Proceedings

# Beef Cow Efficiency Forum

May 29-30, 1984
Michigan State University
East Lansing, Michigan

May 31-June 1, 1984
Colorado State University
Fort Collins, Colorado

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# FORWARD

The original idea that eventually culminated in the Beef Cow Efficiency Forum was almost simultaneously conceived by two people - Dr. Ron Nelson at Michigan State University and Dr. Jim Brinks at Colorado State University. They urged their colleagues at both institutions to initiate planning for an event that could serve as a "forum" for discussing one of the key issues of our time - beef cow efficiency and those factors related to it. Dr. David Ames, Head of Animal Science at CSU, called representatives from each university together in July, 1983. It was agreed to proceed with an event of this kind and to hold the program at two locations, East Lansing and Fort Collins. Since then, a great deal of effort has been expended by personnel at both universities in developing and organizing the Forum program.

Because of time constraints, it was not possible to include on the program all of those scientists working in this important area of research. Nevertheless, an attempt was made to present a rather broad spectrum of the work that has been completed as well as some that is still in progress. It was deemed important to include presentations by researchers in dairy cattle and sheep as well as in beef cattle. It was also decided that a systems component should be included in an attempt to tie the facts together. A reaction panel and a summary speaker were included to further crystallize the program.

It was not the objective of the Forum to design an ideal cow. Instead, the goal was to present some ideas that would assist beef producers in specific areas under specific conditions tpwards making better genetic and management decisions in the years ahead. To that end, this Proceedings is dedicated.

Harlan Ritchie
David Hawkins
Editors

June, 1984

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# INTRODUCTION--OVERVIEW OF FACTORS AFFECTING BEEF COW EFFICIENCY

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My objective is to briefly open this Forum and then turn the podium over to the distinguished speakers who will follow. During the next day and a half, you will have an opportunity to hear some of the most eminent authorities in the U.S. speak on beef cow efficiency and the factors that affect it. As a prelude to their presentations, I will attempt to introduce the subject.

## Two Kinds of Efficiency

Beef cow efficiency is generally expressed in one of two ways: (1) as biological efficiency, or (2) as economic efficiency. Those who favor biological efficiency argue that economic conditions are too unstable and unpredictable to be used for such long-term decisions as breeding goals (Fowler et al., 1976; Maijala, 1976). Others support the view that biological efficiency has limited usefulness because it does not account for differences in feed costs associated with various genotypes or age classes, nor for the impact of important non-feed costs on efficiency (Dickerson, 1978; Tess et al., 1983). In the papers presented during this Forum, you will hear that biological and economic efficiency are often closely related, but in other instances there may be only a limited relationship. Surely, there is no incentive for improving biological efficiency unless some economic benefit can accrue from it.

## Measures of Biological Efficiency

Biological efficiency is usually expressed as a ratio of: (1) output over input; or (2) input over output. Following are a few examples of how various research groups have measured it.

Calf's Weaning Weight. Several studies have shown that weaning weight per se is highly correlated with cow efficiency.

Calf Weight/Dam's Weight. In this measure of efficiency, it is assumed that the dam's weight is related to her annual feed requirements. Actual body weight is often used in the denominator. In other cases, metabolic weight (body weight to the 0.75 power) is used because it has been generally agreed that maintenance requirements are more closely related to metabolic weight than to body weight.

Calf Weight Weaned/Cow Exposed. This is a function of cow fertility, calf survival rate, milking ability, and the calf's genotype for pre-weaning growth. Unfortunately, it does not account for the major cost input in a cow-calf enterprise; namely feed consumed (40 to 70% of all costs).

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Calf Weight Weaned/TDN Consumed. This is a function of milking ability, calf's genotype for growth, and TDN (total digestible nutrients) consumed by the cow and her calf (if creep-fed) up to weaning time. Some studies have utilized megacalories of digestible energy (DE) or metabolizable energy (ME) in place of TDN as a measure of dietary energy. The reciprocal of this ratio is often used, which allows efficiency to be expressed in whole numbers instead of fractions. This measure of efficiency does not account for differences in reproductive rate (fertility and survivability). In some studies, cull cow weight is included in the output data along with weaned calf weight.

Calf Weight Weaned/Cow Exposed/TDN Consumed. This is the preferred measure of biological efficiency up to weaning time because it accounts for differences in reproductive rate, milking ability, calf's growth rate and feed consumed. However, if small numbers are involved, a few open cows or a few dead calves may exert an undue influence on biological efficiency. As mentioned above, cull cow weight may be added to weaned calf weight to account for total output. In so doing, however, an adjustment for difference in value of weight sold should be applied.

Final Product Weight/TDN Consumed. In this measure of efficiency, the output (final product) may be expressed in several ways: (1) slaughter weight; (2) empty body weight; (3) carcass weight; (4) retail cut, lean cut, or edible product weight; (5) energy in the calf at time of slaughter; (6) edible energy in the calf at slaughter. In some studies, the data are adjusted for differences in reproductive rate; in others, reproduction is not considered. If differences in reproductive rate are large, they can have a dramatic impact on biological efficiency, as noted above.

## Measures of Economic Efficiency

Economic efficiency has not been studied to the same extent as biological efficiency. Nevertheless, most animal scientists today agree on its importance and that it should be considered in research projects whenever possible. Following are a few measures of economic efficiency that have been used by researchers.

Cost of Production/Weight of Live Animal Marketed. In this case, all production costs are accounted for and divided by weight of live animal marketed. Live animal weight may consist of weaned calf weight, or final slaughter weight, plus cull cow weight adjusted for value differences between cow weight and progeny weight. Historically, cull cow weight has sold for approximately 55 to 60% of the value of feeder calf weight (see E.R. Hauser's paper in these proceedings). When calves are sold at weaning time, 40 to 45% of the live weight marketed annually may come from the sale of cull cows. This means that 25 to 30% of gross income could be derived from the sale of cows, and 70 to 75% from the calves. If calves are fed out to slaughter, cull cows account for about 20% and calves 80% of gross income.

Cost of Production/Weight of Retail Yield Marketed. From the standpoint of total life cycle beef production, this is an excellent measure of efficiency because it attempts to assess the cost of producing the final product - saleable retail beef. However, it does not account for potential value differences between quality grades of beef (choice, good, etc.).

Net Return per Cow-Calf Unit. Everyone is (and ought to be) interested in net profit. However, it is not always the most useful concept because it means different things to different people. The basic problem is: what costs are included upon which to base net return? For example, land, livestock and labor charges may or may not be included in the total cost of production, depending upon the nature of the operation. This can have a major impact on net profit.

Net Return to the Beef Cattle Enterprise. This is a more useful measure of economic efficiency than one based on a per animal unit. It is really the whole enterprise that determines the economic fate of the beef producer. Nevertheless, the question of which costs are to be included remains a problem, as suggested above.

Return on Investment. This measure is not often cited in beef cow efficiency research. However, it may be one of the most useful barometers of economic efficiency.

## Factors Affecting Beef Cow Efficiency

A host of factors have been identified as possibly having an impact on beef cow efficiency. They are listed in the sections that follow.

### Genetic/Biological Factors

1. Size (weight, frame, etc). Much of the research to be reviewed in this Forum will deal either directly or indirectly with physical size.

2. Milk production. Next to size, milk production has received the most attention from cow efficiency researchers.

3. Level of feed (energy) intake. Dietary energy intake has been shown to affect body maintenance requirements which can, in turn, influence efficiency of production.

4. Body condition. Degree of body fatness has also been shown to exert some influence on maintenance requirements.

5. Additive gene effects (breed differences): There is evidence to indicate that breeds do differ in efficiency, depending upon how it is defined and measured.

6. Nonadditive gene effects (heterosis). The dramatic impact of heterosis on increasing output per cow exposed is well-documented in the scientific literature. Its effect on efficiency is perhaps less clear.

7. Crossbreeding systems. This Forum will show that the crossbreeding system chosen can have a significant effect on efficiency.

8. Age at puberty. The age when heifers reach puberty and when they subsequently give birth to their first calves will affect life cycle efficiency.

9. Photoperiod. Daylength has been shown to affect age at puberty, and in that manner could influence life cycle efficiency.

10. Longevity. Length of life in the herd can affect efficiency in several different ways: (1) More progeny are sold when cows produce longer and the culling (replacement) rate is lower; (2) Up to a point, mature cows wean heavier calves than 2- to 4-year-old cows; (3) Maintenance requirements for mature cows are somewhat higher than for replacement heifers.

11. Functional defects. Unsoundnesses of the feet, eyes, udder, and reproductive tract can impair productivity, increase costs, and reduce longevity.

12. Dystocia and related problems. Calving difficulty and its associated problems can result in reduced output and increased costs, thereby reducing efficiency.

Environmental/Management Factors

1. Climate. Research has shown that climate can have a profound effect on maintenance costs as well as on output (progeny performance).

2. Soils and vegetation. Fertility of the soil and quality of the vegetation that it will support can aid in determining the type of cattle that will be most efficient.

3. Topography/terrain. As indicated above for soils and vegetation, type of terrain and distances required to travel for feed and water can influence the type of cattle best adapted to the conditions.

4. Supplemental feed resources. The availability, cost and quality of supplemental feed can also influence decisions regarding the most efficient biological types.

5. Labor and facility resources. If labor and facilities are limited or expensive, the type of cattle selected must be relatively trouble-free and easily managed in order to maximize efficiency.

6. Pathogens, parasites and predators can reduce output and thereby lower efficiency.

7. Growth implants and feed additives. Growth implants can stimulate pre- and post-weaning gains by 5 to 15%. Ionophores can improve post-weaning feed efficiency by 6 to 10%. The overall biological efficiency of beef production is generally enchanced through the use of these materials.

8. Beta adrenergic agonists. Beta-agonists, such as clenbuterol, have been shown to significantly increase lean deposition in meat animals. These experimental products have exciting implications for improving efficiency of production.

Marketing/Economic Factors

1. Carcass weight preferences. The boxed beef trade accounts for about 80% of the beef marketed in the U.S. To meet specifications for this market, carcasses should generally weigh within a range of 550 to 850 lb. This can have a major impact on cow size and efficiency.

2. Carcass cutability preferences. In order to earn top economic returns, beef carcasses must have a yield grade of 3 or better. A yield grade of 2 would seem to be a reasonable goal.

3. Quality grade preferences. At the present time in the U.S., beef carcasses must quality grade low choice or higher in order to achieve top price. In the future, a grade equivalent to the present quality grade of high good may be sufficient.

4. Breed and/or color preferences. There is no doubt that cattle feeders in various regions of the country will pay more for calves of certain breedtypes than they will for others. This was well-documented in a recent study by Lambert et al. (1983). Meat packers also have preferences, but they do not necessarily coincide with those of cattle feeders.

5. Slaughter age preferences. It is perceived that U.S. consumers prefer the flavor of yearling to 2-year-old beef over that from cattle less than 12 months of age. Moving in the direction of younger slaughter ages could have some impact on economic efficiency.

There are undoubtedly other factors that impact on the biological and eonomic efficiency of beef production; some will likely be identified during the course of this Forum.

## Literature Cited

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

Fowler, V.R., M. Bichard and A. Pease. 1976. Objectives in pig breeding. Anim. Prod. 23:365.

Lambert, C., L. Corah and O. Gruewald. 1983. Factors affecting prices of calves and yearlings in Kansas. Kansas State Univ. Coop. Ext. Bull. MF-667.

Maijala, K. 1976. General aspects in defining breeding goals in farm animals. Acta Agr. Scand. 26:40.

Tess, M.W., G.L. Bennett and G.E. Dickerson. 1983. Simulation of genetic changes in life cycle efficiency of pork production. II. Effects of components on efficiency. J. Anim. Sci. 56:354.

# MAINTENANCE REQUIREMENTS FOR BEEF CATTLE: IMPORTANCE AND PHYSIOLOGICAL AND ENVIRONMENTAL CAUSES OF VARIATION

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Production of choice beef in Colorado typically involves burning 71% of the feed metabolizable energy input in meeting the animals first priority: maintenance energy requirements (figure 1). Among animals within the typical herd, this proportion of feed used for maintenance varies markedly by class of animal (table 1). It ranges from approximately 40% for animals in the feedlot phase to 93% for the mature cow. The fraction of feed used for maintenance in any specific beef production system then will reflect the relative proportions of the numbers of animals in each class. The higher the number of mature cows the higher the fraction of feed energy burned for maintenance. The overall very high proportion of feed used for maintenance in beef production is primarily the result of relatively low dietary intake per unit of maintenance, low product per female year or incubator costs, and the harsh uncontrolled environments used in production.

Maintenance requirement is defined as the amount of daily dietary intake which will cause the animal to neither gain nor lose body energy. At this point, the metabolizable energy (ME) intake of the animal is exactly equal to the heat production of the animal and the energy retained in body tissues is zero (figure 2). The experimental determination of this point requires precise measure of body energy stores and ME intake. This expression of maintenance requirement as $ME_m$ is not independent of the diet being consumed by the animal. A typical beef cow requirement of 132 kilocalories per unit of weight raised to the 3/4 power is therefore characteristic only of a medium quality roughage diet and would vary approximately 25% depending on diet quality and the resulting efficiency of ME use for maintenance.

Two experimental methods which are frequently used as indexes of maintenance energy requirements are fasting heat production (FHP) and weight maintenance. Most world energy requirement schemes use FHP as the index of maintenance requirement because it is "independent of diet being fed to the animal." The second index of maintenance determines the amount of diet to cause the animal to neither gain nor lose weight. Potential body compositional changes require that information obtained in this way be considered cautiously. Any propensity towards protein storage, such as occurs in pregnant or growing animals, may grossly underestimate maintenance energy requirements.

The expected range of maintenance requirement, abbreviated $ME_m$*, across minimal activity, thermoneutral situations is from 80 to 160 kcal of ME per kg $W^{.75}$. Measurements made of animals below thermoneutral ambiencies or under high activity levels would push the upper limit much further.

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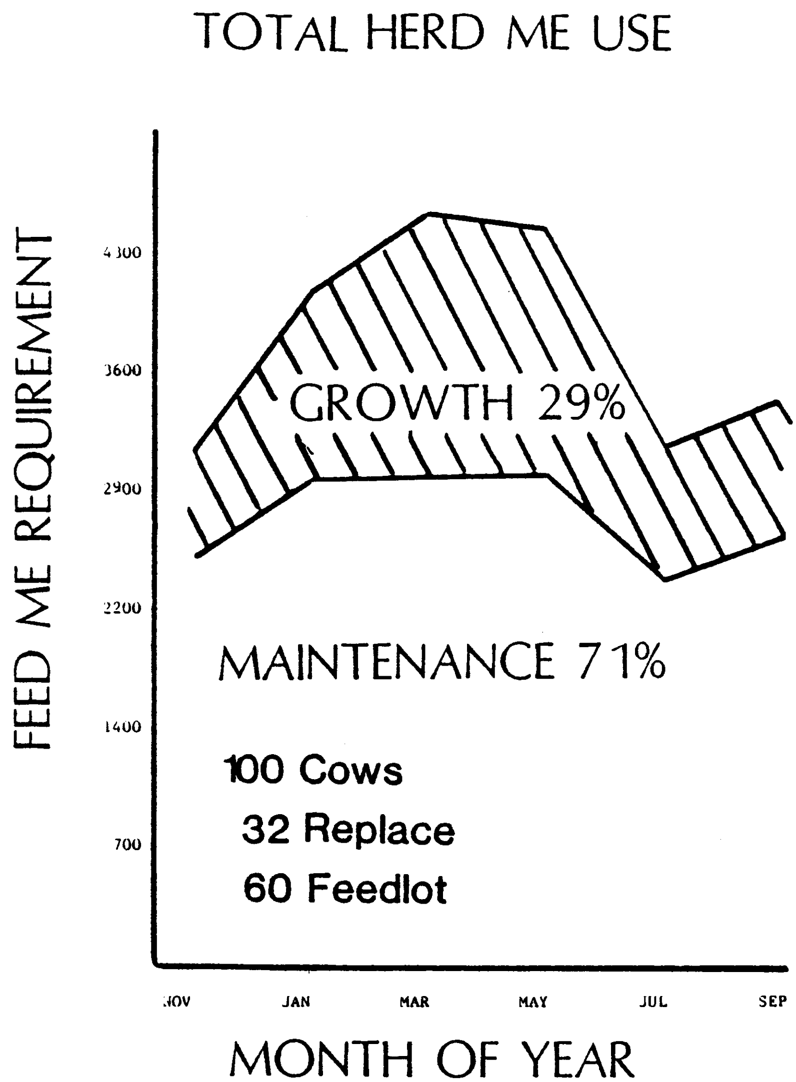


Figure 1. Feed ME requirement for maintenance and growth in typical Colorado production of choice beef.

TABLE 1. FRACTION OF FEED USE FOR MAINTENANCE BY BEEF CATTLE

| Class | % of total |
|---|---|
| Feedlot steer | 40-55 |
| Feedlot heifer | 40-55 |
| Cow, 2-year-old | 83 |
| Cow, 6-year-old | 91 |
| Replacement heifer | 65 |

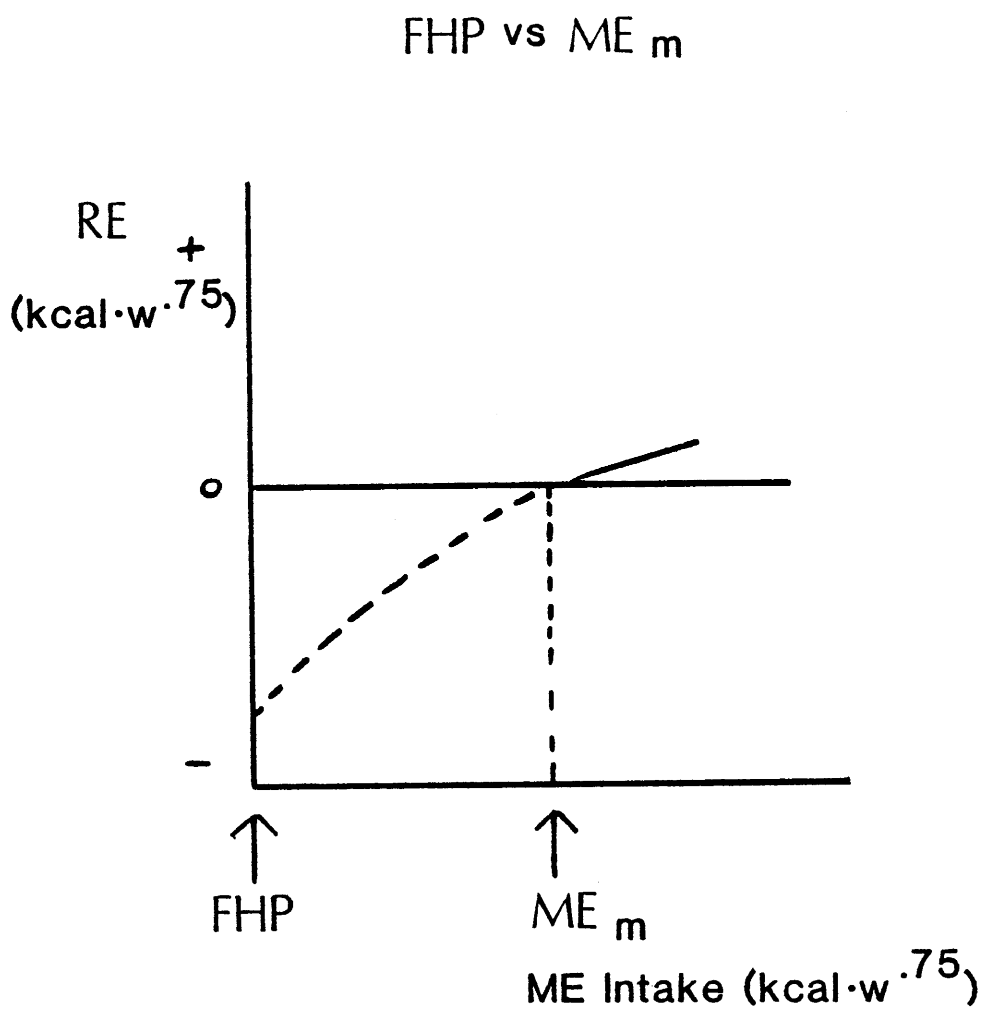


Figure 2. Graphical illustration of maintenance energy requirement ($ME_m$) where body tissue retained energy (RE) is zero and the commonly used index of maintenance, fasting heat production (FHP).

Sources of variation in $ME_m$* can be largely described as those emanating from physiological/compositional origins, environmental circumstance or animal uniqueness factors. Changing these circumstances or pheuomena can result in relatively small or relatively large changes in maintenance energy requirements, as indicated in table 2. The factors are not mutually exclusive but interact with each other within and across category. Recent experiments depicting changes in vital organ mass and in level of ion pumping in these tissues promise to increase our understanding of shifting basal metabolic rate and/or maintenance requirements across a wide range of animal circumstances. The weight of vital organs (liver, gastrointestinal tract, etc.) can vary markedly in animals in response to several factors independent of the live weight of the animal. Organs weighing 25 to 50% heavier at equal body weight have been shown in response to lactation (table 3, Smith and Baldwin, 1974) and in response to prior level of alimentation/rate of gain (table 4, Koong et al., 1982). The major portion of the lactation effect is also likely a level of alimentation/level of feed intake effect. These general effects on vital organ mass have now been illustrated in rats, sheep, swine, and cattle. Additionally, high levels of alimentation have been associated with high fasting heat productions (Marsten, 1948; Koong et al., 1982).

TABLE 2. SOURCES OF VARIATION IN CATTLE MAINTENANCE ($ME_m/W^{.75}$) AND THEIR RELATIVE IMPACT

| Factor/Source | Relative % $ME_m$ change |
|---|---|
| I. Physiological/Compositional Changes | |
| Vital Organ Mass | 20-30 |
| Ion Pumping | 20-30 |
| Protein Turnover | 5-10 |
| Muscle Mass | 5-15 |
| Lactation | 10-15 |
| Age | <10-20 |
| II. Environmental | |
| Climate/Season | 40-50 |
| Level of Alimentation-ADG | 30-40 |
| Diet | 20-30 |
| Activity | 10-50 |
| III. Animal Uniqueness | |
| Genetic/Individual | 20-30 |
| Sex | 10-15 |
| Activity | ? |
| Sweat Glands | ? |
| Hair Color, etc. | ? |

TABLE 3. VITAL ORGAN MASS OF DRY AND LACTATING COWS[a]

| Tissue/ Breed | Dry | Lactating | % Change |
|---|---|---|---|
| | g/kg W | | |
| Liver | | | |
| Holstein | 13.0 | 16.3 | +25% |
| Jersey | 15.6 | 19.2 | +23% |
| Intestine | | | |
| Holstein | 11.7 | 17.0 | +45% |
| Jersey | 16.4 | 20.9 | +27% |

[a]Smith and Baldwin (1974)

TABLE 4. VITAL ORGAN MASS AND FASTING HEAT PRODUCTION (FHP) CHANGES WITH LEVEL OF ALIMENTATION[a]

| Item | Alimentation Sequence High Low | Low High | % Change |
|---|---|---|---|
| | --------g/kg W-------- | | |
| Liver | 10.3 | 15.1 | +47% |
| Small intestine | 7.8 | 12.1 | +55% |
| | -----Kcal $W^{.75}d^{-1}$----- | | |
| FHP | 69.3 | 98.3 | +42% |

[a]Koong et al. (1982) - sheep.

The metabolic activity of tissue is also changing dramatically across situations and may be a major contributor to shifting maintenance requirements and/or ancillary costs of product formation. Ion pumping (primarily $Na^+/K^+$ATPase) associated oxygen consumption has been shown to range from 20 to 60% of total oxygen consumption in muscle, gut and liver tissues (Milligan and McBride, 1984). Ion pumping oxygen consumption of body tissues also changes as much as 250% in response to changing animal situation. Level of alimentation (table 5), lactational state, age, and/or cold exposure all will change ion pumping energy use.

TABLE 5. ION PUMPING $O_2$ CONSUMPTION VS LEVEL OF ALIMENTATION OF SHEEP[a]

| Tissue | ----Na+K+ATPase----- Fast | Adlib | % Change |
|---|---|---|---|
| | ------mM $O_2$/mg---- | | |
| Gut | 1.5 | 3.7 | +247% |
| Liver | .5 | 1.3 | +260% |

[a]McBride (1984) - sheep.

The increasing organ mass along with the increased ion pumping costs may create a multiplier affect on increasing or decreasing energy needs. Whether these uses of energy are best described as maintenance requirements or whether they should be defined as ancillary costs to product formation remains to be determined.

Environmental impacts on the maintenance requirement of beef cattle are frequently the most striking. Level of alimentation effects have been partially described. High and low levels of alimentation might alternately be described as high and low rates of body weight gain. While these processes may be more important in understanding biological processes relating to growth, they certainly are adaptive processes that help get the cow through the lean months or years and are involved in the compensatory gain phenomenon. An interesting speculation is that some animals may be more effective in adapting to low dietary regimes than others.

