We moved hear in 1981 from our first ranch operation in Central Texas. The 3R Ranch elevation varies from 5,700 feet to 7,800 feet, is roughly 60% prairie and 40% timber, supports a combination of short, medium and tall grasses, averages 15.2 inches of rainfall and 100 inches of snow annually. We own an excellent irrigation water right of 26.2 second feet which will irrigate up to 1,300 acres depending upon the amount of snow pack. Our bred females number between 650 and 700 head, calve from April 20th to June 5th after a 45-day natural breeding season. We also raise between 100 and 125 replacement heifers annually. We are integrated through the packer level with membership in US Premium Beef Cooperative. We adhere to Beef Quality Assurance principles, practice individual identification on all animals and strive to make carcass quality and yield, along with consumer preference, our production and marketing guide. We are presently attempting to place a conservation easement on the ranch to preserve its productivity, integrity and natural beauty in order to allow future generations of ranchers to have the opportunity to experience the joy and satisfaction of the lifestyle offered here.

Agri-Services Division
Oklahoma Department of Correction, Dick Davis, Manager, Oklahoma

The Division operates 10 agriculture units, in all regions of the state, ranging in size from 1500 acres to 6800 for a total of 26,000 acres. Some of the units are as young as 15 years old and as old as 93; beef production has been the top priority since 1909. The Division has grown to a total herd size of 2,800 head with 2,000 head of breeding age females and two registered herds, one Beefmaster and one Gelbvieh, used to produce the bulls needed to cover the commercial cows.

The breeding system is a very simple two-breed rotation. Beefmaster-sired females kept as replacement heifers are bred to Gelbvieh bulls and Gelbvieh-sired females are bred to Beefmaster bulls. Backing up this breeding program is an extensive set of breeding records on the commercial cows. A 90-day breeding season is still maintained; no A.I. is used on the commercial herds and the pastures are rough and large. The system is critical of the type of female that remains in the herd. The two most critical areas for culling are not weaning enough pounds of beef and extending her length of breeding cycle three consecutive years. Either of these will cost a female her place in the herd.

With the help of the Oklahoma State University, USDA and the Oklahoma Department of Agriculture, a sample of steers (ten from each unit, five Beefmaster and five Gelbvieh sired) is tested each year for forage gain, feed conversion and carcass quality to include tenderness. The number of animals tested each time is not large enough to have a significant bearing on the industry, but results give us direction in achieving our production and efficiency goals.

Alpine Farms
Walter Nelson, Virginia

Alpine Farms is located along the James River in Botetourt and Rockbridge Counties in the southern Shenandoah Valley of Virginia. Walter Nelson and one full-time employee operate this beautiful farm of 600 acres of open ground that varies from river bottom to mountain pasture. The farm currently sustains 210 cow-calf pairs in addition to replacement heifers, bulls being developed for sale, stockers, and 275 ewes. Walter managed the farm from 1983-87 and then took the opportunity to purchase the cattle and continue to farm the land. The Angus based spring calving herd utilizes controlled grazing and strives to be a low input cost herd. Alpine Farms' cattle have been cooperator herd for both university research and an AI stud and uses estrous synchronization for AI and ET programs. Like many farm families, Walter works full time on the farm while his wife works off of the farm. She and the children contribute to labor and decision-making and keep a full schedule including 4-H projects.

Amana Farms, Inc.
John McGrath, Manager; Iowa

The ancestors of the Amana people first came to the United States in 1842, settling near Buffalo, New York. The group soon sought land further west, and in 1855 established the Amana Colonies in eastern Iowa. By 1865, seven villages were established on nearly 26,000 acres.

On arrival in America, the group adopted a religious communal way of life. In 1932, the people voted to end the communal way of life. They created Amana Church

Society to direct matters of their faith, and the Amana Society, Inc. to oversee their business and farming operations.

The Amana Farms Beef Division is just one of the divisions of the Amana Society, Inc. A herd of 2,200 Gelbvieh/Angus crossbred cows that are bred to Charolais bulls is maintained on the farms 6,000 acres of pasture. The Beef Division Manager is responsible for developing an annual budget as well as monthly forecasts predicting financial success of the business.

Producing replacement heifers and feeder cattle and developing bred heifers is the focus of the four herd supervisors. Sixty percent of the cows calve in April and May. The remaining 40% calve in August and September.