Climate/season effects on beef cattle maintenance requirements and productivity have been detailed recently (NRC, 1981). The major effect of heat stress is to depress dietary intake while the major effect of cold environments is to increase maintenance requirements or basal metabolic rate. Beef cattle are described as shifting their maintenance requirements upward by .9% for each one degree fall in effective ambient temperature below 20$^{o}$C (figure 3). The beef animal responds to, or possibly anticipates cold ambiencies, and shifts his metabolic rate accordingly. A cold adapted steer thus would have a high metabolic rate/maintenance requirement even if measured in warm thermoneutral conditions. Other factors (decreased digestibility, heat loss below the critical temperature) also may aggravate cold effects but are quantitatively of less importance. Long term accumulations of feedlot information (Johnson, 1984) indicates somewhat greater effects on maintenance requirements than the above .9 factor predicts. Long term measurements with mature cows are sparse. Recent data accumulations on British breed beef cows indicate requirements of approximately 100 kcal per metabolic size in Texas (10 to 27C) while requirements determined in Nebraska (OC) or in Minnesota (-5C) indicate requirements of 130 and 140. This may indicate an environmental effect and also suggest that the warm climate requirements are lower than those projected by NRC (1976). Fat Hereford cows had 6% lower maintenance requirements in Minnesota winters than thin ones; however, Holstein crossbred cows were unaffected by body fat level (Thompson et al., 1983).

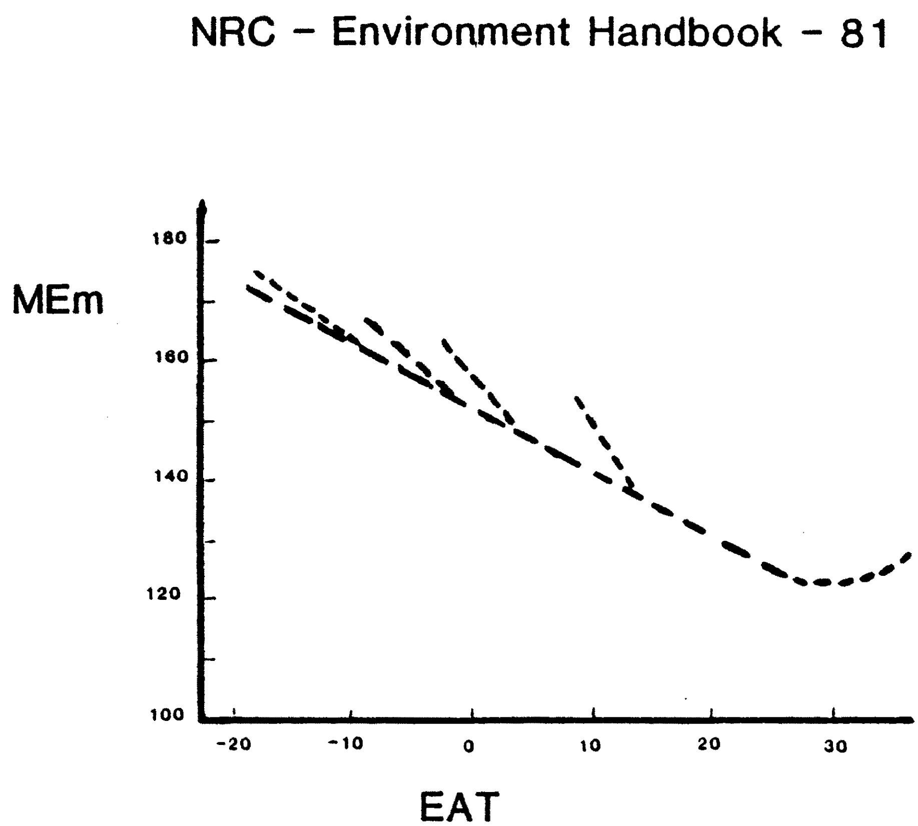


Figure 3. Maintenance requirement ($ME_m$) of beef cattle unsheltered at varying effective ambient temperatures (EAT).

There have been several recent suggestions for modification of the single constant times $W^{.75}$ method to calculate maintenance requirements of any and all all beef cattle (table 6). The recommendation for cold ambiency adjustment mentioned above is an example. The Agricultural Research Council (1980) recommends that $ME_m$ be set at 127 times weight raised to the .67 power. This formula largely overcomes the problems of the high fasting heat productions of young animals that were observed when weight to the .75 was used. Other proposed formulas would take into account the variable of average daily gain (Koong et al., 1984) or both age and rate of gain as suggested by Corbett and Graham (1981). Other models are reviewed by Gaey (1984).

TABLE 6. VARIOUS APPROACHES TO MODIFYING THE SINGLE CONSTANT MAINTENANCE REQUIREMENT OF CATTLE

| Reference | NEm (kcal) |
|---|---|
| NRC 1976 | $77\ W^{.75}$ |
| NRC (Env-81) | $[77+.7\ (20-EAT)]W^{.75}$ |
| ARC 1980 | $127\ W^{.75} + .001W$ |
| Corbett and Graham (proposed) | $(400\ E^{-.05y} + 4.5g)\ (s)\ (W^{.75})$ |
| Koong and Ferrell (proposed) | $106\ W^{(.686\ +\ .165\ ADG)}$ |

y = age
G = ADG, g $W^{.75}\ d^{-1}$
S = 1.0 sheep, 1.3 cattle
W = body weight, kg
EAT = effective ambient temp.

The coefficient of variation in maintenance energy requirements between animals of similar weight or age on the same diet, equal intake, etc. has been generally assessed at 5 to 10% (table 7). Such a range is indicated by summarization of a large number of experiments (mostly dairy cows) by van Es (1972). The standard deviation between animals in $ME_m$* in four recent experiments with growing animals at Colorado State university has ranged from 2 to 15. These observations, however, are made within quite uniform groups of animals by design. Measurements of more genetically diverse animals such as across breed, frequently show larger deviations, as illustrated in recent data from Nebraska and Texas (table 8).

TABLE 7. BETWEEN ANIMAL VARIATION IN MAINTENANCE REQUIREMENT

| Reference | Trials | $ME_m$* | SD |
|---|---|---|---|
| van Es (1972) | 237 | 110 | ±5-10 |
| Hashizume et al. (1962) | | | |
| Jap. Blk | 24 | 96 | ±13 |
| Holstein | 15 | 114 | ±10 |
| Holstein | 8 | 116 | ±9 |
| CSU[a] | | | |
| Trial I | 24 | 113 | ±3 |
| Trial II | 24 | 113 | ±2 |
| Trial III | 48 | 125 | ±8 |
| Trial IV | 32 | 138 | ±15 |

TABLE 8. GENETIC BASE EFFECTS ON MAINTENANCE REQUIREMENTS OF BEEF COWS

| Breeding | Source of data: Nebraska[a] | Source of data: Texas[b] |
|---|---|---|
| Angus-Hereford | 130 | 104 |
| Charolais | 129 | |
| Jersey | 145 | 152 |
| Simmental | 160 | |
| Holstein | | 119 |
| Brahma | | 98 |

[a]Ferrell and Jenkins (1984).
[b]Byers et al. (1984).

Some of the genetic/animal differences in maintenance requirements may result from relative sizes of the animals vital organs. Cows with Jersey breeding showed relatively high maintenance requirements in both the Nebraska (Ferrell and Jenkins, 1984) and Texas (Byers et al., 1984) experiments and have also exhibited relatively high liver and intestine mass (Smith and Baldwin, 1974). Also, Brahma breeding results in lower vital organ mass (Butler et al., 1956) than British breeding and low fasting heat production (Frisch and Vercoe, 1977), although the Texas data show Brahma cow maintenance to be lower than British only in the summer (Byers et al., 1984).

## Literature Cited

ARC. 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureau, England.

Butler, O.D., R. L. Reddish, G. T. King, and R. L. Simms. 1956. J. Anim. Sci. 15:523.

Byers, F. M., G. T. Schelling, C. R. Long, J. C. Solis, and L. W. Greene. 1984. J. Anim. Sci. Proceedings Western Section 35: (in press).

Ferrell, C. L. and T. G. Jenkins. 1984. J. Anim. Sci. 58:234.

Frisch, J. E. and J. E. Vercoe. 1977. Anim. Prod. 25:343.

Geay, Y. 1984. J. Anim. Sci. 58:766.

Hashizume et al. 1962. (Quoted by van Es, 1972).

Johnson, D. E. 1984. W-135 regional bulletin on environmental stress (in press).

Koong, L. J., C. L. Ferrell and J. A. Nienaber. 1982. Proceed. 9th Symposium on Energy Metabolism of Farm Animals. Editors, Ekern and Sundstol.

Koong, L. J., J. A. Nienaber and C. L. Ferrell. 1984. J. Nutr. (in press).

Marston, H. R. 1948. Aust. J. of Sci. Res. 1:93.

McBride, B. W. T. 1984. Ph.D. Thesis, University of Alberta, Edmonton.

Milligan, L. P. and B. W. McBride. 1984. J. Nutr. (in press).

NRC. 1976. Nutrient Requirements of Beef Cattle. Nat. Acad. Sci., Washington, D.C.

NRC. 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. Nat. Acad. Sci., Washington, D.C.

Smith, N. E. and R. L. Baldwin. 1974. J. Dairy Sci. 57:1055.

Thompson, W. R., J. C. Meiske, R. D. Goodrich, J. R. Rust, and F. M. Byers. 1983. J. Anim. Sci. 56:1241.

van Es, A. J. H. 1972. Maintenance, In: Handbuch der tierernahrung, Verlag Paul Parey, Berlin.

# OUTPUT/INPUT DIFFERENCES AMONG BIOLOGICAL TYPES

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The topic of "Beef Cow Efficiency" is not a new area of interest. In a review by Morris and Wilton (1976), over 100 publications were cited that addressed this or closely related topics. Included in the citations was a paper by Kleiber (1936) entitled, "Problems involved in breeding for efficiency in food utilization". Brody and Cunningham (1936) addressed the question of how the relationship between biological and economic efficiency may be affected by body size. Within a span of five years, the British Society of Animal Production devoted a symposium and a memorial lecture series to the relationship of animal size and production efficiency. In numerous studies, size appears to be the predominant causal factor being questioned with regard to efficiency. Dickerson (1978) suggested that associated factors such as gestation and lactation lengths, dystocia and postweaning average daily gain may reduce the effects of size per se on life-cycle production efficiency (biological output/input) if the product is marketed at the optimal body weight (Joandet and Cartwright, 1969). Morris and Wilton (1976) state, "Little variation is expected in biological efficiency due to differences in size of cows, although considerable changes in outputs and requirements per animal may be induced by change in cow size". If mature size in cattle is considered a productive function, this statement appears to suggest that as environment (nutrition) changes, increased energetic cost may increase variation in output.

If associative factors (Dickerson, 1978) affect production efficiency, life cycle production efficiency (Cartwright, 1970; Gregory, 1972) should be of paramount importance. Conditions within a given annual production cycle could be above levels necessary for optimum performance. However, factors such as a high incidence of dystocia or poor nutrient environment during the present production cycle could have a negative effect on the succeeding year's performance, resulting in differences among differing biological types for life cycle production efficiency. Stewart and Martin (1983) reported the relationship of lifetime weaning records of Angus cows with mature size and rate of maturing to determine optimal cow size. Results indicated a negative relationship between lifetime total calf weight weaned and mature cow weight but a positive relationship between average calf weight weaned and mature cow weight. Likewise, a positive relationship between total calf weight weaned and maturing rate and a negative relationship between average calf weight weaned and maturing rate were reported. Associative factors such as those described previously may have an effect on output of a cow herd.

At the Roman L. Hruska U.S. Meat Animal Research Center, research was initiated to compare a broad range of cattle breeds that differ widely in production characteristics such as growth rate, mature size and milk production. This report contains information describing productivity of the breeds and information regarding energy utilization and variation among types for production

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efficiency. In addition, energy requirements for maintenance and factors affecting these components of maintenance will be considered.

## Characterization of Traits Affecting Outputs

The Germ Plasm Evaluation program has included three cycles of sire breeds that were bred by artificial insemination (AI) to Hereford and Angus dams. The first cycle involved breeding Hereford (approximately equal numbers of horned Hereford and Polled Hereford), Angus, Jersey, Limousin, South Devon, Simmental and Charolais sires (20-35 sires per breed) by AI to Hereford and Angus dams (ranging from 2 to 7 years old at calving to produce three calf crops in March and April of 1970, 1971 and 1972. In Cycle II, Hereford and Angus dams (ranging from 4 to 9 years at calving) used in Cycle I were bred to Hereford, Angus, Red Poll, Brown Swiss (predominantly European), Gelbvieh, Maine Anjou and Chianina sires to produce two calf crops in 1973 and 1974. The same Hereford and Angus sires were used in the cycles of the program to ensure a stable control population of Hereford-Angus reciprocal crosses, enabling comparison of breeds included in different cycles.

Puberty of $F_1$ heifers. Females produced in the program were retained to evaluate reproduction and maternal performance traits. Simmental, Maine Anjou and South Devon crosses were similar to Hereford-Angus crosses in average age at puberty and intermediate to other breed groups. Gelbvieh, Brown Swiss and Red Poll crosses reached puberty earlier than Hereford-Angus crosses, and Jersey crosses were the youngest of all breed groups when puberty was observed. Among *Bos taurus* breed groups, Limousin, Charolais and Chianina crosses were oldest at puberty (Laster et al., 1976; Laster et al., 1979).

Larger breeds with lower maturing rates tended to be older at puberty. Considering their mature size, South Devon, Simmental, Maine Anjou, Pinzgauer, Brown Swiss and Gelbvieh crosses reached puberty at relatively young ages. Breeds which have been selected for milk production appear to reach puberty earlier than breeds of similar growth rate and mature size that have not been selected for milk production. The negative relationship between milk production and age at puberty may be as large as the positive relationship between mature size and age at puberty.

Reproduction and maternal performance of $F_1$ females. Results on production of $F_1$ cows are summarized in table 1. It is not appropriate to make comparisons between $F_1$ crosses used in different cycles of the program because complete data are not available for Cycle II cows. Within each cycle of the program, differences between breed groups in calving difficulties, calf crop percentage and calf weights at birth and 200 days have decreased as cows have advanced in age and as the number of records have increased. Valid comparisons can be made between breed groups used in the same cycle which have been managed as contemporaries through 8 years of age in Cycle I and 7 years of age in Cycle II.

Jersey cross females experienced less calving difficulty than other breed groups in Cycle I, especially as 2-year-olds. Differences in calving difficulty of $F_1$ cows were associated with birth weight of their calves. Relatively heavy weaning weights of calves from Simmental and Jersey cross dams in Cycle I reflect their greater milk production (table 3). Jersey cross dams produced more milk but calves from Charolais cross dams were heavier at weaning than calves from

TABLE 1. BREED GROUPS MEANS FOR REPRODUCTION AND MATERNAL PERFORMANCE OF $F_1$ COWS

| Breed group[a] | Number births | Calving difficulty[b] | Calf crop weaned(%) | Birth weight(lb) | 200-day weight (lb) Per calf weaned | 200-day weight (lb) Per cow exposed | Ratio[c] |
|---|---|---|---|---|---|---|---|
| | | | Cycle I | | | | |
| Hereford/ Angus-X | 738 | 10 | 85 | 86 | 472 | 401 | 100 |
| Jersey-X | 628 | 4 | 85 | 79 | 490 | 415 | 104 |
| Limousin-X | 851 | 9 | 83 | 88 | 481 | 400 | 100 |
| South Devon-X | 603 | 12 | 86 | 91 | 489 | 420 | 105 |
| Simmental-X | 872 | 14 | 84 | 91 | 518 | 436 | 109 |
| Charolais-X | 693 | 12 | 81 | 93 | 500 | 408 | 102 |
| | | | Cycle II | | | | |
| Hereford/ Angus-X | 395 | 17 | 84 | 87 | 476 | 400 | 100 |
| Red Poll-X | 415 | 19 | 79 | 90 | 501 | 398 | 100 |
| Brown Swiss-X | 621 | 11 | 85 | 92 | 535 | 455 | 114 |
| Gelbvieh-X | 400 | 15 | 87 | 91 | 532 | 461 | 115 |
| Maine Anjou-X | 429 | 15 | 86 | 97 | 521 | 449 | 112 |
| Chianina-X | 426 | 11 | 87 | 97 | 523 | 455 | 114 |

[a]Breed groups identified by sire breed.
[b]Includes calves requiring calf puller or C-section.
[c]Ratio relative to Hereford-Angus cross.

Jersey cross dams because of greater growth potential transmitted by Charolais cross dams. Calf weight at 200 days per $F_1$ cow exposed to breeding among the breed groups included in Cycle I had a range of 9%, i.e., 100% for Limousin and Hereford-Angus crosses and 109% for Simmental crosses.

Differences in average calving date, percentage calf crop born and percentage calf crop weaned among the breed groups in Cycle II were small. Calving difficulty has been relatively low for Brown Swiss and Chianina $F_1$ females in spite of the relatively heavy birth weight of their calves. Brown Swiss and Gelbvieh cross females milked at the highest level and produced calves that were 12% heavier at 200 days than Hereford-Angus cross females. Maine Anjou cross and Chianina cross females were comparable to Hereford-Angus crosses in milk production, but produced calves that were 10% heavier at 200-day weight. Red Poll cross females were intermediate in the range among breed groups for milk production and 200-day weight of progeny. Weaning weight per cow exposed was 12% to 15% greater for progeny of Brown Swiss, Gelbvieh, Maine Anjou and Chianina $F_1$ females than for progeny of Red Poll and Hereford-Angus $F_1$ females.

<u>Size of $F_1$ females.</u> Breed group means for weight and hip height are provided in table 2 for Cycle I $F_1$ cows and Cycle II $F_1$ cows at 7 years of age. These data were taken in October at weaning time and represent the oldest age for which data are available on $F_1$ females produced in each cycle of the program.

TABLE 2. BREED GROUP MEANS FOR WEIGHT AND HEIGHT AT HIPS OF MATURE $F_1$ COWS[a]

| Breed group[b] | Cow weight (lb) | Hip weight (in) |
|---|---|---|
| | Cycle I | |
| Hereford-Angus-X | 1225 | 48.8 |
| Jersey-X | 1069 | 48.3 |
| Limousin-X | 1235 | 50.3 |
| South Devon-X | 1266 | 50.6 |
| Simmental-X | 1282 | 51.0 |
| Charolais-X | 1357 | 51.1 |
| | Cycle II | |
| Hereford-Angus-X | 1200 | 48.6 |
| Red Poll-X | 1115 | 48.5 |
| Brown Swiss-X | 1215 | 50.8 |
| Gelbvieh-X | 1255 | 50.4 |
| Maine Anjou-X | 1355 | 51.2 |
| Chianina-X | 1359 | 54.6 |

[a]At 7 1/2 years of age.
[b]Breed groups identified by sire breed.

In Cycle I, Charolais $F_1$ cows at maturity were 24% heavier than Jersey $F_1$ cows. However, there was little difference between Charolais and Jersey $F_1$ cows in 200-day weight of their calves (table 1). Jersey $F_1$ cows tended to exceed Charolais $F_1$ cows by 2% in 200-day weight of calf weaned per cow exposed to breeding (table 1). Limousin and South Devon $F_1$ cows were only 1% and 3% heavier, respectively, and 2 inches taller than Hereford-Angus $F_1$ cows as 7-year-olds when their calves were weaned.

Maine Anjou and Chianina $F_1$ cows were 11 to 12% heavier at 7 years of age than Hereford-Angus $F_1$ cows in Cycle II. Gelbvieh $F_1$ cows were 4% heavier than Brown Swiss and 5% heavier than Hereford-Angus $F_1$ cows. Red Poll $F_1$ cows were lighter than any other breed group in Cycle II. Chianina $F_1$ cows were taller than other breed groups while Brown Swiss, Gelbvieh and Maine Anjou $F_1$ cows were intermediate for hip height and 4 to 6% taller than Hereford-Angus and Red Poll $F_1$ cows.

TABLE 3. ESTIMATES OF TIME OF PEAK LACTATION, YIELD AT PEAK LACTATION AND TOTAL YIELD FOR SEVERAL BREEDS AND BREED CROSSES

| Breed group[a] | Time of peak lactation (wk) | Yield at peak lactation (kg) | Total milk yield (kg) |
|---|---|---|---|
| Cycle I | | | |
| Angus x Hereford | 8.5 | 9.7 | 1218 |
| Charolais-X | 7.0 | 11.5 | 1298 |
| Jersey-X | 8.3 | 12.1 | 1503 |
| Simmental-X | 7.6 | 13.1 | 1564 |
| RSD | 1.56 | 3.29 | 387 |
| Cycle II | | | |
| Angus x Hereford | 8.8 | 7.4 | 1051 |
| Red Poll-X | 8.2 | 8.7 | 1176 |
| Brown Swiss-X | 9.4 | 9.2 | 1300 |
| Gelbvieh-X | 8.7 | 9.2 | 1269 |
| Maine Anjou-X | 8.6 | 9.0 | 1224 |
| Chianina-X | 8.6 | 7.0 | 949 |
| Angus | 8.4 | 7.8 | 1050 |
| Hereford | 7.5 | 6.4 | 796 |
| Brown Swiss | 9.0 | 10.6 | 1523 |
| RSD | 1.72 | 1.66 | 244 |
| Straightbred | | | |
| Angus | 10.4 | 5.9 | 874 |
| Hereford | 8.6 | 4.2 | 574 |
| Charolais | 9.9 | 5.5 | 795 |
| Simmental | 10.4 | 5.8 | 858 |

[a]Sire breed listed. All sire breeds mated to Angus or Hereford cows.

Lactation Curves of Mature Cows. Weigh-suckle-weigh techniques were used to estimate parameters to describe lactation curves for a sample of breed crosses from Cycle I, all the breed crosses in Cycle II and straightbred Angus, Hereford, Charolais, Simmental and Brown Swiss. These data were collected in separate studies under dry lot conditions from cows that were a minimum of 6 years of age(table 3). For Cycle I cows, individual cow data were collected at eight to ten different times during the lactation period. Data for individual Cycle II cows and straightbred cows were collected at five or six different points during the lactation cycle as were data from straightbred Angus, Hereford, Charolais and Simmental in a separate study. An empirical model was fitted within cow to derive individual parameter estimates (Jenkins and Ferrell, 1984). Within breed or breedcross, parameter means were used to predict the lactation curves depicted in figures 1, 2 and 3. For breed crosses sampled from Cycle I, Simmental and Jersey $F_1$ cows produced a greater total yield than that of Angus x Hereford (and reciprocal) and Charolais $F_1$ cows (table 3). Maximum yield at time of peak lactation (table 3) was higher for Simmental $F_1$ and lower for the Hereford x Angus $F_1$ in Cycle I.

Among the Cycle II cows, the Red Poll, Brown Swiss, Gelbvieh and Maine Anjou $F_1$ cows tended to have a greater 203-day yield of milk than did the Angus x Hereford and Chianina $F_1$ cows (table 3). Time of peak lactation and yield at time of peak lactation tended to be similar. The Angus x Hereford $F_1$'s within both Cycle I and II were observed to have an early time of peak lactation relative to the breed crosses. Among the straightbreds, Brown Swiss had the greatest yield, both total and at time of peak lactation, when compared to Angus, Hereford, Charolais, and Simmental (table 3). Total yield and yield at time of peak lactation was lowest for the Hereford.

Although not measured directly, inspection of figures 1, 2 and 3 suggest that persistency of lactation (maintaining level of production after time of peak lactation) tends to be lower in those breeds or breed crosses being characterized as having the lowest milk yield. Notter et al. (1978) has reported similar findings. What effect persistency has on production output has not been investigated for beef cattle.

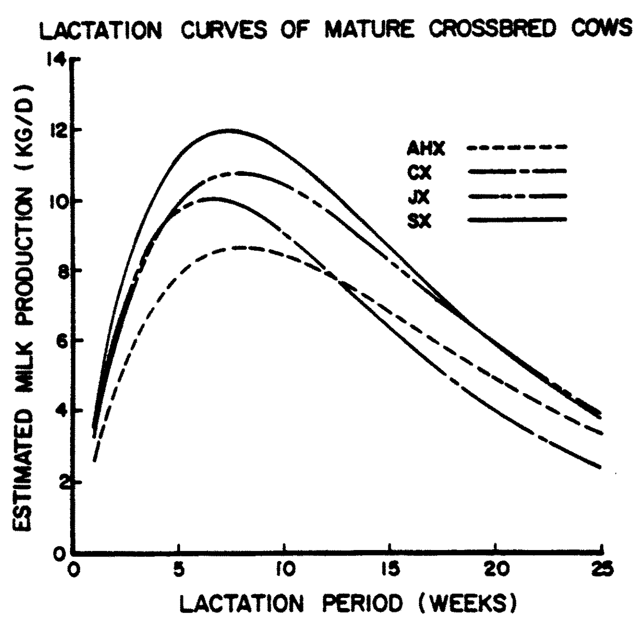


Figure 1. Estimated daily milk production of 8- and 9-year-old Angus x Hereford or Hereford x Angus (AHx), Charolais x Angus/Hereford (Cx), Jersey x Angus x Hereford (Jx) and Simmental x Angus/Hereford (Sx) $F_1$ cows (Jenkins and Ferrell, 1984).

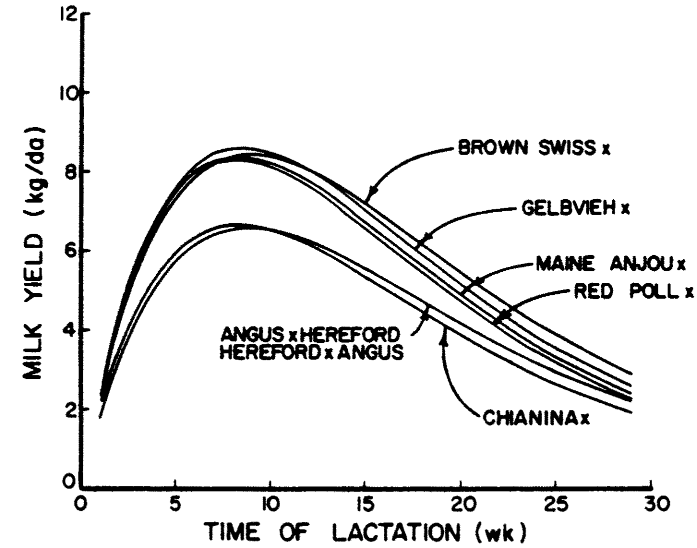


Figure 2. Estimated daily milk production of 8- and 9-year-old Angus x Hereford or Hereford x Angus (reciprocals pooled), Brown Swiss x Angus/Hereford, Gelbvieh x Angus/Hereford, Maine Anjou x Angus/Hereford, Red Poll x Angus/Hereford and Chianina x Angus/Hereford $F_1$ cows (Jenkins and Ferrell, 1984 unpublished).

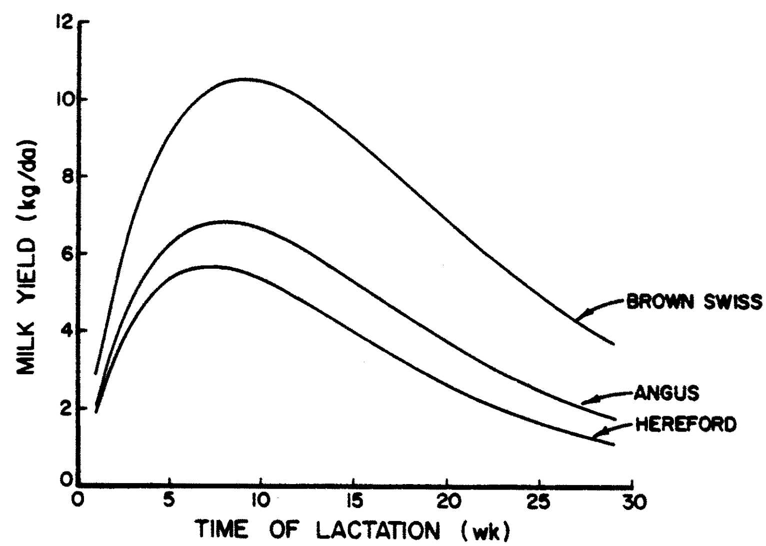


Figure 3. Estimated daily milk production of 8- and 9-year-old Angus, Hereford and Brown Swiss cows (Jenkins and Ferrell, 1984 unpublished).

## Characterization of Input Requirements of Varying Biological Types

Characterization of energetic requirements for a cow/calf enterprise may be partitioned into production unit components; for example, producing cows, replacement animals, preweaning calves, and bulls (Cartwright, 1970). Energy inputs for each production unit are required for maintenance, growth and development; for the producing female, gestation and lactation. To optimize production efficiency, these energy requirements should be satisfied in order to insure that the desired level of output is not restricted.

In 1979, a series of studies was initiated to characterize the energy requirements of mature crossbred females differing in genetic potential for mature size and milk production. To quantify energy requirements, feed intake during the defined physiological states of gestation, lactation and for open, dry cows has been collected and is being analyzed.

Indirect estimates of energy requirements for gestation and lactation of mature Angus x Hereford (AHx), Charolais x Angus/Hereford (Cx), Jersey x Angus/Hereford (Jx) and Simmental x Angus/Hereford (Sx) are reported in tables 4 and 5. Ferrell (1976) reported that energy requirements for gestation are a function of birthweight; therefore, the energy requirements for gestation were estimated using the average birthweights over a five-year period for each of the breed crosses. Assuming 1.06 Mcal of ME (NRC) required per kilogram of milk produced, the energy requirements for the physiological state of lactation were predicted using estimates of the milk yield for the breed crosses reported earlier.

TABLE 4. PREDICTED METABOLIZABLE ENERGY (ME) REQUIREMENTS FOR GESTATION OF DIVERSE BIOLOGICAL TYPES

| Breed cross | N | Calf birth weight (kg) | Gravid uterus energy (Mcal) | ME for gestation (Mcal) |
|---|---|---|---|---|
| Angus x Hereford | 528 | 41.5 | 72.4 | 529 |
| Charolais-X (A/H) | 483 | 44.3 | 78.5 | 573 |
| Jersey-X (A/H) | 431 | 37.8 | 66.3 | 484 |
| Simmental-X (A/H) | 624 | 42.0 | 77.0 | 562 |

TABLE 5. PREDICTED METABOLIZABLE ENERGY (ME) REQUIREMENT FOR A 165-DAY LACTATION PERIOD OF DIVERSE BIOLOGICAL TYPES

| Breed cross | N | Milk yield (kg) | ME intake[a] (Mcal) |
|---|---|---|---|
| Angus x Hereford | 15 | 1218 | 1300 |
| Charolais-X (Angus/Hereford) | 14 | 1298 | 1380 |
| Jersey-X (Angus/Hereford) | 14 | 1503 | 1600 |
| Simmental-X (Angus/Hereford) | 17 | 1564 | 1660 |

[a]Assumed 1.06 Mcal ME$\cdot$kg$^{-1}$ milk.

Energy requirements for maintenance (table 6) were predicted by using energy balance methodologies. Cows in this phase were open and dry. In each of two years, individual feed intakes were recorded for all animals along with weight change data. Body composition was estimated using deuterium oxide ($D_2O$) procedures at the initiation and termination of the study. Additional details of the procedures are reported by Ferrell and Jenkins (1984a,b). Metabolizable energy (ME) requirements per metabolic body size per day tended to be higher for the Jx and Sx relative to the AHx and Cx (145 and 160 kcal ME/kg$^{.75}$/day vs 130 and 129 kcal/kg$^{.75}$/day). This suggests that the genetic potential for level of milk production may affect maintenance requirements. Ranking for ME requirements for maintenance was 14.0, 14.2, 15.0 and 17.9 Mcal/day for the AHx, Jx, Cx and Sx, reflecting differences associated with size and level of milk production. Although the Jx had liveweights less than the AHx, the per day requirements for maintenance of Jx were greater than the AHx, with the greater milk production potential of Jx thought to be the underlying causal factor. Similarly, the Cx and Sx were comparable in liveweight; however, the maintenance energy requirement of Sx was greater than that of Cx. Again, this apparently reflects differences in energy required for maintenance that may be negatively related to genetic potential for milk production.

TABLE 6. PREDICTED METABOLIZABLE ENERGY (ME) REQUIREMENTS FOR MAINTENANCE OF MATURE NON-PREGNANT, NON-LACTATING COWS OF DIVERSE BIOLOGICAL TYPES

| Breed cross | N | Energy requirement (ME) | | |
|---|---|---|---|---|
| | | $kcal/kg^{.75} \cdot d^{-1}$ | $Mcal \cdot d^{-1}$ | $Mcal \cdot year^{-1}$ |
| Angus x Hereford | 22 | 130 | 14.0 | 5010 |
| Charolais-X (A/H) | 18 | 129 | 15.0 | 5475 |
| Jersey-X (A/H) | 17 | 145 | 14.2 | 5183 |
| Simmental-X (A/H) | 21 | 160 | 17.9 | 6533 |

The predicted energy expenditures of the above four breed crosses for a cycle are represented graphically in figure 4 with the breed crosses expressed relative to AHx. Differences existed among the breed crosses for predicted energy requirements during an annual production cycle. The largest component of energy requirement was maintenance and the relative variation among the breed crosses was largest for maintenance.

Energy intake for mature (8 and 9 years) lactating cows of the breed crosses from Cycle II of GPE is reported in table 7. The energy consumption of calves during the test interval are reported in table 8 (Cundiff et al., 1983). Cow size, milk production and growth characteristics of the calves (sired by Simmental bulls) are also reported for the 138-day test during the lactation period. These data were collected over a 2-year period, with feed consumption collected on replicated pens within breed crosses. The cows received energy at a level to allow expression of milk production potential but not weight change. AHx cows consumed the least amount of feed during the test interval while Brown Swiss x Angus/Hereford (BSx), Chianina x Angus/Hereford (CHx) and Gelbvieh x Angus/Hereford (Gx) consumed the greatest amount of feed. Conversely, AHx calves' consumption of ME from creep feed exceeded that of calves from BSx, CHx and Gx dams.

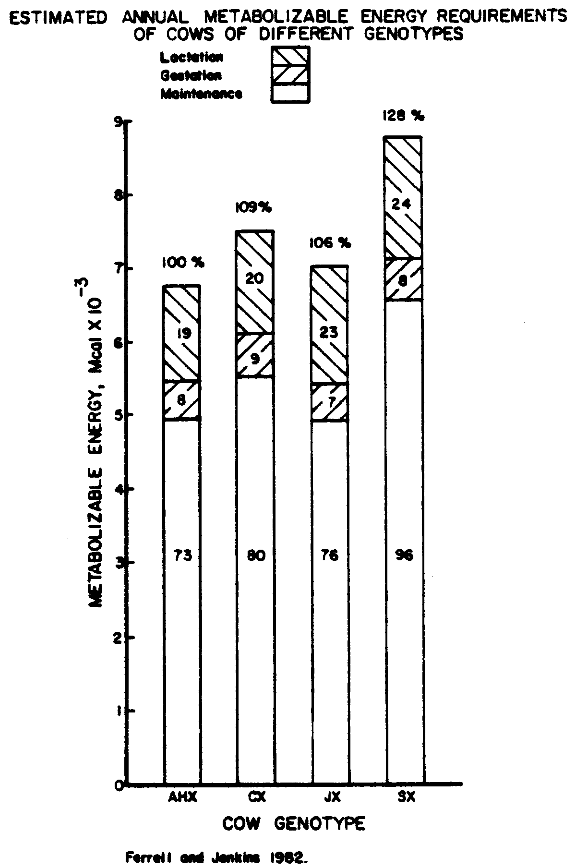


Figure 4. Estimated annual production cycle metabolizable energy requirements partitioned by physiological state for mature Angus x Hereford or Hereford x Angus (AHx), Charolais x Angus/Hereford (Cx), Jersey x Angus/Hereford (Jx) and Simmental x Angus/Hereford (Sx) cows. ME requirements of Cx, Jx and Sx are expressed relative to the AHx.

TABLE 7. CYCLE II GPE BIOLOGICAL EFFICIENCY STUDY[a]

| Breed cross | Average cow weight (lb) | Milk production (lb/day) | ME (Mcal) |
|---|---|---|---|
| Angus x Hereford | 1130 | 14 | 3443 |
| Red Poll-X (A/H) | 1040 | 18 | 3629 |
| Brown Swiss-X (A/H) | 1110 | 21 | 3967 |
| Gelbvieh-X (A/H) | 1153 | 19 | 3966 |
| Maine Anjou-X (A/H) | 1234 | 18 | 3972 |
| Chianina-X (A/H) | 1228 | 14 | 3922 |

[a]138-day period; Cundiff et al. (1983).

TABLE 8. PROGENY CHARACTERISTICS FOR CYCLE II GPE BIOLOGICAL EFFICIENCY STUDY[a]

| Breed cross | Age on test (d) | Initial wt. (lb) | Final wt. (lb) | ADG (lb) | ME (Mcal) |
|---|---|---|---|---|---|
| Angus x Hereford | 44 | 176 | 509 | 2.41 | 792 |
| Red Poll (A/H) | 46 | 195 | 541 | 2.48 | 761 |
| Brown Swiss (A/H) | 45 | 200 | 554 | 2.56 | 734 |
| Gelbvieh (A/H) | 46 | 202 | 548 | 2.53 | 711 |
| Maine Anjou (A/H) | 45 | 205 | 559 | 2.56 | 730 |
| Chianina (A/H) | 44 | 200 | 539 | 2.45 | 738 |

[a]Sired by Simmental bulls; Cundiff et al. (1983).

the test interval while Brown Swiss x Angus/Hereford (BSx), Chianina x Angus/Hereford (Chx) and Gelbvieh x Angus/Hereford (Gx) consumed the greatest amount of feed. Conversely, AHx calves' consumption of ME from creep feed exceeded that of calves from BSx, CHx and Gx dams.

## Output/Input Differences in Biological Types

Efficiency is normally described as a ratio of output to input and will be defined as the pounds of weight weaned per cow exposed (Cycle I) or weight gain in a period (Cycle II) relative to the Mcal of metabolizable energy consumed. To derive efficiency estimates for the four breed crosses from Cycle I, the following assumptions were made regarding energy inputs:

1) Energy requirement for protein accretion (growth) is equal to zero for mature cows.
2) Energy was provided at the level required to maintain body weight, gestation and lactation (i.e. body compostion remained constant) throughout a production cycle.
3) Energy requirements are additive across physiological states.

Output information was based on the average performance of the cows from 4 to 8 years of age as reported by Cundiff (1981) and are given in table 9. As Dickerson (1978) suggested, genetic potential for performance affects production efficiency through associative factors. For this reason, weaning weights per calf weaned for each breed cross were multiplied by the average weaning percentage. Output for Cycle I cow is defined as pounds of calf weaned per cow exposed (table 9). Efficiency ratios (lb/Mcal ME x 100) for AHx, Jx, Cs and Sx were 6.54, 6.14, 6.14 and 5.56, respectively (table 10). Expressed relative to the average of the four breed crosses (6.10 lb/Mcal ME x 100), the AHx cross was six (6) percentage units more efficient than the Jx and Cx which were ten (10) percentage units more efficient than the Sx. The pounds of calf weaned per cow exposed of the AHx was approximately 9% less than the Sx, 2% less than the Cx and equal to the Jersey. This extra production by the Cx and Sx was not sufficient to offset the increased energy requirements (primarily from maintenance), resulting in reduced efficiencies.

TABLE 9. PRODUCTION CHARACTERISTICS OF DIVERSE BIOLOGICAL TYPES OF COWS

| Breed cross | Mature wt (kg) | Calves born | Calf birth-wt. (kg)[a] | Weaning % | Weaning wt. (kg)[a] Avg. | Weaning wt. (kg)[a] Per cow exposed |
|---|---|---|---|---|---|---|
| Angus x Hereford | 514 | 528 | 41.5 | 88.2 | 230 | 203 |
| Charolais-X (A/H) | 572 | 483 | 44.3 | 84.8 | 245 | 207 |
| Jersey-X (A/H) | 451 | 431 | 37.8 | 86.4 | 235 | 203 |
| Simmental-X (A/H) | 540 | 624 | 42.0 | 88.0 | 251 | 221 |

[a]Average of male and female calves sired by Brown Swiss bulls.

TABLE 10. PREDICTED EFFICIENCY OF MATURE COWS OF DIVERSE BIOLOGICAL TYPES (X100)[a]

| Cow breed cross | Weaning (lb/ME, Mcal) | Feed lot (lb retail) product/ME, Mcal) | System (lb retail product/ total ME intake) |
|---|---|---|---|
| Angus x Herford | 6.54 (1.07) | 8.99 (1.00) | 3.65 (1.04) |
| Charolais-X (A/H) | 6.14 (1.01) | 9.71 (1.08) | 3.64 (1.04) |
| Jersey-X (A/H) | 6.14 (1.01) | 7.49 ( .84) | 3.35 ( .96) |
| Simmental-X (A/H) | 5.56 ( .91) | 9.64 (1.08) | 3.35 ( .96) |

[a]Per cow exposed; Jenkins and Ferrell (1983).

Cundiff et al. (1983) reported intake and output of mature cows with 100% calf crop from Cycle II of the GPE for a 138-day interval during the lactation period. Efficiency was defined as pounds of weight gain by the calf relative to the Mcal of ME consumed by the cow and calf during the test interval (lb gain/Mcal ME, cow + calf x 100). The efficiency estimates reported in table 11 indicate significant differences among breed crosses for production. The AHx, Red Poll x Angus/Hereford (RPX) and Maine Anjou x Angus/Hereford (MAx) were significantly more efficient than the Gelbvieh x Angus/Hereford (Gx) and Chianina x Angus/Hereford (CHx). The Brown Swiss x Angus/Hereford (BSx) was intermediate and did not differ (P>.05). As indicated earlier in the discussion, the cows were fed at a level that allowed potential for milk production without change in cow weight. Inspection of the information in tables 7 and 8 indicate that calves from AHx cows consumed the greatest amount of energy from creep and tended to have the lowest daily weight gain, resulting in the smallest output. However, less energy was required by the AHx cows for lactation and maintenance resulting in a favorable efficiency ratio. Cows of the breed cross with the smallest efficiency ratio, CHx, consumed the greatest amount of feed and had a daily milk yield similar to the AHx, thus suggesting a higher maintenance requirement.

TABLE 11. PREDICTED EFFICIENCY OF BREED CROSS DURING THE LACTATION PERIOD (X 100)[a]

| Cow breed cross | Mcal + ME (cow + calf) | Weight gain calf (lb) | Calf weight gain per Mcal (cow + calf) | Ratio |
|---|---|---|---|---|
| Angus x Hereford | 4235 | 333 | 7.86 | 103 |
| Red Poll-X (A/H) | 4390 | 346 | 7.88 | 103 |
| Brown Swiss-X (A/H) | 4701 | 354 | 7.53 | 99 |
| Gelbvieh-X (A/H) | 4677 | 346 | 7.39 | 97 |
| Maine Anjou-X (A/H) | 4522 | 354 | 7.83 | 103 |
| Chianina-X (A/H) | 4660 | 339 | 7.27 | 95 |

[a]Progeny sired by Simmental sires; Cundiff et al. (1983).

Based on data collected on output (pounds of calf weaned) and input (Mcal ME consumed), variation apparently exists among breed crosses. When energy intake is predicted within defined physiological states, information suggests that the primary difference among breed crosses may be attributable to differences in energy required to maintain body mass in mature cows. From 65 to 75% of the energy consumed in a cow/calf operation may be required to ensure the existence of a viable herd of females, and failure to meet this requirement may be reflected in poorer reproductive performance.

## Maintenance

The term maintenance may be defined as the level of feed or energy intake required by an animal for zero body weight or body energy change. Maintenance is an indirect estimate of fasting heat production (FHP) which is the heat production of an animal during a postabsorbative state. Feeding systems such as NRC and ARC have assumed that the energy required for maintenance is proportional to body weight to some exponent (.70 to .75), referred to as metabolic size. Information is now being reported that suggests maintenance requirement, per unit metabolic size, is not static but is affected by such factors as sex, age, previous and present level of nutrition, thermal environment and germ plasm potential. Anderson (1980) reported estimates of maintenance for growing bulls from 300 to 550 kg sired by Limousin, Hereford, Charolais, Blond d'Aquitaine, Simmental and Chianina bulls (table 12). A trend observed was that as level of performance (performance defined as rate of live weight change) increased, so did the estimate of maintenance.

Maintenance requirement estimates for various breeds and breed crosses during defined physiological states are reported in table 13. These again are point estimates and should be compared within study. As reported earlier, maintenance requirements estimated during the winter for open, dry cows from Cycle I (Ferrell and Jenkins, 1984) appear to be related to milk production

TABLE 12. BREED CROSS ESTIMATES OF MAINTENANCE REQUIREMENTS[a,b]

| Breed[c] | Maintenance (kcal/kg$\cdot^{73}$/d)[d] | Ratio (X100) |
|---|---|---|
| Limousin | 118 | 93.4 |
| Hereford | 124 | 98.2 |
| Charolais | 125 | 98.9 |
| Blond d'Aquitaine | 126 | 99.7 |
| Simmental | 131 | 103.7 |
| Chianina | 134 | 106.1 |

[a]Anderson (1980).
[b]Estimated from bulls between 300-550 kg.
[c]$F_1$ produced from matings of Limousin, Hereford, Charolais, Blond d'Aquitaine, Simmental and Chianina with Red Danish, Black Danish and White Danish cows.
[d]SE=4.54

TABLE 13. ESTIMATES OF METABOLIZABLE ENERGY REQUIRED FOR MAINTENANCE OF VARIOUS BREEDS AND BREED CROSSES[a,b]

| Breed or breed cross | Physiological state | | Maintenance (kcal/kg$\cdot^{75}$/day) | |
|---|---|---|---|---|
| Angus x Hereford[a] | 9-10 yrs. non-pregnant, non lactating[b] | | 130 | |
| Charolais-X | '' '' '' | | 129 | |
| Jersey-X | '' '' '' | | 145 | |
| Simmental-X | '' '' '' | | 160 | |
| Angus x Hereford[a] | 8-9 yrs. lactating[c] | | 151 | |
| Red Poll-X | '' '' | | 157 | |
| Brown Swiss-X | '' '' | | 156 | |
| Gelbvieh-X | '' '' | | 158 | |
| Maine Anjou-X | '' '' | | 146 | |
| Chianina-X | '' '' | | 174 | |
| Angus | 5-6 yrs. lactating[d] | | 141 | |
| Hereford | '' '' | | 149 | |
| Simmental | '' '' | | 166 | |
| Charolais | '' '' | | 165 | |
| Angus | 5-6 yrs. non-lactating[e] | 86 | | 149 |
| Hereford | '' '' | 99 | | 142 |
| Simmental | '' '' | 116 | | 151 |
| Hereford | 9-15 months[f] | | 106 | |
| Simmental | '' | | 126 | |

[a]$F_1$'s produced from Angus, Hereford, Charolais, Jersey, Simmental, Red Poll, Brown Swiss, Gelbvieh, Maine Anjou and Chianina matings on Angus or Hereford cows.
[b]Ferrell and Jenkins (1984b).
[c]Cundiff et al. (1983).
[d]Ferrell and Jenkins (unpublished).
[e]Ferrell and Jenkins (1984c).

potential. Among mature lactating cows from Cycle II monitored during the summer, variation among breed crosses for ME required per weight$^{.75}$ was observed (estimated from Cundiff et al., 1983). However, trends associating milk production potential or size with maintenance estimate were not observed. Ranking from high to low for kcal ME/kg$^{.75}$/day for lactating straight breeds during the summer was Simmental (166), Charolais (165), Angus (149) and Hereford (141) (Ferrell and Jenkins, unpublished data). To evaluate the effect of previous nutrition on maintenance requirements, dry Angus, Hereford and Simmental cows differing in subjective condition score within breed were evaluated (Ferrell and Jenkins 1984c). Within each breed, cows above average condition required more energy to maintain body mass per unit of metabolic body size than did cows that were below average in body condition. The highest energy requirement per unit body size under both levels of previous condition was observed for the Simmental; however, the differences among breeds were greatest among cows in poorer condition. For growing bulls and heifers, Ferrell and Jenkins (1984d) reported significant breed differences in ME requirements per unit metabolic body size between Hereford and Simmental. Relative to the Herefords, postweaning Simmental cattle required 19% more ME per metabolic body size for maintenance.

The basis for variation among cattle germ plasm resources may reflect differences in response (natural or artificial selection) to nutrient conditions in which the breeds evolved. At high energy intake levels, Bos taurus breeds characteristically have higher average daily gain than Bos indicus (Baker et al., 1973), but in tropical or subtropical conditions the rankings may be reversed (Kennedy and Chirchir, 1971). Frisch (1973) reported that during drought conditions (restricted nutrient environment) Zebu crossbred cattle lose less weight than do British cattle. The information seems to suggest that as animal performance increases, the level of adaptability with regard to energy requirements for maintenance may be decreased. Frisch and Vercoe (1977) reported data on the effect of quality and availability of forage on FHP for postweaning steers (table 14). The animals used in the study were $F_3$ and $F_4$ generation Brahman x Hereford x Shorthorn (Bx), Africander x Hereford x Shorthorn (Ax) and Hereford x Shorthorn (HS). At ad libitum levels of intake, the highest FHP was observed for the HS on both the high quality (alfalfa) and low quality (pasture hay) diets. While all breed crosses exhibited the ability to alter FHP due to diet, the reduction in FHP was smallest in the HS. Similar findings were reported under restricted levels of intake. These results agree with work by Ledger and Sayer (1977), who reported maintenance requirements of imported vs cattle indigenous to tropical areas. In this study, all breed crosses' energy requirements for maintenance decreased as level of nutrition decreased, but the decrease in requirements of the Boran was the greatest.