The operation also has a 3,000 head feedyard that it is uses to finish its calves, develop its breeding heifers and custom feed cattle. The Amana Society also markets beef under its own brand name in Midwestern grocery stores.

Griffith Seedstock
John and Terry Griffith, Connie Griffith; Kansas

Our family has been raising beef cattle here in northwest Kansas since 1878. Located in an area averaging 22" of moisture per year, our land is now split almost evenly between dryland cultivation and native range. Our cow-calf herd dovetails with our farming operation, allowing us to more efficiently utilize land, labor, and machinery.

We annually calve about 250 Angus and high percentage Red Angus cows, with heifers calving in 30 days starting in early February, and the cows in 45-50 days starting in March. We sell enough pairs in April to summer the balance on about 2,000 acres of native grass. After weaning in early September, cows are wintered on stockpiled grass and crop residue until calving. They receive prairie hay, sorghum hay, and alfalfa until green-up.

Steers are backgrounded at home, then fed to finish at a commercial feedlot and sold in the meat on a quality grid. Replacement heifers are wintered on grass and stalks with a minimum supplement of a high-fiber pellet. We sell about 30 registered bulls after developing them on grass, stalks, cane hay, and the same high-fiber pellet.

We make extensive use of A.I. on both heifers and cows, and raise all our own replacement females.

Our goal is to develop a self-sustaining herd of efficient, well-adapted cows producing desirable end products, whether replacement seedstock or quality carcasses. We believe that kind of cattle will optimize our profitability.

Indian Knoll Cattle Co.
Kevin and Penny Bliler, Illinois

Indian Knoll Cattle Co. is a family owned and operated cow/calf operation located in central Illinois, in the heart of corn and soybean country. Kevin is a third generation beef seedstock producer.

Expansion of the cattle enterprises began in 1996, and the purebred herd of 80 Hereford cows served as the foundation seedstock for the commercial heifer development program that has become the focus of the operation. High quality red and black Angus bulls were used to produce outstanding replacement heifers that have been retained within the herd. In addition to the commercial herd, a purebred herd of Red Angus is maintained. Currently, Indian Knoll Cattle Co. maintains 225 females.

Since 1996 carcass data and feed efficiency has been recorded and tracked on steers through retained ownership and cooperation with feedlots. Indian Knoll genetics have proven to consistently produce very high quality carcasses. However, the focus of the herd continues to target the commercial female market, of which there is a tremendous demand for in Illinois.

Two thirds of the cows calve March/April and one third calve September/October. To meet the expanding pasture and forage needs, the Bliler's have been seeding marginal cropland to pastureland. As operation continues to expand, winter annuals are being utilized in crop residue to lengthen the grazing season and reduce winter feed costs.

In addition to the cattle operation, Kevin and his brother Mike farm 2000 acres in row crops.

Miles Land & Livestock Co.
Jim & Peggy Price, Wyoming

Miles Land & Livestock Co., located 25 southwest of Casper in central Wyoming is a fourth generation family owned and operated business. Peggy's grandfather homesteaded in the area in the early 1900's starting with 160 acres of land. He first raised horses, then later cattle and sheep. This was the start of the present day Miles Land and Livestock Co. The ranch is a diversified operation with a 2,150 head commercial herd of Limousin/ Charolais cross cattle and a 3,500 head feedlot that offers us feeding and marketing options. We also farm around 1,100 acres of irrigated land to provide corn for silage, oats and alfalfa hay for the confined feedlot and to supplement the cowherd through the winter months. We feed our own cattle, and custom feed for others. We also offer a "Heifer back grounding and A.I. service" that has been successful for a growing number of customers. The cows are wintered along the North Platte River, range calved in March, and then trailed 35 miles to summer pasture. The calves are weaned in September and brought to the feedlot. We retain approximately 20% of our heifers for replacements. The remaining calves are marketed to programs wanting an all-natural product. The ranch consists of approximately 21,027 acres of Deeded lands, 5,753 acres of BLM and 12,027 acres of State land. The ranch headquarters, feedlot, irrigated croplands and winter pasture are located in the Alcova area. The cropland portion of the ranch borders approximately eight miles of the North Platte River. The summer pastures are located 35 miles east of the main ranch on the headwater of the Bates Creek drainage with approximately nine miles of creeks flowing though it. This spring we will implement an intensive grazing program on one of the center pivot irrigation systems. We plan to run 400 pairs under this 190-acre sprinkler from mid May through September. We are continually striving to implement new innovative programs into our operation. It is the dedication and hard work of our family that accounts for the success of this ranching operation.