TABLE 14. FASTING METABOLISM OF HEREFORD X SHORTHORN, BRAHMAN X (HEREFORD X SHORTHORN) AND AFRICANDER X (HEREFORD X SHORTHORN) STEERS AT TWO LEVELS OF INTAKE OF TWO DIETS DIFFERING IN QUALITY

| | Fasting metabolism (kcal/kg) | | | | | |
|---|---|---|---|---|---|---|
| | Ad libitum hay intake | | | Restricted hay intake | | |
| Breed | Alfalfa | Pasture | % | Alfalfa | Pasture | % |
| BX | 22.4[a] | 19.9[a] | 11.2 | 19.8[a] | 18.6 | 6.1 |
| AX | 23.6[b] | 20.3[a] | 14.0 | 19.8[a] | 19.1 | 3.5 |
| HS | 23.4[b] | 21.2[b] | 9.2 | 21.5[b] | 21.0 | 2.3 |

[a]HS = Hereford x Shorthorn; AX = Africander x (Hereford x Shorthorn); BX = Brahman x (Hereford x Shorthorn); $F_3$ and $F_4$ generation.

The above information provides indirect evidence that improvement in breed characteristics that are deemed of importance by a producer may have an undesirable effect on the ability of the animal to adjust to fluctuations in the nutrient environment. Further documentation may be found in a study reported by Sundstol et al. (1979). This report contains information regarding the effects of selection on the FHP of two lines of pigs. From a common population, one line was selected for daily gain to 90 kg during the postweaning period and a second line was selected for increased backfat thickness. After six to seven generations of selection, differences in average daily gain and backfat depth were observed between the two lines (table 15). Fasting heat production (kcal/kg$^{.75}$) was measured when animals from each line were fed at maintenance and at three times maintenance. At high feed intakes, no differences were observed in FHP between the two lines; however, at maintenance the FHP of the line selected for increased fat deposition was significantly lower than that of the line selected for increased growth rate. Perhaps these results may serve as possible evidence that single trait selection to maximize an output component may reduce adaptability of animals to low levels of energy intake.

TABLE 15. EFFECT OF ENERGY INTAKE LEVEL ON FASTING HEAT PRODUCTION OF SWINE SELECTED FOR EITHER RATE OF GAIN OR THICKNESS OF BACKFAT[a]

| Selection line | Daily gain to 90 kg (g/d) | Backfat thickness (mm) | Heat production (kcal/kg$^{.75}$) |
|---|---|---|---|
| Lean | 594 | 21.8 | |
| Fat | 531 | 42.2 | |
| Lean | | | |
| Maintenance | | | 119 |
| 3 x maintenance | | | 176 |
| Fat | | | |
| Maintenance | | | 104 |
| 3 x maintenance | | | 173 |

[a]Sundstol et al. (1979).

Increasing rate of gain during the postweaning interval may be partitioned into accretion of the major chemical components of the body, specifically fat, protein and ash. Leymaster and Jenkins (1984a,b) evaluated the effects of fat (ether extract), protein and ash accretion of the carcass and offal on rate of growth in ram lambs between 70 and 160 lb. Figure 5 summarizes the results obtained from a path coefficient analysis. Eighty percent of the variation in average daily gain among Suffolk ram lambs was accounted for by direct and indirect effects of the deposition rates. The largest direct effect on rate of growth was attributable to rate of offal protein accretion. This suggests that selection for average daily gain may represent indirect selection for protein accretion in the offal. Ferrell et al. (1983) reported similar results where rate of gain in sheep constituted treatment groups with rate of gain controlled by feed intake. Weights of the gastrointestinal tract, liver, pooled internal organs, hard drop and carcass accounted for 67% of the variation in average daily gain (figure 6). The highly metabolically active tissues, liver and gastrointestinal tract, had the largest direct effect.

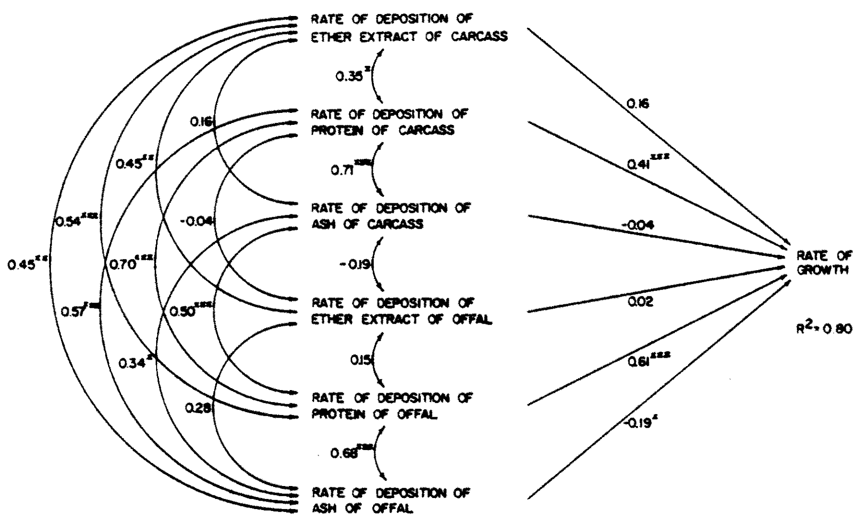


Figure 5. Results from path coefficient analysis depicting direct and indirect relationships among accretion rates of carcass and offal chemical components and average daily gain for *ad libitum* fed Suffolk rams between 70 and 160 lb (Leymaster and Jenkins, 1984a,b).

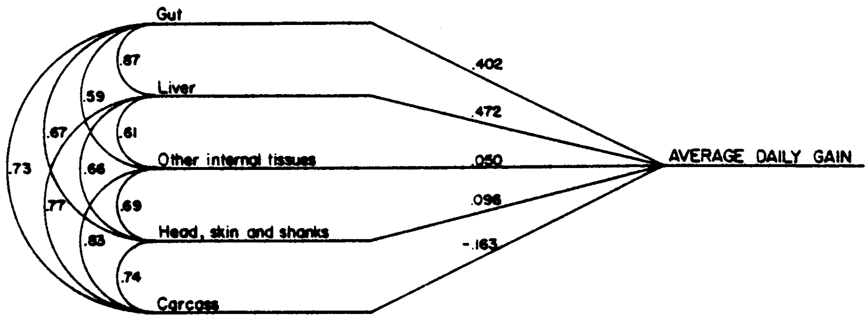


Figure 6. Results from path coefficient analysis depicting direct and indirect relationships among weights of body components and average daily gains for lambs fed to attain constant slaughter weights via differing average daily gains (Ferrell et al., 1983).

Offal protein accretion and weight of the gastrointestinal tract have been shown to be of major importance in affecting postweaning average daily gain. The question now becomes: "What contributions do these tissues make to maintenance?" In the previous paragraph, the term "highly metabolically active tissue" was used. This term indicates the relative activity of the internal organs with regard to protein synthesis, which has been shown to be highly related to FHP. As indicated earlier, FHP is the major component of maintenance. Webster (1980) reported that 58% of protein synthesis occurs in the gut and liver compared to 14% in muscle. Therefore, these metabolically active tissues would be expected to require a large fraction of ingested energy. As indicated earlier in the discussion, FHP is affected by previous nutritional treatment both between and within breeds. Ferrell et al. (1983) reported significant energy intake effects on sheep for the weight of stomach, large intestine and liver. Animals slaughtered at the same weight that were on the low-high intake treatment prior to slaughter had heavier organs than the animals that were on the high-low treatment. Fasting heat production followed the same significance pattern (figure 7).

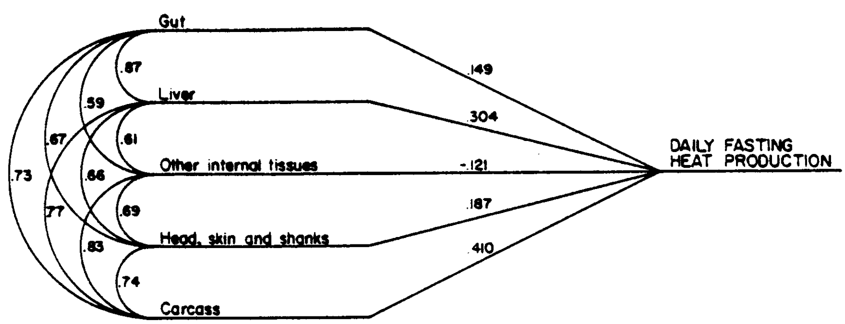


Figure 7. Results from path coefficient analysis depicting direct and indirect relationships among weights of body components and daily fasting heat production for lambs fed to attain constant slaughter weights via differing average daily gains (Ferrell et al., 1983).

Postweaning average daily gain is only one example of a characteristic of performance. In the producing cow, level of milk production is another characteristic that can be associated with metabolically active tissues. Jenkins et al. (1981) reported that dairy breeds and dairy breed crosses had significantly greater soft drop (offal) components than did beef breeds or crosses among beef breeds. Weights of metabolically active organs such as the lung, liver and kidney were obtained in the slaughter of the cows from Cycle II of GPE. If high milk producing crosses (RPx, BSx, Gx and Mx) are contrasted to breed crosses characterized as having lower milk production (table 16), the results indicate that on a metabolic size basis, higher milk producing cows have heavier livers and lungs (Jenkins et al., unpublished).

TABLE 16. LINEAR CONTRAST OF BODY ORGANS OF HIGHER METABOLIC ACTIVITY FOR HIGH VS MEDIUM MILK PRODUCTION BREED CROSSES AND LEVEL OF NUTRITION FROM CYCLE II OF GERM PLASM EVALUATION

| | Heart ($g/kg^{.75}$) | Lung ($g/kg^{.75}$) | Liver ($g/kg^{.75}$) | Kidney ($g/kg^{.75}$) |
|---|---|---|---|---|
| Contrast | | | | |
| Milk[a] | 1.92 | 5.61** | 5.83** | 1.86 |
| Nutrition | | | | |
| b | -1.04** | -2.17** | 2.44* | -0.35** |
| c | -0.17 | .58 | 2.98* | 0.37* |

[a] 1/4 (Red Pollx + Brown Swissx + Gelbviehx + Maine Anjoux)-(Angus x Hereford + Chianinax).
[b] 1/2 (Ad libitum - 1/4 (Restricted + Initial).
[c] 1/2 (Initial) - 1/2 (Restricted).

As would be expected, differences exist among breeds for transmitted and maternal effects on weights of organs. Results for Angus, Hereford and Brown Swiss are reported in table 17 (Jenkins et al., unpublished). The Hereford transmitted effect for these organs was signficantly less than the Brown Swiss for all organs ($gm/kg^{.75}$) and differed from the Angus for all organs except the heart.

TABLE 17. BREED DIFFERENCES IN TRANSMITTED AND MATERNAL EFFECTS OF BODY ORGANS OF HIGHER METABOLIC ACTIVITY

| Parameter | Breed[a] | Heart ($g/kg^{.75}$) | Lung ($g/kg^{.75}$) | Liver ($g/kg^{.75}$) | Kidney ($g/kg^{.75}$) |
|---|---|---|---|---|---|
| Purebreds ($\mu$) | $P_n$ | 23.2 | 30.3 | 51.4 | 11.6 |
| Transmitted ($g_i^I$) | A | -0.50[a] | -0.80[a] | 2.26[a] | 0.48[a] |
| | H | -1.15[a] | -2.84[b] | -4.75[b] | -0.87[b] |
| | BS | 1.65[b] | 3.63[c] | 2.49[a] | 0.39[a] |
| Maternal ($g_i^M$) | A | 0.09[a] | -0.54[a] | -1.93[a] | -.23[a] |
| | H | 0.45[a] | -1.23[a] | -0.35[a] | 0.14[a] |
| | BS | -0.54[a] | 1.78[b] | 2.28[b] | .09[a] |
| Average heterosis | h[c] | 0.43 | -2.28** | 0.21 | 0.40 |
| Mean | | 23.0 | 28.3 | 51.2 | 11.5 |

[a]A = Angus, H = Hereford and BS = Brown Swiss.
[b]Values with superscripts not in common differ at $P \leq .05$.
[c]**Differ at $P \leq .01$.

## Summary and Conclusions

Information was presented indicating that breeds and breed crosses differ in production characteristics with regard to both output (weaning weight) and input (ME required during defined physiological states). For cow/calf production, the ratio of output to input may be affected by the energy requirements during each of the defined physiological states and the ability of the producing female to respond to the fluctuating nutrient environment. Breeds or breed crosses evolving (via natural or artificial selection) to higher levels of performance (mature size, milk production or post weaning growth potential) could have decreased ability to adapt to poorer nutrient environments. Evidence was presented that this may be especially true when the maintenance component is considered.

Maintenance is not static but can be affected by factors such as breed, previous and present nutrient intake and thermal environment. Reproductive performance of the cows in production years following nutrient restriction would be expected to be decreased resulting in lower production efficiency. If cows that fail to conceive because of feed energy restrictions are retained in the cow herd until the following breeding season, the value of the efficiency ratios assigned would be zero, a valid measurement.

Additional research effort is required to establish the genetic relationships between performance traits and energy consumption of metabolically active tissues. This information could be used to classify females for use in the producing herd.

## Literature Cited

Anderson, B.B. 1980. Feeding trials describing net requirements for maintenance as dependent on weight, feeding level, sex and genotype. Ann. Zootech. 29:85-92.

Baker, F.S., Jr., A.Z. Palmer and J.W. Carpenter. 1973. Brahman x European crosses vs British breeds. In: Crossbreeding Beef Cattle. Series 2. (ed. M. Koger, T.J. Cunda and A.C. Warnick), pp. 277-284, Univ. Florida Press, Gainesville.

Brody, S. and R. Cunningham. 1936. Growth and development. XXXIX. Relation between monetary profit and energetic efficiency of milk production with special reference to the influence of liveweight thereon. Mo. Agr. Exp. Sta. Res. Bull. 239.

Cartwright, T.C. 1970. Selection criteria for beef cattle -- for the future. J. Anim. Sci. 30:706-711.

Cundiff, L.V. 1981. Germ Plasm Evaluation Program Progress Report No. 9. USDA-ARS Publ.

Cundiff, L.V., C.L. Ferrell and T.G. Jenkins. 1983. Output/input differences among $F_1$ cows of diverse biological type. J. Anim. Sci. 57 (Suppl. 1):L48 (Abstract).

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

Ferrell, C.L., W.N. Garett and N. Hinman. 1976. Growth development and composition of the udder and gravid uterus of beef heifers during pregnancy. J. Anim. Sci. 42:1477-1489.

Ferrell, C.L. and T.G. Jenkins. 1984a. Relationship among various body components of mature cows. J. Anim. Sci. 58:222-233.

Ferrell, C.L. and T.G. Jenkins. 1984b. Energy utilization by mature, nonpregnant, non-lactating cows of different types. J. Anim. Sci. 234-243.

Ferrell, C.L. and T.G. Jenkins. 1984c. A note on energy requirements for maintenance of lean fat Angus, Hereford and Simmental cows. Anim. Prod. (Accepted).

Ferrell, C.L. and T.G. Jenkins. 1984d. Energy utilization by Hereford and Simmental males and females. Anim. Prod. (Submitted).

Ferrell, C.L., J.A. Neinaber and L.J. Koong. 1983. Effects of previous nutrition on maintenance requirements and efficiency of feed utilization of growing lambs. J. Anim. Sci. 57 (Suppl. 1): 431-432 (Abstr.).

Frisch, J.E. 1973. Comparative drought resistance of Bos indicus and Bos taurus crossbred herds in central Queensland. 2. Relative mortality rates, calf birth weights and weight changes in breeding cows. Aust. J. Exp. Agric. An. Husb. 13:117-126.

Frisch, J.E. and J.E. Vercoe. 1977. Food intake, eating rate, weight gains, metabolic rate and efficency of feed utilization in Bos taurus and Bos indicus crossbred cattle. Anim. Prod. 25:343-358.

Gregory, K.E. 1972. Beef cattle type for maximum efficiency "putting it all together". J. Anim. Sci. 34:881-884.

Jenkins, T.G. and C.L. Ferrell. 1983. Estimated production efficiencies of crossbred cows. J. Anim. Sci. 57 (Suppl. 1):154 (Abstr.).

Jenkins, T.G. and C.L. Ferrell. 1984. A short note on the lactation curves of mature cows. Anim. Prod. (Accepted).

Jenkins, T.G., C.R. Long and T.C. Cartwright. 1981. Characterization of cattle of a five breed diallel. IV. Slaughter and carcass characteristics of serially slaughtered bulls. J. Anim. Sci. 53:62-79.

Joandet, G.E. and T.C. Cartwright. Estimation of efficiency for beef production. J. Anim. Sci. 29:862-868.

Kennedy, J.F. and G.I.K. Chirchir. 1971. A study of the growth rates of $F_2$ and $F_3$ Africander cross, Brahman cross and British cross cattle from birth to 18 months old in a tropical environment. Aust. J. Exp. Agric. Anim. Husb. 11:593-598.

Kleiber, M. 1936. Problems involved in breeding for efficiency of food utilization. Proc. Amer. Soc. of Anim. Prod. 29:247-248.

Laster, D.B., G.M. Smith and K.E. Gregory. 1976. Characterization of biological types of cattle. IV. Postweaning growth and puberty. J. Anim. Sci. 43:63-70.

Laster, D.B., G.M. Smith, L.V. Cundiff and K.E. Gregory. 1976. Characterization of biological types of cattle (Cycle II). II. Postweaning growth and puberty of heifers. J. Anim. Sci. 48:500-508.

Ledger, H.P. and A.R. Sayers. 1977. The utilization of dietary energy by steers during periods of restricted food intake and subsequent realimentation. J. Agric. Sci. Camb. 88:11-26.

Leymaster, K.A. and T.G. Jenkins. 1984b. Phenotypic variation in chemical composition of male Suffolks. 1. Composition at 32 and 73 kg live weight. Anim. Prod. (Submitted).

Leymaster, K.A. and T.G. Jenkins. 1984b. Phenotypic variation in chemical composition of male Suffolks. 2. Rates of deposition. Anim. Prod. (Submitted).

Morris, C.A. and J.W. Wilton. 1976. Influence of body size in the biological efficiency of cows: A review. Can. J. Anim. Sci. 56:613-647.

Notter, D.R., L.V. Cundiff, G.M. Smith, D.B. Laster and K.E. Gregory. 1978. Characterization of biological types of cattle. VII. Milk production in young cows and transmitted and maternal effects on postweaning growth of progeny. J. Anim. Sci. 46:908-921.

Stewart, T.S. and T.G. Martin. 1983. Optimal size of Angus cows for maximum cow productivity. Anim. Prod. 37:179-182.

Sundstol, F., N. Standel and O. Vangen. 1979. Energy metabolism in lines of pigs selected for thickness of backfat and rate of gain. Acta. Agr. Scand. 29:337-345.

Webster, A.J.F. 1980. The energetic efficiency of growth. Livestock Prod. Sci. 7:243-25

# ENERGETICS FROM BIRTH TO SLAUGHTER

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## Introduction

This presentation dealing with energetics from birth to slaughter will be restricted to the aspects of cow and calf efficiency in line with the title of the forum and the time restrictions on the presentation. Topics dealt with are annual cow efficiency, what a cattleman might expect to find in the way of variation in this trait in his own herd, factors affecting the trait and methods that might be used to improve it.

If we are to discuss cow efficiency, we need to define the term so that everyone is thinking about the same thing. Efficiency is the relationship between input and output and is frequently calculated as a ratio of one to the other. At South Dakota State University we have used pounds of Total Digestible Nutrients (TDN) required to produce a pound of product either at weaning or at slaughter. The TDN input is that consumed by the cow for the year from weaning to weaning plus the consumption of the calf from birth to weaning or slaughter. In our situation, calf consumption to weaning is creep consumption. In the producer's situation, it is grass consumed plus creep consumption if it is provided.

In addition to defining efficiency, it might be well to indicate that we will be primarily discussing the situation in your herd and not comparing your herd to some other alternative breeding plan such as changing from a British to a Continental breed or changing from small to large frame cattle. As you will see, our studies indicate that breed type and size have little or no effect on efficiency. This is not to say that breed differences other than those studied are not important but rather to emphasize that important differences in cow efficiency probably exist in every herd.

## Factors Affecting Cow Efficiency

The first phase of our cow efficiency research started in 1970 and involved cows of the Angus and Charolais breeds and the reciprocal crosses of these breeds. These cows were produced from a wide sampling of cows of the two breeds in South Dakota and one bull of each breed. Half sib cows were carried under two management groups, one managed as a typical farm cow herd utilizing pasture as available and usual winter time feeds while the other was maintained in drylot where complete energy intake of cow and calf could be measured. The drylot cows were fed to maintain growth and condition patterns similar to the pasture cows. This experiment started with 18 cows of each of the four breed groups and continued until the oldest cows had had an opportunity to produce eight calves.

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Among the first studies of these data was that of Marshall et al. (1976) which evaluated factors that cause differences in efficiency at weaning. Results indicated that year effects with their usual large influence on weaning weight significantly influenced efficiency at weaning. In addition, sex and age of calf were important, but age of dam and breed were not. Breed of dam groups evaluated were Angus, Charolais and the reciprocal crosses. A second part of the study evaluated the importance of cow weight, condition and milk production in determining efficiency at weaning. For this population of cows, cow weight and condition had no effect, but milk production did influence efficiency, tending to improve it as milk production increased. Evaluations of the prediction of efficiency at weaning indicated that cow weight or cow condition alone had accuracies of only 1%, milk production 23% and weaning weight 62%. One might expect the latter since weaning weight is the measure of output in the efficiency equation. Brown and Dinkel (1982) studied data from the first 5 years of the project and found essentially the same results. There were a few differences but none of them significant. For example, in the first 3 years of the study efficiency seemed to increase slightly as cow weight increased, whereas the 5-year study indicated efficiency decreased slightly with increased cow weight. As indicated earlier, however, the association between cow weight and results would be alternating plus and minus around the zero point. Recent analysis of the data from the 8-year study by Buckley (1982) indicated essentially the same results.

A second phase of our cow efficiency project initiated in 1978 involved cows of the Hereford breed and the Simmental x Hereford and Angus x Hereford breed groups. A summary completed last year involving 43 Hereford, 87 Simmental x Hereford and 36 Angus x Hereford cows indicated no significant difference among these groups in cow efficiency at weaning. The largest difference between groups was .3 pound TDN per pound of weaning weight and that difference was between the Angus-Hereford and Hereford groups. This phase of the study is continuing with one of the major objectives being an estimate of the heritability of cow efficiency.

Perhaps an easier way of translating these results to your own herd is provided in table 1. Because cow weight and cow height have received so much attention, these have been included along with weaning weight, milk production and age of dam. Each breed group is listed separately with the number of cow year records indicated in parenthesis. The 10% of the breed group most efficient and the 10% least efficient are evaluated for the eight factors and the range is given in parenthesis to indicate the variability present. In addition, the breed group averages for the factors are presented. The relationships of weaning weight and milk production to efficiency (TDN/WW) closely agree in all breed groups with the possible exception of milk production in the Charolais-Angus. Since efficiency is measured as feed per pound of weaning weight produced, smaller values indicate higher efficiency.

Those people having difficulty accepting the fact that small cows are not more efficient should note that the difference in averaging cow weight between the most efficient and least efficent is quite small, with the range indicating that selection for the smallest cow in an attempt to select for efficiency would have resulted in selection of a least efficient cow in all breed groups. Both the analysis of the first 3 years' data and the first 5 years' data indicate

TABLE 1. HERD DESCRIPTION BY BREED GROUP

| Breed group | Weaning weight (lb) | Milk production (lb) | Weaning efficiency TND/WW[a] | Cow weight (lb) | Cow height (inches) | Cow age (yr) | Postweaning efficiency TDN/SW[b] | Postweaning efficiency TDN/RC[c] |
|---|---|---|---|---|---|---|---|---|
| Angus (63) | | | | | | | | |
| 6 most efficient | 602 | 46 | 8.7 | 909 | 46.1 | 3.7 | 7.6 | 19.7 |
| | (504-663) | (36-57) | | (834-1045) | (44-48) | | | |
| 6 least efficient | 393 | 39 | 13.1 | 902 | 45.3 | 2.7 | 9.3 | 26.8 |
| | (350-443) | (34-47) | | (829-976) | (44-47) | | | |
| Angus average | 495 | 50 | 10.7 | 927 | 45.7 | 3.6 | 8.3 | 22.3 |
| Ang x Char (52) | | | | | | | | |
| 5 most efficient | 560 | 55 | 9.0 | 1006 | 47.6 | 4.2 | 7.4 | 18.6 |
| | (504-614) | (41-67) | | (966-1066) | (46-50) | | | |
| 5 least efficient | 398 | 40 | 13.5 | 988 | 47.2 | 3.8 | 9.4 | 26.9 |
| | (366-432) | (32-54) | | (848-1130) | (46-49) | | | |
| A x C average | 502 | 47 | 11.0 | 969 | 47 | 3.5 | 8.6 | 23.3 |
| Char x Ang (62) | | | | | | | | |
| 6 most efficient | 580 | 48 | 8.6 | 992 | 46.9 | 4.3 | 7.1 | 16.6 |
| | (566-602) | (28-64) | | (975-1051) | (46-47) | | | |
| 6 least efficient | 366 | 48 | 14.4 | 976 | 46.5 | 2.8 | 10.3 | 30.1 |
| | (355-440) | (27-74) | | (921-1149) | (46-49) | | | |
| C x A average | 494 | 46 | 10.9 | 996 | 46.9 | 3.5 | 8.5 | 22.6 |
| Charolais (44) | | | | | | | | |
| 5 most efficient | 590 | 49 | 8.8 | 1021 | 48.4 | 4.2 | 7.7 | 19.2 |
| | (542-635) | (32-72) | | (959-1087) | (47-50) | | | |
| 5 least efficient | 420 | 39 | 13.5 | 1043 | 48.8 | 3.4 | 9.2 | 24.9 |
| | (316-490) | (32-44) | | (818-1188) | (47-50) | | | |
| Charolais average | 505 | 43 | 10.9 | 1050 | 48.8 | 3.5 | 8.5 | 22.2 |
| All breed average | 498 | 47 | 10.9 | 981 | 47.2 | 3.5 | 8.5 | 22.6 |
| | (316-663) | (22-74) | | (756-1247) | (42-52) | | | |

[a]TDN per pound of weaning weight.
[b]TDN per pound of slaughter weight.
[c]TDN per pound of retail cut.

essentially no effect of cow size on efficiency, and the range in weight for these most efficient and least efficient groups support these findings. It is obvious from these data, that if the cow herd were culled on the basis of cow weight, the average weight of the herd might change; but the efficiency of producing a pound of calf at weaning would not.

Cow height was included in the analysis because of recent emphasis on frame size. The results for frame size are similar to the results for cow weight. The largest difference in height between the most efficient and least efficient is in the Angus group and that amounts to about 3/4 inch. The other breed groups differ by only 3/8 inch. The range in cow height indicates that cow height could be affected considerably through culling a herd on that basis, but again the efficiency groups; and, in addition, these two groups overlap almost completely with regard to weight and height. Contrast this with weaning weight where there is no overlap at all. Obviously, this does not suggest that one select for intermediates on weight or height, as the data indicate that there are efficient and inefficient cows over a wide range of weights and heights. What these results do suggest is that one needs to select for the trait (efficiency) or the best predictor of the trait that is available rather than weight or height.

## Current Status

The lack of weight or height effect on weaning efficeincy has led some people to forget efficiency, either through feeling that efficiency is no longer important or that there is nothing in addition to their current selection for weaning weight that they can do about it anyway. If one considers the extreme range in individual cow records for weaning efficiency, we find in these data the most efficient cow required 8.2 lb and the least efficient 17 lb of TDN per lb of weaning weight. The difference of 8.8 lb is larger than the requirement of the most efficient cow. Temporary environmental effects that influence feed consumption and weaning weight can have a large effect on individual records such as these. Taking the average for the three calves which each of these cows produced, we find the difference has narrowed to 9.6 for the most efficient and 14 for the least efficient. This translates into an additional 2 ton of alfalfa hay required by the least efficient cow to produce a 500-lb calf. Another way of looking at it is that these inefficient cows are not producing 500-lb calves, but they are still consuming feed. In this case the inefficient cow produced a 385-lb calf while consuming the equivalent of 600 more lb of alfalfa hay than the most efficient cow which produced a 530-lb calf. This difference of 145 lb less calf and 600 lb more hay consumption does indicate the trait is important.

Because of this importance, it is necessary that we avoid the "nothing we can do about it" attitude and learn more about cow efficiency in order that we might better manage as well as breed for more efficient production. The analysis by Buckley and Dinkel (1981) has indicated that the repeatability of cow efficiency is probaby close to the level of repeatability of weaning weight. This means that we would have reasonably good accuracy in culling among cows on the basis of their efficiency of production for their first calf. Perhaps of more importance is the matter of finding better predictors of weaning efficiency in order that we might select our replacement heifers at weaning or yearling ages more accurately. The reason that is so important is that the high accuracy of weaning weight as a predictor of cow efficiency quoted earlier is based on the weaning weight of the calf produced by the cow rather than her own weaning weight. If we wait until the cow is in the herd and produced a calf, providing us the information to make our efficiency predictions, economically we have a hard time culling her as long as she settles for the next calf crop. To avoid this and to make maximum progress by selection, we need predictors of efficiency that can be utilized in selecting replacement heifers either at weaning or yearling ages.

Considerable confusion exists both in industry and in scientific circles with regard to interpretation and application of experimental results currently available. Part of this stems from faulty design and interpretation of some experiments and experiments involving too few animals. For example, if one is truly interested in evaluating effects of cow size free of other sources of variation, then all cows should be fed at a level that will allow them to reproduce at their genetic potential. If this is not done, the experimental results will not be indicative of cow size effects alone but will be a mixture of cow size and nutritional level. This confounding of the two sources of variation prevents accurate interpretation of the results. Similar confounding of breed of service sire, breeding value of service sire and calf heterosis with cow size effects exists in other research results. In addition, part of the confusion arises from the method used in the past to estimate feed requirement for cows. The method has resulted in recommendations that underfeed small cows and overfeed large cows (Anderson et al., 1983).

Another example is confusion of economic evaluation with biologic evaluation. This paper deals primarily with the relationships of cow efficiency to other biological traits and does not deal with dollar evaluation. Economic evaluation requires some sort of system evaluation in order to bring in all the interrelationships among biologic traits that sometimes result in trade-off. That is, one can sacrifice biological improvement in one desirable trait in order to gain in net dollars through a related improvement in another trait. Trade-offs exist between weaning weight, percent weaned and price per pound in evaluations of net return at weaning which allow increases in one trait to offset losses in one or more of the others. These are only part of a number of such relationships that exist in a ranch situation which is a combined biologic and economic system.

A third area that may cause some people confusion is that of equating fast gain with large mature size. Animals can grow to a large size by growing slowly for a long time and this is not desirable growth for present production systems. We need rapid growth at a young age, but there is little to recommend large mature size. Unfortunately, we will have to accept some increase in mature size as we increase early growth rate because of the correlation between the two traits. It is important to remember that measures of early growth such as weaning weight and yearling weight are not direct measures of mature size even though they are correlated with it. This is especially important in consideration of measures of frame size, since frame size is primarily a predictor of mature size and birth weight rather than a predictor of growth rate. Feeders have discriminated against calves from small cows because of lower growth rates and increased finish at desirable weights. Producers with small cows interested in increasing cow size should keep in mind that the trait needed by the feeder is growth rate at an early age and should make their selections directly for that trait, thereby increasing cow size only through the correlated effects of early growth with mature size. Selection for frame size will result in larger cows at maturity but will not necessarily achieve that desired increase in early growth rate. This assumes selections are made in the same population of replacement heifers, which is the only way two methods of selection can be fairly compared. Optimum improvement in early growth can be obtained by purchasing bulls from breeders who have the longest history of selecting their herd sires on their breeding value for early growth. Since breed association breeding value programs are relatively new, selection for high ratios within contemporary groups should be considered where breeding vlaues are not available.

## Application of Current Knowledge

The following prediction equation for weaning efficiency would be useful in ranking cows that have had at least one calf:

Cow efficiency = 16.458 + .006 x WA - .0181 x WW + .0025 x CWTW where cow efficiency equals lb of TDN required to produce one lb of weaning weight, WA equals weaning age in days, WW equals weaning weight in lb and CWTW equal cow weight at weaning. This equation was calculated from our first phase study with the Angus-Charolais cattle. In order to validate the predictive accuracy, we predicted the efficiency of the 166 efficiency records obtained in the second phase using straight Hereford, Simmental x Hereford and Angus x Hereford crossbred cows and we found a 79% ($R^2$) accuracy. Until research can develop a means of selecting heifers at weaning or yearling ages for cow efficiency, we suggest the following procedures: Work only in contemporary groups. For example, treat spring calving cows separate from fall calving cows or creep fed groups separate from noncreep groups. It appears that breed or breed type of sire of calf and perhaps breeding value of sire of calf should be included in the definition of contemporary groups, the latter only if large differences in breeding value for weaning weight exist among herd sires represented. Use the formula to predict the efficiency of the cow and select the heifers based on their dams' efficiency, utilizing as well the other traits that you currently consider in heifer selection. The same procedure may be utilized in incorporating selection for cow efficiency into replacement bull selection. To compare contemporary cows on their efficiency, subtract 8.5% from predicted efficiency of mothers of heifers. While this procedure will result in slower progress than could be achieved with direct selection of the heifers and bulls on their own record, dairy breeders have made substantial genetic progress in milk production through this method of selection.

Most current economic evaluations favor larger cows principally because fewer large cows for the same feed supply will produce as much, or perhaps some more, than small cows, and the costs that vary with the number of cows in the herd such as veterinary, personal property tax, etc. are large enough to tip the balance. This assumes that cows are larger because of selection for early growth and therefore will raise calves that are heavier at weaning and will gain faster postweaning. Actually, it appears that combining the now common selection for rapid early growth with the progeny test selection for efficiency indicated above might very well serve to direct the overall result toward the faster early growth with a restricted mature size in view of the absence of all four breed groups of the extremes in weight and height among the most efficient cows.

Practical aspects in applying these results to the range then become that of reducing carrying capacity sufficiently in proportion to increase in cow size or milk production to allow the larger or higher producing animal to reproduce. In a ranch situation, the producer needs to be careful that he does not increase the nutrient requirement of the larger, high producing cow beyond her ability to extract the necessary energy from the types of feed available on the ranch. There is a definite need for more research information that will assist the producer in matching cow size and levels of milk production to available feed resources.

## Postweaning Efficiency

Since calves sold at weaning must go on and produce efficienctly for the backgrounder and feeder, we need to be concerned with the relationship between weaning efficiency and measures of postweaning efficiency. Dr. Brown found correlations between weaning efficiency and total TDN per pound of slaughter weight and per pound of retail cut of .51 and .48, respectively. These correlations indicate a favorable relationship with more efficient calves at weaning tending to be more efficient at the later age. This relationship can be partially evaluated for the different breed of dam groups in table 1. In each group the more efficient calves at weaning were also more efficient in slaughter weight and retail cut production. Cow size was not closely related to efficiency of production of slaughter weight or retail cuts. Dr. Brown also evaluated breed of dam effects on TDN requirements per pound of slaughter weight and per pound of retail cut in data collected in the first 5 years of the project. Calves from Angus dams required less TDN per unit of slaughter weight than calves from Charolais or crossbred cows, although the differences were not large. On the other hand, there were no significant differences among breed of dam groups for TDN requirement per unit of retail cuts. It is possible that calves from the Angus cows deposited more fat in the postweaning period and this fat was trimmed when carcasses were broken down into retail cuts.

There is the additional consideration of the size of the market animal on the economics of postweaning performance in addition to the effects on efficiency just discussed. The first two columns of data in table 2 were taken from a Meat Animal Research Center report (Cundiff et al., 1980). These are carcass weight and percent retail product data for 15 different crossbred groups. I have added the third column which is simply the product of these two which gives pounds of retail product produced per animal. One can visualize the reason for some of the changes in price per pound paid by packers which has been reflected also in the price per pound paid by feeders over the past few years. These data say in another way the same things we were saying 12 to 15 years ago when our carcass steer project told us that we could make six times more improvement in genetic merit of yield of retail product through selection on yearling weight than through any combination of live animal measurement, live animal estimate of carcass traits or eyeball evaluation of muscling or conformation. This should not be interpreted as meaning that the highest value in the pounds column represents the breed cross that everybody should be raising. Cattlemen will still have to fit their cow herd to their individual operation from the standpoint of cow efficiency discussed above. All traits important to the rancher as well as the feeder and packer will need to be considered.

TABLE 2. BREED GROUP MEAN RETAIL PRODUCT ADJUSTED TO 19% FAT TRIM[a]

| Breed group | Carcass weight, lb. | Retail product, % | Retail product, lb |
|---|---|---|---|
| Limousin-X | 787 | 69.7 | 549 |
| Charolais-X | 828 | 69.1 | 572 |
| Chianina-X | 910 | 68.8 | 626 |
| Gelbvieh-X | 741 | 68.7 | 509 |
| Simmental | 791 | 68.6 | 543 |
| Tarentaise-X | 645 | 68.6 | 442 |
| South Devon-X | 639 | 68.5 | 438 |
| Sahiwal-X | 606 | 68.5 | 415 |
| Brahman-X | 665 | 68.4 | 455 |
| Maine-Anjou-X | 787 | 68.4 | 538 |
| Hereford-Angus-X | 584 | 68.4 | 400 |
| Red Poll-X | 581 | 68.2 | 396 |
| Brown Swiss-X | 723 | 68.1 | 492 |
| Pinzgauer-X | 640 | 68.0 | 435 |
| Jersey-X | 537 | 68.0 | 365 |

[a]USDA. 1980. MARC Report.

## Summary

It would appear that through selection we can develop efficient cows of any size within the relatively wide range of weights studied and there does not seem to be any antagonism between cow efficiency and other desirable production traits. From an economic standpoint, early growth rate and resulting heavier lean carcasses at normal feedlot marketing time appear desirable under current conditions. Carrying larger cows but fewer of them may have some economic advantage in situations where the cow costs that depend on the number of cows such as personal property tax as opposed to costs such as real estate taxes may be important in the profit picture. In South Dakota, these variable costs now approach $200 to $225 per cow per year. Cow efficiency is a trait that has received little attention from the standpoint of genetic improvement. It appears to have economic advantage sufficient to warrant greater attention. Maximum improvment will depend upon the development of accurate indicators that can be used in selecting heifers at weaning or yearling ages. Some improvement could be achieved through selecting bull and heifer calves from dams with higher estimated efficiencies.

## Literature Cited

Anderson, V.L., Lorna Jost, C.A. Dinkel and M.A. Brown. 1983. Prediction of daily total digestible nutrient requirement of beef cows in northern climates. J. Anim. Sci. 56:271.

Brown, M.A. and C.A. Dinkel. 1982. Efficiency of slaughter of calves from Angus, Chaorlais and reciprocal cross cows. J. Anim. Sci. 55:254.

Buckley, Brent. 1982. Repeatability of efficiency, weaning weight and milk production in Angus, Charolais and reciprocal cross cows. M.S. Thesis. South Dakota State University, Brookings.

Buckley, B.A. and C.A. Dinkel. 1981. Repeatability of efficiency, weaning weight and milk production in Angus, Charolais and reciprocal cross cows. J. Anim. Sci. 53(Suppl. 1):136.

Cundiff, L.V., R.M. Koch and K.E. Gregory. 1980. Beef production characteristics of breeds representing diverse biological types. Mimeograph. Meat Animal Research Center, U.S.D.A., Clay Center, NE.

Marshall, D.A., W.R. Parker and C.A. Dinkel. 1976. Factors affecting efficiency to weaning in Angus, Charolais and reciprocal cross cows. J. Anim. Sci. 43:1176.

# REALISTIC LIMITS ON REPRODUCTION IN BEEF COWS

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For the purposes of this discussion, I would like to define reproduction in the beef cow as all of those events from estrus through the subsequent weaning of a healthy, viable calf. Utilizing this definition, there are two major factors which limit reproductive performance in beef cows. The first is failure of the cow to become or stay pregnant and the second is loss of the calf. The largest single factor which prevents beef cows from becoming pregnant is anestrus. There are two types of anestrus. First is the postpartum anestrus period which occurs after every calf is born. This period is highly variable and is influenced by the level of nutrition of the cow both before and after calving, environmental factors such as cold or heat, uterine infections, and breed. From an economic standpoint, postpartum anestrus is probably the biggest single factor limiting reproductive performance of beef cattle in the West where many animals are maintained at a less than optimal level of nutrition from a reproductive standpoint. The second form of anestrus is that which occurs in animals prior to puberty. Most beef animals do not reach puberty until 10 to 14 months of age and in those animals where puberty is delayed, it often limits reproductive performance for the entire life. Finally, embryonic wastage can be a major problem due to inadequate nutrition and/or various diseases and toxins. If an embryo is lost early during the breeding season, there is the possibility that the cow will re-breed and re-establish pregnancy. However, if the embryo is lost after the end of the breeding season, that cow will not produce a calf for an entire year.

The economic costs associated with maintenance of a cow which fails to become or stay pregnant in a 100-cow herd are detailed in table 1. The cost to carry a calf for one year was placed at $250. In addition, it was assumed that there would be fifteen heifers kept as replacements and that five bulls would be required to breed the 100 cows in the producing herd. This table indicates the cost of reducing the number of calves weaned for whatever reason. Obviously, if 100 calves were weaned (100% calf crop), one might think that the break-even point for sale of that calf is $250. However, that fails to take into account the cost associated with the 15 heifers and 5 bulls which fail to produce a calf. The real cost to produce each calf in this case was $300. If 90 calves are weaned, there is a cost of $333 to produce each calf. This is due to the fact that 25% of the animals in this herd (i.e., 10 dry cows, 15 replacement heifers, 5 bulls) will not produce calves. Thus, there is a real cost of $83 per calf associated with the non-productive animals in this herd. Obviously, as the number of calves weaned is reduced to 80, the cost per calf increases an

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TABLE 1. NON-PRODUCERS IN A 100-COW HERD[a]

| No. calves weaned | No. dry cows | No. heifers | No. bulls | Total Non-producers No. | Total Non-producers % | Cost per calf, $ |
|---|---|---|---|---|---|---|
| 90 | 10 | 15 | 5 | 30 | 25 | $333 |
| 80 | 20 | 15 | 5 | 40 | 33 | 375 |
| 70 | 30 | 15 | 5 | 50 | 42 | 428 |

[a]$250 per animal carrying cost.

additional $42 and if the number of calves weaned is reduced to 70 there are 42% non-producing animals in this herd and the cost per calf is increased $178 per animal to $428. It is apparent that for maximal return a producer must keep the number of dry cows to a minimum, must maintain a minimal number of highly fertile bulls and should be very concerned about the number of replacement heifers. We often encourage producers to keep a large number of heifers as replacements since they theoretically represent the best genetic material in the herd. However, this recommendation should be tempered with the understanding that you keep these heifers at a high economic cost. If one is to keep large numbers of heifers as replacements, it is important that they truly be genetically superior and that financially this practice be demonstrated to be economically viable.

A second important point is illustrated in figure 1. Although there are some differences, the average length of gestation in a beef cow is about 285 days. This means that one has only 80 days to re-establish pregnancy in this cow to maintain a 365-day calving interval. Therefore, the length of the postpartum anestrous period becomes critical. Under good conditions with optimal management, this interval can be as short as 35 days. However, even under these

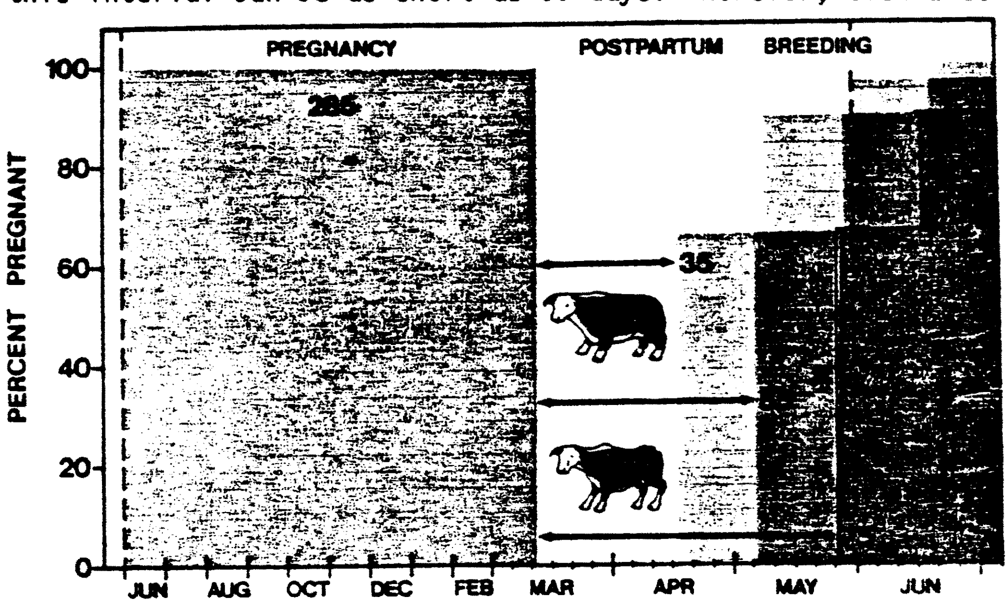


Figure 1. The relationship of the postpartum anestrous period and the percent of a hypothetical cow herd pregnant at various times during the year. Conception rates were assumed to be 66% per service. See the text for additional details regarding the calculations.

optimal conditions and with the average 66% pregnancy rate to each service, one finds that after the first 21 days of breeding season, or 56 days after calving, only 66% of the herd is pregnant. If an additional 66% become pregnant during the second cycle, then 88% of the cows are pregnant at 77 days and approximately 90% of the cows can become pregnant within a 365-day period. Thus, even under optimal conditions, it is not uncommon for 10% of a herd to have a calving interval longer than 365 days. If the postpartum anestrus period is 55 days, which is closer to average in the Western United States, the problem becomes even more apparent. Under these conditions, by 76 days post-calving only 66% of the herd are pregnant and at the end of 80 days there is only an additional 5% of the animals pregnant. Therefore, only 71% of this cow herd will have a calving interval of 365 days. Obviously, in the case where there is a 75-day postpartum anestrous period, there will only be 18-20% of the cows pregnant to calve within a 365-day period.

Table 2 summarizes the economic costs associated with the failure of cows to maintain a 365-day calving interval. If calves are born during the first 20 days of the calving season and average age at weaning is 220 days, the average weaning weight will be 565 lb if these calves gain 2.25 lb per day, 510 lb if they gain 2 lb per day or 455 lb if they gain 1.75 lb per day. Calves born between 21 and 40 days of the calving season will have an average age at weaning of 200 days and there is an associated 35- to 55-lb reduction in weaning weight. As you can see, when calves are born 120 to 140 days after the beginning of the calving season, they are only 100 days old at weaning (if weaned at a constant time of

TABLE 2. WEANING WEIGHT AS INFLUENCED BY TIME OF BIRTH AND AVERAGE DAILY GAIN

| Day of Calving | Average age at weaning, days | Average daily gain (lb)[a] | | |
|---|---|---|---|---|
| | | 2.25 | 2.0 | 1.75 |
| 0-20 | 220 | 565 | 510 | 455 |
| 21-40 | 200 | 520 | 470 | 420 |
| 41-60 | 180 | 475 | 430 | 385 |
| 61-80 | 160 | 430 | 390 | 350 |
| 81-100 | 140 | 385 | 350 | 315 |
| 100-120 | 120 | 340 | 310 | 280 |
| 121-140 | 100 | 295 | 270 | 245 |

[a]Birth to weaning.

year) and weaning weights are very light. The economic impact of these data is shown in table 3. Once again we have computed the cost of keeping a cow at $250 per year. As you can see, if the calves wean at 500 lb and sell at $.70 per lb, there is a total of $350 income from that cow or $100 in net return. However, if the weaning weight of the calf is 400 lb, at $.70 per pound he would sell for $280 and there would be a net return of $30 on that cow. At a weaning weight of 300 lb, the producer has lost $50 on that cow that year. However, the picture is not even this rosy. As seen in table 4, if we return to a typical 100-cow herd where 90 calves are weaned there were really 120 animals in this herd of which 30 were non-producers. Therefore, the average weaning weight per animal in that

TABLE 3. WEANING WEIGHT AND NET RETURN

| Weaning weight, lb | Gross return at $.70/lb | Cost of keeping a cow, $ | Net return, $ |
|---|---|---|---|
| 500 | $350 | $250 | $100 |
| 450 | 315 | 250 | 65 |
| 400 | 280 | 250 | 30 |
| 350 | 245 | 250 | -5 |
| 300 | 210 | 250 | -40 |

TABLE 4. INFLUENCE OF NON-PRODUCERS AND WEANING WEIGHT ON POUND OF CALF WEANED AND NET RETURN IN 100-COW HERD

| No. calves Weaned | No. animals in herd | No. non-producers | Pounds of calf weaned per animal | | | Net return per animal[a] | | |
|---|---|---|---|---|---|---|---|---|
| | | | 500 | 400 | 300 | 500 | 400 | 300 |
| | | | | lb | | | $ | |
| 90 | 120 | 30 | 375 | 300 | 225 | 12 | -40 | -92 |
| 80 | 120 | 40 | 333 | 267 | 200 | -17 | -63 | -110 |
| 70 | 120 | 50 | 292 | 233 | 175 | -46 | -87 | -128 |

[a]Calves at $.70/lb and $250 carrying cost.

herd drops from 500 to 375 lb due to the non-producers and the net return per animal is only $12. If 80% of the cows wean calves, there are 40 non-producers in that hypothetical herd and that producer is going to lose $17 per animal. Clearly, the numbers of non-producers in a cow herd must be kept down if it is to be an economically viable production unit. It is obvious that the loss of a calf at birth due to dystocia or the loss of calves prior to weaning have as much or more impact on the total income to a production unit than the failure to get cows pregnant.