Shovel Dot Ranch
Larry and Nickie Buell, Homer and Darla Buell, Nebraska

Shovel Dot Ranch is located in North Central Nebraska on the eastern edge of the Sandhills. It was established in 1883 by Benjamin Franklin Buell and presently has the 5th generation, Larry's daughter and son-in-law and Homer's son and daughter-in-law, working on the ranch. We operate 28,000 acres with 25,000 acres owned and 3000 acres leased. Of those, about 2000 are sub-irrigated meadow, 240 acres are under center pivot in alfalfa, and the rest is native unimproved grazing land. We have a commercial cow calf herd, a backgrounding operation, and run stockers on grass. Our cows, which are Hereford, Angus or crosses thereof, whose numbers can vary from year to year but are presently 1,423 head, begin calving in late April with our heifers starting a few weeks earlier. Charolais bulls are used as a terminal cross on some of the cows. The calves are weaned in late September and early October, graze on sub-irrigated meadow regrowth until November then are moved to our backgrounding lots for the winter. In early May calves go to grass and are marketed through the Bassett Livestock Auction in late June, July, and August when the prices for yearling are traditionally the highest. During the fall we buy steers, some are marketed when they weigh 850 pounds and some are finished in a commercial lot. The cows are grazed most of the year and fed hay and supplement in the winter when the snow is deep or the grazing runs short.

Torbert Farms, Ltd.
C.C. "Bo" Torbert, Alabama

Torbert Farms is a diversified farming operation located 8 1/2 miles south of Opelika, Alabama in the Beauregard Community. The original farm was some of the first homesteaded land in eastern Alabama by Torbert ancestors. Today, the farm consists of 6,000 acres supporting cattle, timber, cotton and wildlife game hunting. The cow/calf operation consists of 233 Angus based cows, an embryo transfer recipient cow program for local purebred herds and a heifer development and steer backgrounding station for local commercial herds. Cows are divided into three breeding groups per year: recipient cows, AI and natural service. Quality Angus or Simmental bulls purchased from Alabama BCIA members are used as natural service and clean-up sires. Calves are born from late October through January each year with the ET calves being born first. The percentage of the herd utilized in the ET and AI programs is dependent on the number of ET calves desired by local purebred producers. Replacement heifers for this herd are primarily selected from AI born calves. In addition, Torbert Farms annually develops 200 to 250 replacement heifers for the Piedmont BCIA Heifer Program and other commercial producers utilizing byproduct feeds and winter grazing. Heifers are sold through Alabama BCIA Heifer sales, private treaty or retained in the herd. After weaning, steers are backgrounded and then marketed through the Piedmont Marketing Association Board Sale each August. Steers from other producers are also backgrounded at Torbert Farms for the Board Sale, which generally markets 1200 to 1500 feeder cattle each year. Complete performance and financial information is analyzed on this herd yearly to assist in selection and culling decisions. All cattle are raised under strict beef quality assurance and herd health standards to ensure a safe consistent product.

White Farms
Craig and Margaret White, Iowa

White Farms is a 1,125-acre cattle and crops operation near Estherville, Iowa. Craig and Margaret White started farming with Craig's father in 1969 and purchased the farm where they now live in 1973.

The Whites own a 225-head commercial herd of Angus-crossed cows and a 400-head one-time capacity feedlot. The cowherd produces terminal crosses of Angus-Charolais or Angus-Simmental for the feedlot. Replacement females are primarily Angus-based.

Most of the 550 acres of corn and soybeans are grown for the cowherd and the 550 head of fed cattle marketed annually. About 450 acres of permanent pasture and 125 acres of hay ground protect the highly erodible, clay-based soils on the White's operation in the watershed area of the West Fork of the Des Moines River in northwest Iowa.

Calving season for the White's cowherd is from April 1 to June 1. Heifers and cows are all calved on pastures to coincide with spring green-up. To protect sloping land, the Whites have converted crop acres to hay and an extensive rotational grazing system to provide the highest quality forages throughout the season for their cowherd.

Craig White is the third generation to raise cattle in this area. His son, Brad in continuing the family tradition and is in partnership with his grandfather, Arthur White, Craig's' father.

The Whites operate their farm with the help of Randy Nissen and his wife, Lorie. A 15-year veteran employee, Randy does and "awesome" job helping with the crops and cattle says Craig.