We have been asked to discuss what realistic limits on production exist in beef cattle. These limits are different for the commercial beef producer than for the seedstock producer. Therefore, the limits for the two types of problems will be discussed separately. Perhaps the best way to deal with this subject is to indicate what has been accomplished in a commercial beef cow herd which has been divided into experimental (89 cows) and control (86 cows) groups. The treated group consisted of animals which were managed using Dr. Wiltbank's O'Connor method. There are five major practices associated with this management scheme: 1) the animals are exposed to a 60-day breeding season; 2) a nutrition program is utilized which insures that all cows are in at least moderate body condition at calving; 3) the cows are gaining weight for a 3-week period prior to breeding and for the first 3 weeks of breeding; 4) calves are removed from the cows for 48 hr at the beginning of the breeding season; and 5) the cows are bred to fertile bulls. Control cows were exposed to a 120-day breeding season. At the time cows were assigned to treatment in November of 1981, the body scores in the two groups were identical. There was essentially no change in April of 1982, at the start of the breeding season, nor was there any detectable change in body condition throughout the period of this study. However, there were significant differences in the reproductive performance of these two groups of animals. Table 5 shows the number of animals showing estrus at 25 and 46 days after the beginning of the breeding season. Ninety-five percent of the cows on the O'Connor method had already been in estrus by 25 days of breeding compared to 59% of the controls. By 46 days into the breeding season, 98% of the cows on the O'Connor method had shown estrus compared to 72% of the control cows. The conception rate after first service was 80% in cows treated with the O'Connor method versus 50% in the controls. The percentages of cows which had calved at

TABLE 5. REPRODUCTIVE PERFORMANCE IN BEEF COWS USING THE O'CONNOR SYSTEM

| | Cows managed under O'Connor system | Control system | Difference |
|---|---|---|---|
| No. Cows | 89 | 86 | |
| Showing heat after breeding (%) | | | |
| 25 days | 95 | 59 | 36 |
| 46 days | 98 | 72 | 26 |
| Pregnant after 1 breeding (%) | 80 | 50 | 30 |
| Calved (%) | | | |
| after 20 days | 80 | 28 | 52 |
| after 40 days | 91 | 52 | 39 |
| after 60 days | 99 | 72 | 27 |
| after 120 days | 99 | 93 | 8 |

various stages after the beginning of the calving season are also shown in table 5. Eighty percent of the cows treated with the O'Connor method had calved within 20 days and 99% had calved within 60 days. This is compared to only 28% of the control cows calving within the first 20 days; 72% had calved within 60 days and only 93% of the control cows had calved within 120 days. Finally, the overall reproductive performance in the two groups of cows is summarized in table 6. Ninety-eight percent of the cows were bred with the O'Connor method versus 91% of the controls within the 60-day breeding season. Ninety-nine percent of the cows

TABLE 6. LOSSES OF EMBRYOS OR CALVES FOLLOWING PREGNANCY DIAGNOSIS

| | O'Connor system | Control system | Difference |
|---|---|---|---|
| No. cows bred (%) | 98 | 91 | -- |
| Cows pregnant (% of cows bred) | 99 | 93 | 6 |
| Cows calved (% of cows bred) | 98 | 91 | 7 |
| Live calves born (% of cows bred) | 95 | 87 | 8 |
| Calves weaned (% of cows bred) | 92 | 78 | 14 |

bred under the O'Connor management scheme became pregnant while only 93% of the control cows became pregnant. Ninety-eight percent of the pregnant cows calved under the O'Connor method while only 91% of the control cows calved. There were 95% of the calves born alive with the O'Connor treatment method and 87% of the control calves born alive. Ninety-two percent of the calves were weaned with the O'Connor method versus 78% of the calves in the control group. There is no obvious explanation for the decreased survivability of the calves produced by control cows. The weaning weight was 488 lb for the O'Connor treated cows versus 460 in the control cows (table 7). The total weight of calves weaned was 44,896 lb

TABLE 7. ESTIMATED ECONOMIC VALUE OF THE O'CONNOR MANAGEMENT SYSTEM IN A 100-COW HERD

| | Cows managed under | | |
|---|---|---|---|
| | O'Connor system | control system | Difference |
| Additional cost ($) | | | |
| Feed | 910 | -- | 910 |
| Labor | 60 | -- | 60 |
| Semen Evaluation | 125 | -- | 125 |
| TOTAL | $1,095 | -- | $1,095 |
| Production | | | |
| Calves weaned (%) | 92 | 78 | 14 |
| Age at weaning (days) | 253 | 229 | 24 |
| ADG (lb) | 1.52 | 1.43 | .09 |
| Weaning weight (lb) | 488 | 460 | 28 |
| Total lb weaned | 44,896 | 35,880 | 9,016 |
| Return at 60 cents/lb ($) | $26,938 | $21,528 | $5,410 |
| Additional cost ($) | $1,095 | -- | $1,095 |
| Increase in net return ($) | $25,843 | $21,528 | $4,315 |

versus 35,883 lb. This means there were 9,000 additional lb of calf produced in cows managed with the O'Connor scheme, and at $.60 per lb there is an increase of $5,410 in income. However, as can be seen in table 7, not all of this increased income was profit. There were also increased costs associated with the O'Connor method. The increased feed, which was corn silage fed during the breeding season, cost $910, and $60 was required for labor. The fertility exams on the bulls also cost an additional $125. Therefore, there was $1,095 additional cost associated with this method, or the real difference in profitability was $4,315. These data have been included to indicate what can be done routinely with a little extra effort in terms of enhancing the productivity of a beef herd. We feel that it is realistic to expect that most producers could reach these production goals with a minimum of additional effort and expense.

The discussion to this point has dealt primarily with the commercial producer of grade cattle. We have not attempted to deal with what can be accomplished with a purebred herd, where it is economically feasible in many cases to utilize the techniques of artificial insemination, embryo transfer, splitting of embryos, production of identical twins, etc. With the development of techniques for non-surgical collection of embryos and their non-surgical transfer into recipient animals, it has become economically feasible for those producers who have genetically superior cattle to enhance the production of their seedstock via these techniques. Utilizing these procedures, it is not uncommon for a single cow to produce as many as 20-30 calves per year and with artificial insemination procedures a single bull can sire as many as 100,000 offspring. However, it is unlikely that these procedures will ever have a major impact on the routine production of beef animals. These procedures allow seedstock producers to provide genetically superior bulls to be used by commercial producers. These bulls in turn can have a great influence on maternal ability, growth rate, etc.

Another area which we feel is extremely important for the future is genetic engineering of beef animals. It is now possible to identify and isolate the genetic material which codes for some production traits. For example, the gene which is responsible for the synthesis of growth hormone in humans has been isolated and transferred into mice. With the proper stimulation of this gene, it has been possible to produce mice which grow at a much faster rate than littermate controls. It is clear that within the next decade similar procedures will be applied to beef animals. We also predict that within the next decade genes for other production traits including some reproduction traits, disease resistance and milk production will be identified, isolated and transferred into developing embryos. Once this genetic material is incorporated into new individuals, using the techniques of artificial insemination for bulls or embryo transfer and production of identical twins or triplets for cows should make it possible to rapidly propagate this genetically superior seedstock so that it will become available to our commercial beef producers. A major challenge for researchers in this area within the next decade is to identify those traits which are important. It will not be possible to make rapid improvements in this area until there is some agreement on what traits are important for selection. For example, many producers are selecting for enhanced mothering ability and maternal instincts and are also trying to select for docile behavior. It seems likely that the enhanced mothering ability would be associated with an enhanced aggressive behavior, particularly around the time of calving. Therefore, as one makes progress in one area, he may lose ground in the other. the challenge is to determine which traits are the most important so that our outstanding researchers in the areas of genetics, biochemistry, reproductive physiology, and animal breeding can begin to produce the kind of animals which producers feel are important. It is an exciting time for beef cattle researchers and we are confident that the challenge will be met in a most successful way.

# FUNCTIONAL TRAITS AFFECTING COW EFFICIENCY

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## Summary

Increased emphasis on the need to minimize the costs of production is encouraging cow-calf producers to more critically evaluate the function of their cow herds. Functional problems associated with udders, eyes, feet, prolapse and disposition, to name a few, negatively affect cow-calf profits through (1) a decrease in the pounds of beef sold because of death loss and lower sale weight of both cows and calves; (2) higher costs due to items such as increased labor and veterinary inputs; (3) higher costs and lower production due to higher than optimum replacement heifer rates; and (4) reduced convenience and safety.

While heritability estimates reported for most of the functional traits were low to moderate in magnitude, they do imply that it is possible to diminish the incidence of functional problems through rigid cow culling and effective bull selection.

Realizing the need to minimize the costs of production, cow-calf producers have been placing greater emphasis on cow function. The primary purpose of this presentation is to discuss some of the functional traits affecting beef cow efficiency with emphasis on the heritability of these traits.

## What is a functional cow?

Cow function may be defined in many ways, but four fairly common definitions are: (1) a cow that does not cost extra time and labor; (2) a cow that works for you instead of you working for her; (3) a cow that is problem-free and (4) a cow that returns a profit.

The most appropriate analysis of the effects of functional problems on efficiency considers the cow herd as an integral part of the farm or ranch system. Since the efficiency of the entire system is partially dependent on the efficiency of the cow herd, each individual cow through her own functionality ultimately affects system efficiency. Some general consequences of functional problems that affect cow herd efficiency are:

1. Lower cow and calf sale weight. Impaired production due to functional problems can affect both cow (salvage value) and calf weights resulting in reduced revenue and higher costs per pound of beef produced.

2. Higher than optimum replacement rates. Cows with physical impairments must often be removed from the herd prior to their economically optimum culling age. The net effect is lower total output and increased costs because of the lower production and higher costs per calf produced from younger cows. While young cows may be genetically superior, they typically do not reach their potential until five years of age.

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3. Increased labor. Extra attention required by cows with functional problems represent additional costs.

4. Increased death loss. Severe physical impairments can lead to cow mortality resulting in lost salvage value and reduced revenue. Of course, death loss also requires additional replacements.

5. Diminished convenience. This factor associated with function in gaining increased attention. Anyone who has spent time running a group of crazy cows through a palpation chute or has attempted to coax a newborn calf into nursing its balloon teated mother can indeed associate with convenience.

6. Safety. No one really enjoys the thought of risking injury from unruly animals, particularly when it can be avoided.

The end results of these problems are increased costs and lower production, resulting in reduced net profit.

Some functional traits for consideration

A number of traits may be associated with function. A few are: (1) udder soundness; (2) feet soundness; (3) cancer eye susceptibility; (4) prolapse; (5) disposition; (6) milk production (7) calving ease; and (8) fertility. This discussion will address the first five traits since milk production, calving ease and fertility will be sufficiently covered by other program participants. Additional traits such as foraging ability and maternal instinct could be included, but because of limited research in these areas they will not be discussed.

The accumulation effect of various factors on culling rate was reported by Greer et al. (1980) using 34 years of data beginning in 1943 from the Livestock and Range Research Station, Miles City, Mont. Table 1 shows the proportion of cows culled by age removed for death, physical impairment and management criteria reasons. Physical impairments were factors that signficantly impaired cow performance and were beyond management control. Management decision culling criteria in this study related primarily to a cow's failure to produce a live calf in two consecutive years, low progeny weaning weight and low individual growth through two years of age.

TABLE 1. PROPORTION OF COWS CULLED BY AGE AND REASON FOR CULLING[a,b]

| Reason for culling | Cow age in years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Dead or missing, % | 1.3 | 1.1 | 0.7 | 1.5 | 1.6 | 1.5 | 1.6 | 1.0 |
| Physical impairment, % | 2.8 | 2.4 | 3.7 | 4.0 | 6.3 | 7.4 | 9.2 | 10.7 |
| Management decision, criteria, % | 9.6 | 13.2 | 12.9 | 10.2 | 9.2 | 10.3 | 14.6 | 35.3 |
| Total culled, % | 13.7 | 16.7 | 17.3 | 15.7 | 17.1 | 19.2 | 25.4 | 47.0 |
| Number of cows | 4311 | 3971 | 2996 | 2331 | 1955 | 1439 | 1085 | 766 |

[a]From Greer et al. (1980).
[b]Heifers bred to calve for first time as 3-year-olds.

While the proportion of cows dead or missing was fairly consistent across all age groups, the percentage culled for physical impairments increased from 2.8 percent for three-year-olds to 10.7 percent of ten-year-olds. The percentage of each age group culled for management decisions increased from 9.6 percent for three-year-olds to 14.6 percent and 35.3 percent respectively for nine- and ten-year-old cows.

TABLE 2. ESTIMATED PROBABILITIES OF FEMALES BEING CULLED BY AGE AND PHYSICAL IMPAIRMENTS[a,b]

| Physical impairment | Cow age in years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Bad udder, % | 0.0 | 0.1 | 0.2 | 0.3 | 0.7 | 1.0 | 1.6 | 1.3 |
| Eye cancer, % | 0.1 | 0.5 | 1.2 | 1.5 | 2.5 | 3.9 | 4.1 | 6.7 |
| Prolapse, % | 2.0 | 0.8 | 1.5 | 1.4 | 1.3 | 0.9 | 1.0 | 1.0 |
| Bad feet, % | 0.1 | 0.3 | 0.3 | 0.4 | 0.6 | 0.6 | 0.8 | 0.5 |
| Other injury or illness, % | 0.6 | 0.7 | 0.5 | 0.4 | 1.2 | 1.0 | 1.7 | 1.2 |
| Total, % | 2.8 | 2.4 | 3.7 | 4.0 | 6.3 | 7.4 | 9.2 | 10.7 |

[a]From Greer et al. (1980).
[b]Heifers bred to calve for first time as 3-year-olds.

Table 2 represents a breakdown of the probability of a cow being culled for each physical impairment by cow age group. Prolapse was the most prevalent problem among three-year-olds and decreased in significance among older cows. Cancer eye as a reason for culling increased from 0.1 percent to 6.7 percent respectively for three-year-olds and ten-year-old cows, while culling for bad udders went from zero to 1.3 percent of total culls. One of the lowest frequency of the problems identified was that of bad feet.

Optimum beef cow replacement age was found to be 10, 8, 9, 11 years of age respectively by Rogers (1972), Bentley et al. (1976), Kay and Rister (1977) and Milton (1980). More recently, Bourden (personnal communication) calculated an optimum requirement age of eight years of age for straightbred cows, while Clark et al. (1984) reported optimum replacement of ages of 5, 9 and 12 years for three-breed rotation, criss-out-cross and three-breed terminal crossbreeding systems respectively. These data imply that removal of cows from the herd prior to the optimum replacement age represents a reduction in net profit potential.

The subject of longevity is indeed of interest but has not been widely evaluated in beef cattle. Several studies, however, including Wilcox (1957), Evans et al. (1964), White and Nichols (1965), Hargrove et al. (1969), and Norman and Van Vleck (1972) have estimated the heritability of longevity in dairy cows. Their respective heritability estimates were .37, .39, .14, .15 and .11, showing a lack of consistency regarding the degree of genetic control involved with longevity. A number of researchers including Hargrove et al. (1969) and Norman and Van Vleck (1972) reported milk production to be the most important factor, aside from fertility, contributing to the length of time a dairy cow is restrained in the milking herd. This, coupled with a wide range of culling practices among producers, partially accounts for the variation in the heritability of longevity.

## Udder soundness

Udder and teat soundness are of concern for a number of reasons. A few are: (1) labor associated with extra cost and reduced convenience; (2) longevity which may be reduced because of injury or mastitis; (3) calf performance which can be affected by a reduction in milk flow or an inhibition of colostrum intake by newborn calves having difficulty nursing oversized teats; (4) most udder and teat characteristics appear to be heritable.

TABLE 3. HERITABILITY OF DAIRY UDDER TRAITS

| | Udder Depth | Fore Udder Attachment | Rear Udder Attachment | Center Support | Teat Spacing |
|---|---|---|---|---|---|
| Heritability | .24 | .21 | .24 | .16 | .22 |
| No. studies | 5 | 10 | 8 | 2 | 6 |

Shown in Table 3 is a summary of some heritability estimates for a number of udder and teat traits based on averages calculated from several studies. While these estimates are low to moderate, they do verify that udder and teat traits are heritable.

Moreover, Norman and Van Vleck (1972) suggest that bulls that sire daughters with high production tend to sire daughters with weaker udder attachments. This implies that a negative genetic correlation exists between milk production and the strength of udder attachments. Other correlations reported by Thompson et al. (1981) and Thompson et al. (1983) reflect that dairy cows with more udder depth generally have weaker suspensory ligaments. In addition, Norman et al. (1981) reported that cows with a combination of higher milk production and strong suspensory ligaments had higher lifetime performance. This implies that, while milk production has the highest correlation with longevity in dairy cattle, cows with strong udder support in combination with high milk production will maintain longer productive lives. Although beef cattle are certainly not under the same lactation stress as dairy cattle, it may be wise to place some emphasis on udder quality as it relates to longevity.

The American Polled Hereford Association has adopted an udder scoring system using teat size and udder suspension. This concept is based on the linear type trait scoring system ranging from 0 to 50 developed by the American Holstein Association (1983). Given in Table 4 is a breakdown of the scores for teat size and suspension.

TABLE 4. APHA UDDER SCORING SYSTEM[a]

| Teat Size | Suspension |
|---|---|
| 50 | 50 |
| 45 - Very Small | 45 - Very Tight |
| 40 | 40 |
| 35 - Small | 35 - Tight |
| 30 | 30 |
| 25 - Intermediate | 25 - Intermediate |
| 20 | 20 |
| 15 - Large | 15 - Pendulous |
| 10 | 10 |
| 5 - Very large | 4 - Very Pendulous |
| 0 | 0 |

[a]From Gibb (1983)

Teat size is included primarily to account for the extra labor associated with oversized teats, while suspension relates to the reduced longevity of cows with weak udders. This system was implemented to assist producers in establishing acceptable levels for cow culling and sire selection rather than to identify an ideal udder. It is important to recognize that the most appropriate time to evaluate a cow's udder is immediately after calving when udder and teat problems are likely to create the most difficulty.

## Feet Soundness

Feet soundness can vary greatly between herds. While some herds consist of cows possessing sound, well-shaped feet showing a minimum of excess growth, other herds may include a number of cows with excessively long, curling toes and shallow heels. Excessive growth can lead to curling toes and eventual misalignment of the feet and leg bones. This may result in tendon and joint problems that create lameness. Cracked hooves is also a problem associated with lameness. The heritability estimates for foot characteristics from dairy field records are relatively low but do indicate some degree of genetic control. Heritability estimates of .12 and .11 were reported by Legates (1971) and Cassel et al. (1973) for general foot score, while heritabilty estimates of .20, .08 and .15 were reported by Van Vleck (1964), Norman and Van Vleck (1972) and Thompson et al. (1983) respectively. In addition, Thompson et al. (1981) reported a .19 heritability estimate for foot angle. A more detailed evaluation of heritability of feet characteristics was reported by Thompson et al. (1979). He found respective estimates of .15, .26, .16 and .10 for shallow heel, spread toes, curled toes and faulty pasterns. Brinks et al. (1979) conducted a study using data from the inbred Hereford and Angus lines at the San Juan Basin Research Center near Hesperus, Colorado. His scoring system is shown in Table 5.

TABLE 5. SCORING SYSTEM FOR HOOF GROWTH IN BEEF COWS[a]

| Score | Description |
|---|---|
| 1 | Normal - no sign of excess growth. |
| 2 | Slight growth (1/2") with inward turn of toe. |
| 3 | Growth of 1/2" to 1" with inward turn of toe. |
| 4 | Extreme growth of 1" or more with toes turned in and up with tendency towards low heels. |
| 5 | Horizontal cracks in hooves with growth as described in 4. |

[a]From Brinks et al. (1979).

Cows were first scored in July and again in October 1978. The heritability estimate for each score was .81 with a phenotypic correlation between scores of .65. The phenotypic correlation indicates a relatively good repeatability for the hoof score. A summary of the Brinks et al. (1979) study is as follows:

1. Hoof growth scores increased with age through six years of age and remained relatively constant thereafter.

2. The majority of cracked hooves were observed in cows eight years of age and older.

3. Line of sire differences and the high heritability estimate indicate that selection for normal hooves should be effective.

One can assume that the practice of hoof trimming by some seed stock producers could result in eventual problems for their commerical customers.

Cancer Eye Susceptibility

Over the years, cancer eye has represented a significant economic loss to beef cattle producers. Cancer eye lesions may initially appear on the eyelid, sclera or skin surrounding the eye. Left unattended, these lesions can result in reduced productivity and possibly death. The heritability of cancer eye has been reported to be .27 and .40 for young and old cows respectively by Anderson et al. (1956) and .08 and .24 respectively for young and old cows by Vogt and Anderson (1964). Overall heritability estimates of .46 and .22 were reported by Anderson (1959) and Blackwell (1956). Russell (1976) reported similar results observing that the heritability of the presence of ocular tumors and number of tumors increased with age. The susceptibilty observed primarily in older cows is transmittable and thus cannot be attributed solely to the environment. In their report, Cleaver et al. (1972) concluded that cancer eye may be a complex disease involving the heredity of the animal, ultraviolet light in solar radiation and possibly viruses.

Studies concerning ocular pigmentation and its affect on cancer eye indicate that much of the genetic control of cancer eye susceptibilty is mediated through the inheritance of eyelid and sclera pigmentation. Pounds et al (1981) reported respective heritability estimates for eyelid, skin and sclera pigmentation of .34, .40 and .00, implying that selection for increased eyelid and skin pigmentation would be effective, while sclera pigmentation is not transmittable. Genetic pigmentation suggest that selection of cattle with large amounts of eyelid pigmentation should bring about a rapid increase of skin pigmentation around the eye but not an increase in sclera pigmentation. Therefore, it is safe to assume that in regions where cancer eye is a problem, selection of ocular pigmentation should be effective in reducing the incidence of cancer eye susceptibility.

Prolapse

Not only does prolapse represent a cost in time, labor and convenience, but it too can result in death. The heredity of prolapse has not been widely studied. However, data from the Livestock and Range Research Station at Miles City, Montana reported by Woodward and Quesenberry (1956) indicated that significant line of sire differences in the incidence of prolapse suggest a heredity susceptibility for this characteristic. They concluded that vaginal and uterine prolapse could be controlled to some degree by rigorous culling.

Disposition

While little documented evidence exists relating diposition to net income, producers agree that temperment does have an effect on their psychological, if not their financial welfare. In a study conducted by Pounden and Firebaugh (1956), cows in the intermediate range of nervousness during A.I. had higher percent non-return rates than cows that were extremely quiet or very nervous, thus suggesting that an intermediate range for temperament may be best for A.I.

success. Research literature reports of heritability estimates calculated for milking temperament in dairy cattle using field data ranged from .07 (Thompson et al., 1981) to .53 (Dickson et al., 1970). Other estimates calculated by Norman and Van Vleck (1972), Van Vleck (1964) and O'Bleness et al. (1960) were .08, .16 and .40 respectively.

The temperament of beef cattle was evaluated by Heisler (1979) at the University of Saskatoon in Canada using chute scores ranging from 1 to 5 where: 1 = very docile and 5 = very active. In one study, Hereford calves had the lowest (P<.05) mean chute score followed by Simmental and Angus respectively. In a second study (table 6), Polled Hereford calves had significantly lower (P<.05) weaning chute scores than the other six breeds in the study, while Limousin calves had higher (P<.05) slaughter age chute scores than Chianina, Maine-Anjou, Polled Hereford and Simmental. Heisler (1979) reported heritability estimates for chute score ranging from .13 to .48 while Schrode et al. (1979) reported a heritability estimate of .40.