Voyles Farms, Inc.
Norman Voyles and Family, Indiana

In 1828, Moses Voyles homesteaded an 80-acre parcel of land about four miles southeast of Martinsville, in Morgan County, Indiana. The succeeding six generations of the Voyles family have continued farming that land and added considerably more. Today, the participating family members of the Voyles Farms, Inc. (VFI) – Darrell, his brother Norman Sr. (semi-retired), and Norman's sons, Norman Jr. and Jim – plant and harvest 1900+ acres of corn and soybeans and manage a commercial cow/calf herd of about 105 females.

Typically, 75-80% of females exposed to bulls will calve in March, the remainder in April and early May. A three breed rotational cross system has been used since 1990 consisting of Angus, Simmental, and Limousin bulls. For over 30 years, all replacement females have been raised. All steers and any heifers not selected as replacement females are either fed by the Voyles or placed in the Indiana Beef Evaluation and Economics Feed Program (IBEEF).

Voyles Farm, Inc. has been participated in the Indiana IRM program since 1994, the IBEEF program since 1997 and in 2001 became a partner in the Washing County (Indiana) Quality Beef Partnership, an alliance of several southern Indiana cow/calf operations.

AMBASSADOR AWARD RECIPIENTS

Warren Kester	Beef Magazine	MN	1986
Chester Peterson	Simmental Shield	KS	1987
Fred Knop	Drovers Journal	KS	1988
Forrest Bassford	Western Livestock Journal	CO	1989
Robert C. DeBaca	The Ideal Beef Memo	IA	1990
Dick Crow	Western Livestock Journal	CO	1991
J. T. "Johnny" Jenkins	Livestock Breeder Journal	GA	1993
Hayes Walker, III	America's Beef Cattleman	KS	1994
Nita Effertz	Beef Today	ID	1995
Ed Bible	Hereford World	MO	1996
Bill Miller	Beef Today	KS	1997
Keith Evans	American Angus Association	MO	1998
Shauna Rose Hermel	Angus Journal & Beef Magazine	MO	1999
Wes Ishmael	Clear Point Communications	TX	2000
Greg Hendersen	Drovers	KS	2001

PIONEER AWARD RECIPIENTS

Jay L. Lush	IA	1973
John H. Knox	NM	1974
Ray Woodward	ABS	1974
Fred Wilson	MT	1974
Charles E. Bell, Jr.	USDA	1974
Reuben Albaugh	CA	1974
Paul Pattengale	CO	1974
Glenn Butts	PRT	1975
Keith Gregory	MARC	1975
Braford Knapp, Jr.	USDA	1975
Forrest Bassford	WLJ	1976
Doyle Chambers	LA	1976
Mrs. Waldo Emerson Forbes	WY	1976
C. Curtis Mast	VA	1976
Dr. H. H. Stonaker	CO	1977
Ralph Bogart	OR	1977
Henry Holsman	SD	1977
Marvin Koger	FL	1977
John Lasley	FL	1977
W. L. McCormick	GA	1977
Paul Orcutt	MT	1977
J. P. Smith	PRT	1977
James B. Lingle	WYE	1978
R. Henry Mathiessen	VA	1978
Bob Priode	VA	1978
Robert Koch	MARC	1979
Mr. & Mrs. Carl Roubicek	AZ	1979
Joseph J. Urick	USDA	1979
Bryon L. Southwell	GA	1980

Richard T. "Scotty" Clark	USDA	1980
F. R. "Ferry" Carpenter	CO	1981
Clyde Reed	OK	1981
Milton England	TX	1981
L. A. Moddox	TX	1981
Charles Pratt	OK	1981
Otha Grimes	OK	1981
Mr. & Mrs. Percy Powers	TX	1982
Gordon Dickerson	NE	1982
Jim Elings	CA	1983
Jim Sanders	NV	1983
Ben Kettle	CO	1983
Carroll O. Schoonover	WY	1983
W. Dean Frischknecht	OR	1983
Bill Graham	GA	1984
Max Hammond	FL	1984
Thomas J. Marlowe	VA	1984
Mick Crandell	SD	1985
Mel Kirkiede	ND	1985
Charles R. Henderson	NY	1986
Everett J. Warwick	USDA	1986
Glenn Burrows	NM	1987
Carlton Corbin	OK	1987
Murray Corbin	OK	1987
Max Deets	KS	1987
George F. & Mattie Ellis	NM	1988
A. F. "Frankie" Flint	NM	1988
Christian A. Dinkle	SD	1988
Roy Beeby	OK	1989

Will Butts	TN	1989
John W. Massey	MO	1989
Donn & Sylvia Mitchell	CAN	1990
Hoon Song	CAN	1990
Jim Wilton	CAN	1990
Bill Long	TX	1991
Bill Turner	TX	1991
Frank Baker	AR	1992
Ron Baker	OR	1992
Bill Borror	CA	1992
Walter Rowden	AR	1992
James W. "Pete" Patterson	ND	1993
Hayes Gregory	NC	1993
James D. Bennett	VA	1993
O'Dell G. Daniel	GA	1993
M. K. "Curly" Cook	GA	1993
Dixon Hubbard	USDA	1993
Richard Willham	IA	1993
Dr. Robert C. DeBaca	IA	1994
Tom Chrystal	IA	1994
Roy A. Wallace	OH	1994
James S. Brinks	CO	1995
Robert E. Taylor	CO	1995
A. L. "Ike" Eller	VA	1996
Glynn Debter	AL	1996
Larry V. Cundiff	NE	1997
Henry Gardiner	KS	1997
Jim Leachman	MT	1997
John Crouch	MO	1998
Bob Dickinson	KS	1998
Douglas MacKenzie Fraser	AB	1998
Joseph Graham	VA	1999
John Pollak	NY	1999
Richard Quaas	NY	1999
Robert R. Schalles	KS	2000
J. David Nichols	IA	2000
Harlan Ritchie	MI	2000
Larry Benyshek	GA	2001
Minnie Lou Bradley	TX	2001
Tom Cartwright	TX	2001

CONTINUING SERVICE AWARD RECIPIENTS

Clarence Burch	OK	1972
F. R. Carpenter	CO	1973
E. J. Warwick	DC	1973
Robert DeBaca	IA	1973
Frank H. Baker	OK	1974
D. D. Bennett	OR	1974
Richard Willham	IA	1974
Larry V. Cundiff	NE	1975
Dixon D. Hubbard	DC	1975
J. David Nichols	IA	1975
A. L. Eller, Jr.	VA	1976
Ray Meyer	SD	1976
Don Vaniman	MT	1977
Lloyd Schmitt	MT	1977
Martin Jorgensen	SD	1978
James S. Brinks	CO	1978
Paul D. Miller	WI	1978
C. K. Allen	MO	1979
William Durfey	NAAB	1979
Glenn Butts	PRI	1980
Jim Gosey	NE	1980
Mark Keffeler	SD	1981
J. D. Mankin	ID	1982
Art Linton	MT	1983
James Bennett	VA	1984
M. K. Cook	GA	1984
Craig Ludwig	MO	1984
Jim Glenn	IBIA	1985
Dick Spader	MO	1985
Roy Wallace	OH	1985
Larry Benyshek	GA	1986
Ken W. Ellis	CA	1986
Earl Peterson	MT	1986
Bill Borror	CA	1987
Daryl Strohbehn	IA	1987
Jim Gibb	MO	1987
Bruce Howard	CAN	1988
Roger McCraw	NC	1989
Robert Dickinson	KS	1990
John Crouch	MO	1991
Jack Chase	WY	1992
Leonard Wulf	MN	1992
Henry W. Webster	SC	1993
Robert McGuire	AL	1993
Charles McPeake	GA	1993
Bruce E. Cunningham	MT	1994
Loren Jackson	TX	1994
Marvin D. Nichols	IA	1994
Steve Radakovich	IA	1994
Dr. Doyle Wilson	IA	1994
Paul Bennett	VA	1995
Pat Goggins	MT	1995
Brian Pogue	CAN	1995
Harlan D. Ritchie	MI	1996
Doug L. Hixon	WY	1996
Glenn Brinkman	TX	1997

Russell Danielson	ND	1997
Gene Rouse	IA	1997
Keith Bertrand	GA	1998
Richard Gilbert	TX	1998
Burke Healey	OK	1998
Bruce Golden	CO	1999
John Hough	GA	1999
Gary Johnson	KS	1999
Norman Vincil	VA	1999
Ron Bolze	KS	2000
Jed Dillard	FL	2000
William Altenburg	CO	2001
Kent Andersen	CO	2001
Don Boggs	SD	2001

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