TABLE 6. BREED-CLASS MEANS OF WEANING AND SLAUGHTER CHUTE SCORES[a]

| Breed | Number calves | Weaning chute score[b] | Slaughter chute score[b] |
|---|---|---|---|
| Angus | 48 | 4.34[d] | 5.05[cd] |
| Charolais | 188 | 4.48[d] | 5.07[cd] |
| Chianina | 24 | 5.20[d] | 4.78[c] |
| Limousin | 22 | 4.59[d] | 5.86[d] |
| Maine Anjou | 23 | 4.52[d] | 4.54[c] |
| Polled Hereford | 48 | 3.99[c] | 4.30[c] |
| Simmental | 27 | 4.73[d] | 4.21[c] |

[a]Heisler (1979).
[b]Range 1-5: 2 = very docile; 5 = very active.
[c,d]Unlike superscripts in same column differ (P<.05).

## Literature Cited

Anderson, D.E., D. Chambers and J. L. Lush. 1956. Heritability of eyelid pigmentation and cancer eye susceptibility in cattle. J. Anim. Sci. 15:1124 (Abstr.).

Anderson, D. E. 1959. Genetic aspects of bovine ocular carcinoma. Genetics and cancer. The University of Texas Press.

Bentley, E., J. R. Waters and C. R. Shumway. 1976. Determining optimal replacement age of beef cows in the presence of stochastic elements. Southern J. Agr. Econ. 8:13.

Blackwell, R. L., D. E. Anderson and J. H. Knox. 1956. Age incidence and heritability of cancer eye in Hereford cattle. J. Anim. Sci. 15:943.

Brinks, J. S., M. E. Davis, W. L. Mangus and A. H. Denham. 1979. Genetic aspects of hoof growth in beef cattle. Colo. Exp. Sta. Gen. Series 982.

Cassell, B. G., J. M. White, W. E. Vinson and R. H. Kliewer. 1973. Genetic and phenotypic relationships among type traits in Holstein-Friesian cattle. J. Dairy Sci. 56:1171.

Clark, S. E., C. T. Gaskins, J. K. Hillers and W. D. Hohenboken. 1984. Mathematical modeling of alternative culling and crossbreeding strategies in beef production. J. Anim. Sci. 58:6.

Cleaver, J. E., R. A. Kainer and M. R. Zelle. 1972. Ocular squamous cell carcinoma (cancer eye) in Hereford cattle: Radiation repair processes and a comparison of cultured cells with xeroderma pigmentosum in man. Am. J. Vet. Res. 33:1131.

Dickson, D. P., G. R. Barr, L. P. Johnson and D. A. Wieckert. 1970. Social dominance and temperament of Holstein cows. J. Dairy Sci. 53:904.

Evans, D. L., C. Branton, and B. R. farthing. 1964. Heritability estimates and interrelationships among production per day of production life, longevity, breeding efficiency and type in a herd of Holstein cows. J. Dairy Sci. 47:699.

Gibb, J. B. 1983. Score those cows. Polled Hereford World. Nov. p. 36.

Greer, R. C., R. W. Whitman and R. R. Woodward. 1980. Estimation of probability of beef cows being culled and calculation of expected herd life. J. Anim. Sci. 51:10.

Hargrove, G. L., J. J. Salazar, and J. E. Legates. 1969. Relationships among first lactation and lifetime measurements in dairy population. J. Dairy Sci. 52:651.

Heisler, C. E. 1979. Breed differences and genetic parameters of temperament of beef cattle. M.S. Thesis. Univ. of Saskatoon.

Holstein Association. 1983. Linear. Holstein Association linear classification program. Battleboro, Vermont.

Kay, R. D. and E. Rister. 1977. Income tax effects on beef cow replacement strategy. Southern J. Agr. Econ. 9:169.

Legates, J. E. 1971. Components of variance for descriptive type classification of Holstein-Friesian cows. J. Dairy Sci. 54:775 (Abstr.).

Melton, B. E. 1980. Economics of beef cow culling and replacement decisions under genetic progress. Western J. Agr. Econ. 5:137.

Norman, H. D. and L. D. Van Vleck. 1972. Type appraisal: III. Relationships of first lactation production and type traits with lifetime performance. J. Dairy Sci. 55:1726.

Norman, H. D., B. G. cassell, R. E. Pearson and G. R. Wiggans. 1981. Relation of first lactation production and conformation to lifetime performance and profitability in Jerseys. J. Dairy Sci. 64:104.

O'Bleness, G. V., L. D. Van Vleck and C. R. Henderson. 1960. Heritabilities of some type appraisal traits and their genetic and phenotypic correlations with production. J. Dairy Sci. 43:1490.

Pounden, W. D. and J. G. Firebaugh. 1956. Effects of nervousness on conception during artificial insemination. Vet. Med. 51:469.

Pounds, J. C., J. S. Brinks and R. A. Kainer. 1981. Genetic aspects of ocular pigmentation in Hereford cattle. Colo. Exp. sta. Gen. Series 997.

Rogers, L. F. 1972. Economics of replacement rates in commercial beef herds. J. Anim. Sci. 34:921.

Russell, W. C., J. S. Brinks and R. A. Kainer. 1976. Incidence and heritability of ocular squamous cell tumors in Hereford cattle. J. Anim. Sci. 43:1156.

Thompson, J. R., A. E. Freeman, D. J. Wilson, C. A. Chapin and P. J. Berger. 1981. Evaluation of a linear type program in Holsteins. J. Dairy Sci. 64:1610.

Thompson, J. R. K. L. Lee and A. E. Freeman. 1983. Evaluation of a linearized type appraisal system for Holstein cattle. J. Dairy Sci. 66:325.

Schrode, R. R. and S. P. Hammock. 1971. Chute behavior of yearling beef cattle. J. Anim. Sci. 33:193 (Abstr.).

Van Vleck, L. D. 1964. First lactation performance and herd life. J. Dairy Sci. 47:1000.

Vogt, D. W. and D. E. Anderson. 1964. Studies on bovine ocular squamous carcinoma ("Cancer Eye"): XV. Heritability of susceptibility. J. Hered. 55:13.

Wilcox, C. J., K. O. Pfau, R. E. Mather, R. F. Gabriel and J. W. Bartlett. 1962. Phenotypic genetic and environmental relationships of milk production and type ratings of Holstein cows. J. Dairy Sci. 45:223.

Woodward, R. R. and J. R. Quesenberry. 1956. A study of vaginal and uterine prolapse in Hereford cattle. J. Anim. Sci. 15:119.

# IMPACT OF DHIA RECORDS ON EFFICIENCY OF DAIRY COWS

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## Summary

The Dairy Herd Improvement Association (DHIA) program has made a significant contribution to genetic and management improvement of dairy cattle. Large volumes of data from the field have been assembled into regional and national data bases. Researchers and extension personnel have taken advantage of those data to develop highly effective improvement programs. Industry groups have contributed to the effort and have utilized the results in a splendid show of cooperation, in some cases among competitors, for the common good. One of the primary strengths of the DHIA program has been the national uniformity in basic essential data that have contributed so much to genetic and management improvement.

## The DHIA Program

The National Cooperative Dairy Herd Improvement Program (NCDHIP) frequently is referred to by the acronym DHIA (Dairy Herd Improvement Association). The DHIA program was begun in Michigan in 1906 and has grown since then to the largest, and perhaps most effective, agricultural recordkeeping program in the world. Approximately 66,000 herd with 4.8 million cows presently are enrolled in the program. The primary purpose of the DHIA program is to obtain management information for participating dairy producers so that their herds and cows can be managed in an efficient and profitable manner.

The DHIA program has contributed significantly to improved dairy production by providing information for (1) improved management techniques and (2) a highly effective genetic improvement program. However, as with beef cattle, production efficiency of dairy cattle is difficult to define precisely, and virtually every scientist who has studied production efficiency has arrived at a different definition. The lack of a precise definition for production efficiency has not been a serious obstacle to continued progress. For example, the average milk production per dairy cow in the United States approximately has doubled in the past 30 yr. Virtually all increase in milk yield due to genetic improvement and much of that due to improved management must be associated with greater production efficiency. The DHIA program has concentrated on the improvement of traits such as yield that generally are agreed to be of importance as components of efficiency even though definitive proof is not available.

Figure 1 is a diagram of the major flow of data and information among cooperators in the DHIA program. The majority of data originates on participating dairy farms. The DHIA supervisor plays a key role in obtaining crucial data wth a high degree of integrity and authenticity for the approximately 41,000 herds enrolled in official dairy recordkeeping plans. The

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DHIA supervisor also helps in obtaining data farms, microcomputers help dairy producers obtain on-farm management information and communicate with the dairy records processing center (DRPC). Milk samples are obtained monthly for most of the cows in enrolled herds and then are analyzed at the central testing laboratory for milk components and for somatic cell count, which is an indication of mastitic infection. The nine DRPC are located in California, Iowa, Michigan, Minnesota, New York, North Carolina, Pennsylvania, Utah and Wisconsin. These centers receive monthly data from participating farms in the regions that they serve, analyze and summarize the data and return management information back to each farm. In addition, the DRPC assemble regional data bases for research and extension activities and forward data to the national data base at the Animal Improvement Programs Laboratory (AIPL), part of the US Department of Agriculture in Beltsville, MD.

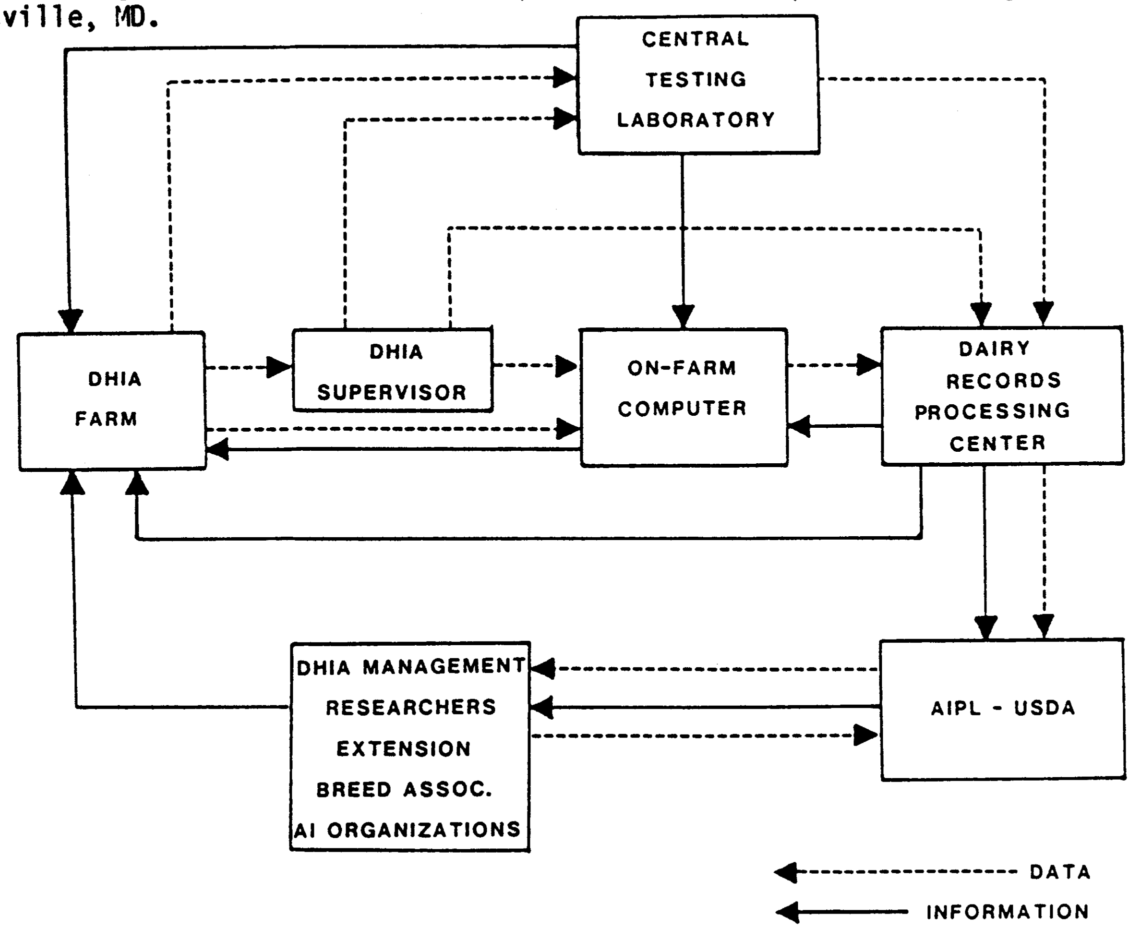


Figure 1. Flow of data and information in the DHIA program.

The AIPL conducts an ongoing research program on the genetic improvement of dairy cattle. An important byproduct of this research is the periodic release of genetic evaluations of bulls and cows. These genetic evaluations are the primary source of information on which selection decisions are based both for animals on individual farms and for bulls that are part of the artificial-insemination (AI) industry.

Several other industry groups participate in the DHIA program: dairy cattle breed associations, AI organizations, extension services in each state and DHIA management. The success of the DHIA program largely has been a result of the superb cooperation among these various groups and the enthusiastic support of producer groups and large numbers of dairy producers.

A wide variety of data is recorded for each cow and farm enrolled in the DHIA program. These data are combined and summarized at the DRPC with highly complex computer systems that produce a large number and variety of management reports for each farm. Aspects of management usually included in standard reports are yield, reproductive performance, indicators of mastitis, producing ability and transmitting ability. Information that is particularly valuable for management planning and action in large herds is reported in "future action lists." Future action lists include information on cows and heifers to calve, cows and heifers to breed, heifers to pregnancy check, cows to dry, heifers to dehorn, vaccinate or register and potential culls. Dairy producers whose cow and herd records are processed at one of the four DRPC with on-line interactive capability can generate an endless variety of management summaries and aids produced to their own specifications whenever they choose.

## Genetic Improvement

Heavy emphasis has been placed in the DHIA program, and throughout the dairy industry, on the genetic improvement of traits that generally are considered to have a high degree of economic importance and, therefore, probably an important impact on production efficiency. Of course, the production traits (i.e, milk yield and milk components) have received the greatest attention. The reason for such emphasis on genetic improvement is that superior genotypes in individual animals are the foundation for a superior herd. After all, management is merely the creation of environment in which animals can express their genetic capabilities. In addition, the benefits from genetic improvement are cumulative and permanent over time, which makes those benefits unique as opposed to benefits from improved management practices. However, the permanency of genetic improvement is true only for additive genetic variation (i.e., the proportion of genetic variation that responds to selection); it is not always true for nonadditive genetic variation, which plays a greater role in the genetic control of many of the economically important traits of beef cattle. Because only a portion of nonadditive genetic variation can be passed from one generation to the next the necessity for the beef industry to rely to a large extent on crossbreeding systems for genetic improvement is a handicap indeed. However, even for traits for which crossbreeding is important, the additive portion of genetic variation also can contribute toward improvement if proper consideration is given. Even though some important traits may have relatively low heritabilities (i.e., a relatively small degree of influence from additive genetic variation), it still may be worthwhile to apply selection pressure to those traits because of their economic importance. An indication of the importance of genetic improvement to the dairy industry may be seen from the fact that during the 1970's, genetic improvement was about two-thirds as great as management improvement (Powell et al., 1982).

Artificial insemination has played an extremely important role in genetic improvement of dairy cattle. It has been the medium by which superior germplasm has been spread throughout the dairy cattle population. Domestic sales of semen for genetic improvement are shown in figure 2 for both dairy and beef cattle. In 1982, approximately 12.8 million units of dairy semen were sold in the United States compared with .9 million units of beef semen (National Association of Animal Breeders, 1983). Genetic improvement of dairy cattle would have been much less rapid over the past 30 yr if AI had not been available as the primary method for dissemination of superior germplasm.

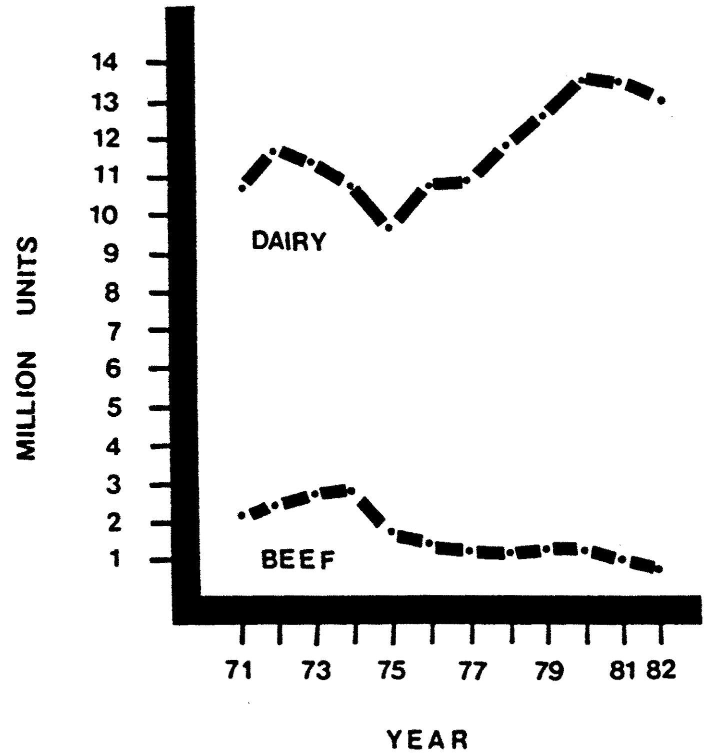


Figure 2. Domestic sales of dairy and beef semen by year (National Association of Animal Breeders, 1983).

Beef producers have utilized custom frozen semen for genetic improvement to a greater extent than semen purchased commercially as shown in figure 3. Beef producers used 1.6 million units of semen in 1982 as opposed to only 1.2 million of custom frozen semen used by dairy producers. Obviously dairy producers rely much more heavily on the genetically superior semen produced by commercial organizations than do beef producers.

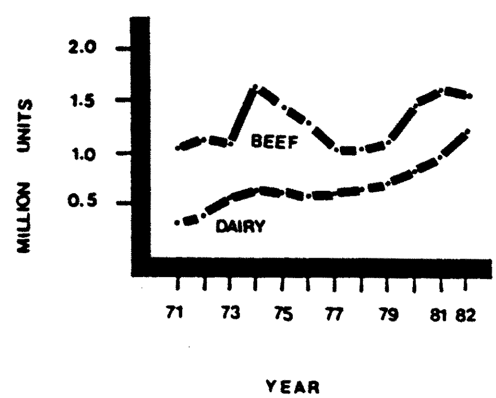


Figure 3. Sales of dairy and beef custom frozen semen by year (National Association of Animal Breeders, 1983).

Several measures are available that indicate the substantial amount of genetic improvement made by the dairy industry. Table 1 shows the genetic merit of Holstein bulls sampled for use in AI from 1960 to 1980. The values all are relative to the average transmitting ability of bulls entering AI in 1960 as a base. For milk yield, the average ancestor merit increased 1,165 lb, whereas the Predicted Difference (PD) increased 1,205 lb. A very close correspondence has been obtained for increase in milk yield between the amount of progress expected form pedigree estimates for transmitting ability (ancestor merit) and the genetic merit transmitted by bulls to their daughters (Predicted Difference). Genetic evaluations of similar scope and accuracy for other species would provide corresponding opportunities for genetic improvement of appropriate traits.

TABLE 1. GENETIC MERIT OF HOLSTEIN BULLS PROGENY TESTED IN AI BY YEAR OF ENTRY INTO AI

| Year of entry into AI | Ancestor merit for milk yield | PD (transmitting ability) for milk yield |
|---|---|---|
| | lb | |
| 1960 | 41 | 0 |
| 1965 | 281 | 302 |
| 1970 | 424 | 494 |
| 1975 | 819 | 783 |
| 1980 | 1,206 | 1,205 |

The average difference in transmitting abilities between active AI bulls and non-AI bulls form 1974 to 1984 is shown in figure 4. During that decade, approximately 1,100 lb of improvement occurred in the genetic merit of active AI bulls. Most of the improvement for non-AI bulls resulted from their sires, which were part of the active AI population. In 1974, the superiority of bulls selected for active AI service was approximately 546 lb; in 1984, that superiority has increased to 1,042 lb. Therefore, in 1984, the average daughter of an active AI bull will produce approximately 1,042 lb more milk than will the average daughter of a non-AI bull because of the superior genes transmitted by active AI bulls to their daughters.

Figure 5 demonstrates the high degree of accuracy with which the transmitting ability of a group of bulls can be predicted from their ancestor merit. The almost perfect correspondence between the pedigree merit and the progeny test of these groups of bulls demonstrates the effectiveness of another principle of genetic improvement--complementary sire selection. For individual bulls, a difference almost always exists between ancestor merit and progeny-test results, and for some bulls the difference is quite large. However, the groups of bulls, the correspondence between ancestor merit and progeny test is much closer. Complementary sire selection uses the close correspondence between pedigree and progeny merit to optimize genetic improvement of an entire herd by optimizing the genetic merit of the total pool of genes across all bulls that are selected for each herd's breeding program. A computerized bull-selection program called MAXBULL is available to dairy producers nationwide; MAXBULL is a linear programming sire-selection procedure that optimizes the overall genetic merit of a group of bulls selected for use in each herd according to selection criteria and degrees of emphasis specified by each herd owner. Similar sire selection schemes could be developed for other species for which sufficient scope and accuracy of genetic information are available.

Table 1 and figure 4 have shown the improvement in the average genetic merit of bulls available for use by dairy producers. Figure 6 shows the extent to which dairy producers have taken advantage of that increased genetic superiority as measured by the increases of PD milk of sires of first-lactation-Holstein cows calving from 1960 to 1982. In 1982, the average first-lactation cow enrolled in an official dairy recordkeeping plan produced about 1,040 lb more milk than did the average first-lactation cow calving in 1960 because of the superior genes received from her sire. This increase almost certainly has resulted in a significant increase in the production efficiency of dairy cows because even though production efficiency is not defined precisely, milk yield per cow must be extremely important component.

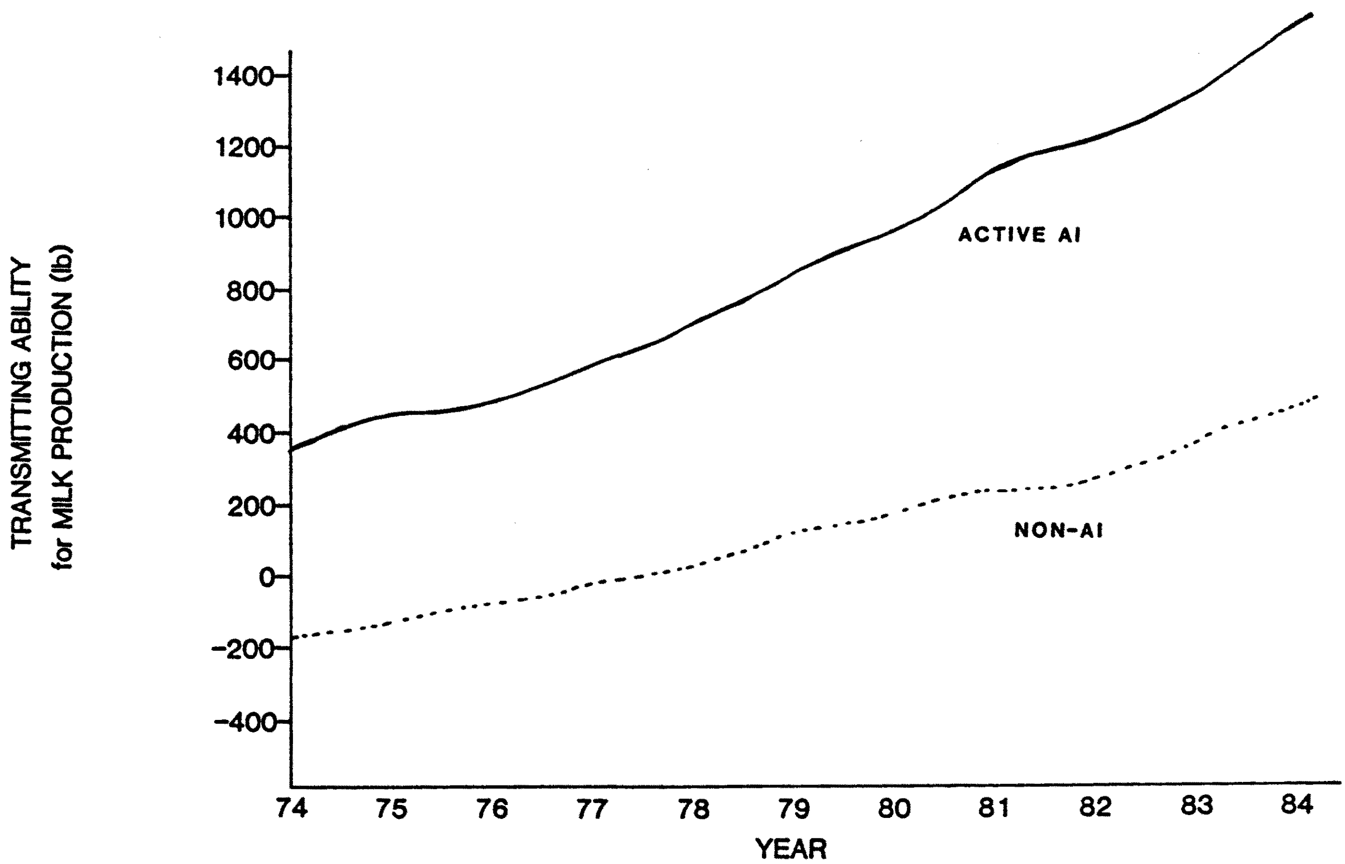


Figure 4. Transmitting abilities for milk production for active AI and non-AI bulls in the United States by year.

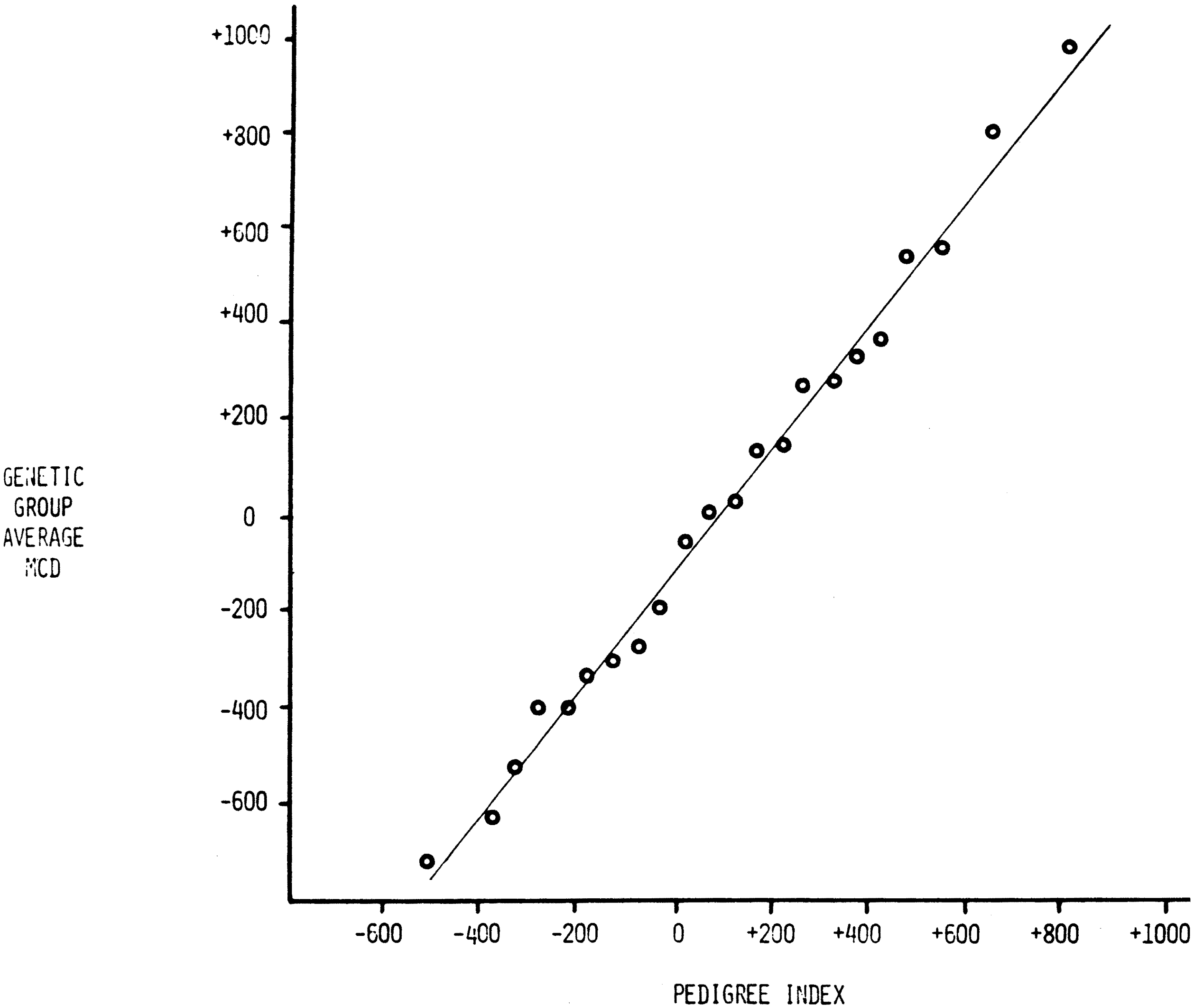


Figure 5. Relation between pedigree index and genetic average Modified Contemporary Deviation for milk yield for groups of Jersey bulls. Circles represent average transmitting abilities ranked according to estimates of pedigree merit.

A comparison of the export sales for dairy and beef semen from 1971 to 1982 is shown in figure 7. The continual increase in export sales of dairy semen is fitting testimony to the genetic superiority of US dairy cattle and the esteem with which that genetic merit is held around the world. The continuing increase in export sales of dairy semen has been an important source of profit to AI organizations and has contributed significantly to lowering the price of genetically superior semen for US dairy producers.

The overall superiority of dairy cows in herds enrolled in official dairy recordkeeping plans over cows not enrolled in DHIA is shown in figure 8. In 1960, DHIA cows were approximately 4,000 lb superior to other cows; in 1982, the superiority of DHIA cows had increased to over 5,000 lb. That increased superiority is the result of a combination of superior management and genetic improvement.

## Increase in Labor Efficiency for Dairy Versus Beef Cattle

One measure of efficiency available to compare progress in the dairy and beef industries is the amount of product produced per hour of labor. Table 2 shows increases in pounds of milk versus live weight of beef produced per hour of labor from 1917 to 1980. Production of milk per hour of labor increased 306 lb, whereas production of beef increased only 69 lb. A direct comparison between these two figures may not be valid. If the two industries are considered separately, milk per hour of labor has increased to over 12 times its level in 1917, whereas beef per hour of labor has increased slightly over 4 times. The DHIA program and its contribution to improved management and genetic improvement has had a major impact on the increased efficiency of dairy production.

TABLE 2. MILK AND BEEF (LIVE WEIGHT) PRODUCTION PER HOUR OF LABOR BY YEAR

| Year | Milk | Beef |
|---|---|---|
| | lb | |
| 1917 | 27 | 22 |
| 1927 | 30 | 23 |
| 1937 | 29 | 24 |
| 1947 | 38 | 25 |
| 1957 | 59 | 31 |
| 1967 | 111 | 48 |
| 1980 | 333 | 91 |

## Literature Cited

National Association of Animal Breeders. 1983. Proc. 37th Ann. Conv., 70 pp.

Powell, R.L., H.D. Norman and F.N. Dickinson. 1982. Genetic and environmental trends for milk production. Proc. 33rd Ann. Meeting of Euro. Asso. for Anim. Prod., Aug. 16-19, 1982, Leningrad, USSR.

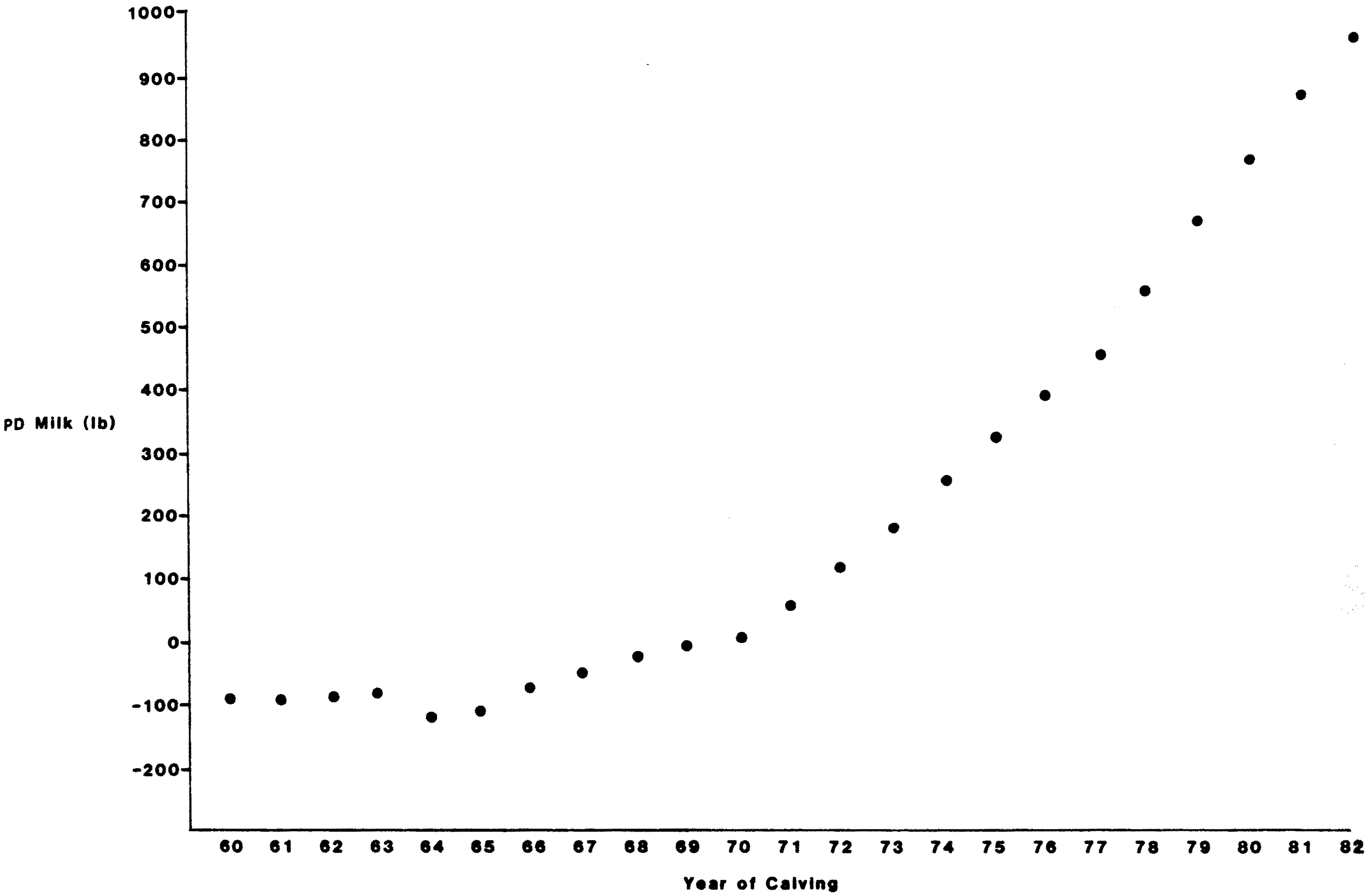


Figure 6. Average PD for milk yield of sires of first-lactation Holstein cows in the United States by year.

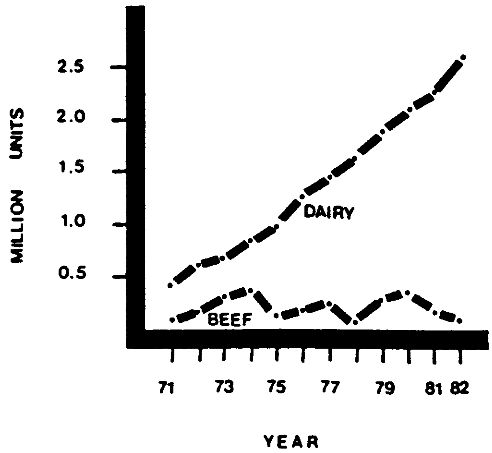


Figure 7. Export sales of dairy and beef semen by year (National Association of Animal Breeders, 1983)

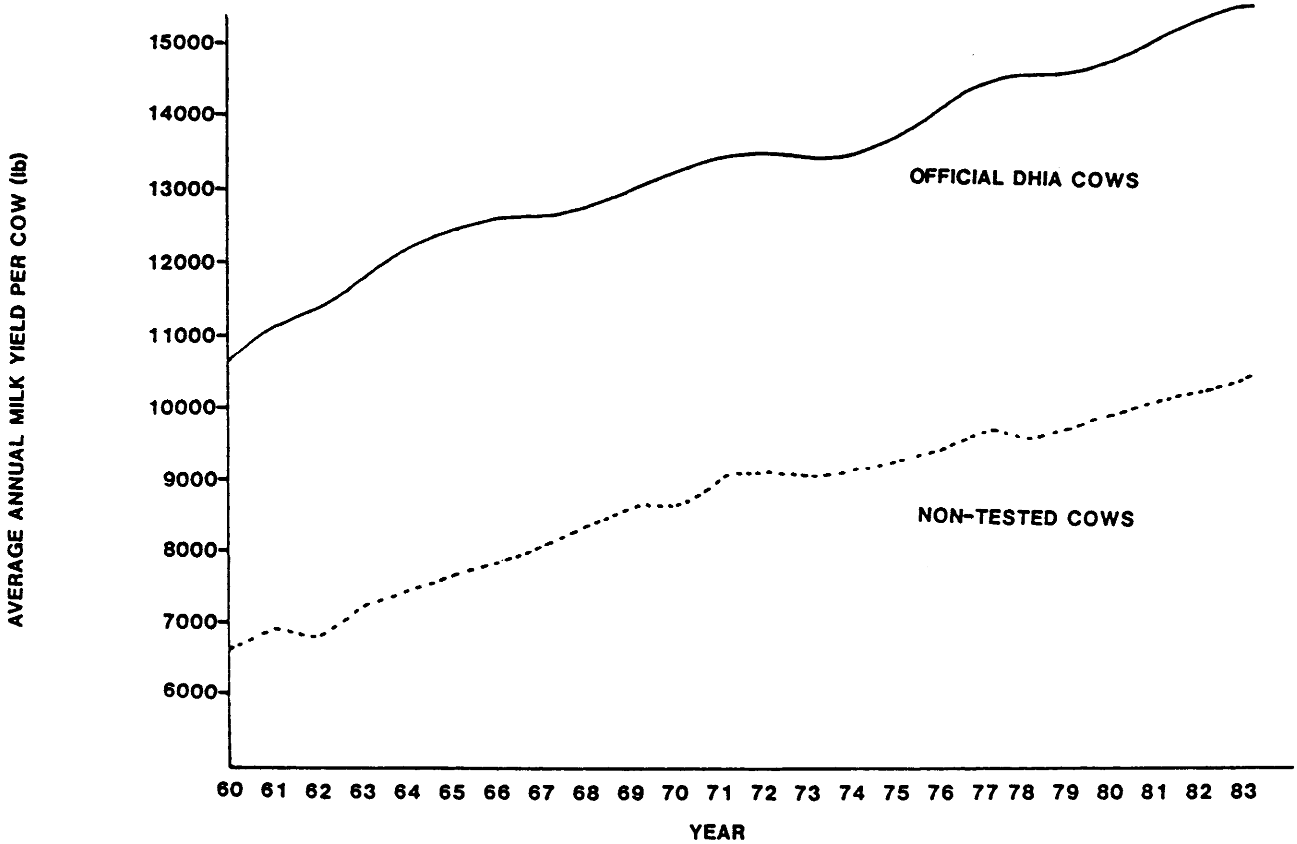


Figure 8. Average annual milk yield of DHIA-tested cows and nontested cows.

# FACTORS RELATED TO INCREASED EFFICIENCY OF THE EWE

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## Summary

The major role of domesticated ruminants is to efficiently convert large quantities of noncompetitive feedstuffs into food and fiber for human use. The task of formulating efficient production systems is biologically and economically complex and not easily amenable to generalized solutions. Feed resources for ruminant animal production are available from many diverse ecosystems throughout the United States. These varying conditions clearly establish the paramount importance of animal adaptability to a given management system for achieving acceptable levels of productive efficiency.

## Introduction

The biological abilities of sheep are exceptional and remain relatively unexploited for intensive and efficient production of lamb meat and wool in the United States. Parker and Pope (1983) recently published an interpretative overview of the changes occurring within the industry during the past 25 yr. They concluded the greatest challenge for improved sheep production is the development, transfer and adaption of unused technology currently available for improving production efficiency. Continual technological improvement for production efficiency will obviously remain a challenge for future animal production.

The objectives of this paper are to present those biological components affecting productive efficiency of the ewe. The author's intent is to accent the relevance of certain common production efficiency factors between cattle and sheep.

## Production Constraints

The decline of sheep numbers in the U.S. has been related to numerous political, sociological and economic conditions. Predation wastage and availability of hired labor have been particularly critical to range sheep production. Increased production costs along with lowered lamb concentration have weakened the relative economic position of the industry. However, the biological abilities and unique characteristics of sheep to harvest high fiber feedstuffs for meat and wool production have great potential value to the future of animal agriculture.

Lamb Crop Percentage. The most important biological factor affecting economic efficiency of sheep production in most areas of the United States is the annual number of lambs produced per ewe. Unfortunately, the national average for lamb crop percentage has not improved during the past 25 yr in the U.S. This lack of change for reproductive performance can easily be identified as the major constraint for improving productive efficiency of sheep.

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Estimates of predation loss, primarily to coyotes, indicate the annual lamb crop percentage has been reduced some 5% in the 17 Western States. However, there is little evidence to suggest recent genetic improvement in reproductive efficiency from direct selection. Long term selection studies by Bradford et al. (1981) have shown that significant improvement in lamb production can be realized from selecting for reproductive efficiency. Techniques and incentives need to be developed to encourage purebred breeders to emphasize selection for those traits affecting reproductive efficiency.

The opportunity for direct and rapid improvement in reproductive efficiency was greatly enhanced by the introduction of Finnsheep into the United States in 1968. Results show a definite productive advantage for Finnsheep crossbred ewes to improve lamb meat production (Dickerson, 1977). Where adapted and properly managed, lambing rates are generally increased an average of 1% for each percentage of Finnsheep breeding. The $F_1$ Finnsheep crossbred ram can be used to effectively introduce Finnsheep breeding into existing flocks for improving the reproductive efficiency of replacement ewes. Crossbreeding has generally improved lamb survivability, growth rate, sexual maturity and other factors affecting reproductive performance.

Optimum reproductive rate for various ecosystems will likely vary according to available feed, labor resources and flock size. Studies by Hohenboken and Clarke (1981) have related important breed by management interactions for lamb production. Numerous studies with sheep and cattle indicate that reproductive performance of a group in a given environment provides an overall measure of general adaptability. This knowledge reflects the importance of matching animal resources (genetic) to the given environment and/or economically alter the environment so animals with higher potential can be utilized for increased production.

## Significant Industry Changes

Technological developments for improving economic and production efficiency of sheep during recent years have been numerous. Most of these developments are applicable where management systems can be altered to increase intensifications of input and resource utilization. Pope et al. (1977) estimated net returns from sheep in the United States could be increased by 94% if 50% of the technology currently being developed were adopted.

Body Size Changes and Productive Efficiency. Possibly the most dramatic recent change in meat animals has been the increase in body size of beef cattle and sheep. The primary trait for selection within the purebred sheep industry during the past 25 yr has been body size. Parker and Pope (1983) calculated from yearling ram weights of eight breeds shown at the Ohio State Fair an increase of 22.8% during the past 25 yr or .85 kg/yr. The emphasis on size has definitely affected the weight of commercial lambs at slaughter. The average increase in slaughter weight during the past 25 yr has been .31 kg/yr. This improvement in weight has contributed significantly to the total amount of lamb produced per ewe.

Research results to date do not indicate a strong within group relationship between body weight and reproductive efficiency. Therefore, it appears that genetic improvement for reproductive efficiency will be attained from a more direct selection for those factors affecting reproductive performance. The lack of change in lamb crop percentage during the past few years would support this suggestion.

## Management Practices and Ewe Efficiency

Hormonal control of reproduction can be successfully employed with sheep provided the techniques are applied under specified conditions. However, a lack of product availability and regulatory agency approval has prevented the commercial application of hormones by sheep producers in this country.

Reproductive Performance of Yearling Ewes. The management of ewe lambs to lamb at 12 to 14 mo of age can improve overall flock performance for lamb meat production. Ewes that lamb at this young age also have higher lifetime performance in well managed flocks (Hulet et al., 1969).

Early Weaning of Lambs. Under intensive management systems, lambs are routinely weaned from 6 to 8 wk of age. Early weaning has also improved the conception rate of ewes on short interval breeding schedules, especially during the late winter and early spring periods. Young lambs are more efficient in their conversion of nutrients to muscle growth than are older lambs. Maximal nutrition levels should be supplied to the young lamb where economically feasible to attain optimal efficiency for market lamb production. Optimal weaning age can be determined from the quality and unit costs of diets available for post weaning feeding and the expected lamb growth performance.

Condition Scoring of Ewes. This "age old" management practice appears to be under rediscovery with recent scientific creditability. Ewes at breeding time with average or slightly above condition scores generally have higher ovulation rates and therefore, more lambs at parturition. Ewes suckling multiple lambs have higher milk yields and therefore, greater lamb survivability if at average or higher body condition during early lactation.

## Ewe Efficiency in the Future

A positive aspect for sheep production in the coming years is the biological potential of sheep to utilize large quantities of cellulosic material efficiently for the production of quality food and fiber.

Seasonality of breeding is a major obstacle for maximizing lamb production. Research to identify selection criteria to enable year-round breeding with higher ovulation and fertility rates is necessary for realizing the true biological potential of sheep as a meat producing animal. Selection emphasis for adaption to particular environments or production systems should receive more attention for improving production efficiency.

Sheep producers should determine production goals necessary for utilizing resources profitably. This obviously involves a systems approach to consider alternative management programs. Breeding technology is currently available for commercial sheep producers to improve the national average annual lamb production by 100%. Higher levels of performance are likely for well managed sheep during the late 1980's.

## Literature Cited

Bradford, G.E., D.T. Torrell, L. Lassio and R. Neira. 1981. Selection for growth and reproduction in Targhee sheep. Summary 1981 Sheep and Wool Day, Oregon State Univ., Corvallis. Spec. Rep. 613, pp 42-55.

Dickerson, G.E. 1977. Crossbreeding evaluation of Finnsheep and some U.S. breeds for market lamb production. North Central Reg. Publ. No. 246. ARS, USDA and Univ. of Nebraska, Lincoln.

Hohenboken, W.D. and S.E. Clarke. 1981. Genetic, environmental and interaction effects on lamb survival, cumulative lamb production and longevity of crossbred ewes. J. Anim. Sci. 53:966.

Hulet, C.V., E.L. Wiggins and S.K. Ercanbrack. 1969. Estrus in range lambs and its relationship to lifetime reproductive performance. J. Anim. Sci. 28:246.

Parker, C.F. and A.L. Pope. 1983. The U.S. Sheep Industry: changes and challenges. Invited paper for 75th Ann. Meet. Am. Soc. Anim. Sci. J. Anim. Sci. 57 Supp 2, pp 75-99.

Pope, A.L., F.M. Husby and R.W. Touchberry. 1977. Research needs in sheep-1977 to 2000 A.D. North Central Reg. Publ. 240. Circ. 404, Agr. Exp. Sta. Kansas State Univ., Manhattan.

# EFFICIENCY DURING THE LIFE CYCLE OF BEEF COWS

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## Introduction

Variation in lifetime cow efficiency is difficult to measure as it requires individual animal estimates of feed intake. Dry lot individual feeding is costly and also has limitations as certain diets or methods of feed preparation seem to be dictated. An additional problem is the definition of efficiency. There are many. They may vary in time, inputs, outputs, be strictly biological or include various degrees of economic evaluation.

In our research we have dealt with estimates of lifetime efficiency. The following is a brief overview of experimental methodology. For fuller explanation of diets, methods of feeding, estimates of milk production, breeding methods and calculations of efficiency the reader must go to our original publications, specifically those of Kress, Hohenboken and Davis as senior authors.

## Experimental Procedures

Wisconsin contributing projects to NC-1 began in 1953. The first two experiments, each lasting 5 years, had the major objectives of determining the heritability of traits in the broad sense through the use of identical and fraternal Hereford twins. The next 10 years, two experiments had the objective of determining genetic-environmental interactions, again employing twins -- Herefords for the first 5 years and Herefords and Holsteins the last 5. In 1974 60 crossbred heifers, 15 each of Hereford x Holstein, Angus x Holstein, Simmental x Holstein and Chianina x Holstein, were started on an experiment to test breed of sire by feeding level interactions. There have been a total of 284 females on the project. Of these, 271 have had at least one progeny. The total number of calves was 709, approximately 655 had weaning records and about 650 had slaughter and carcass records. At present we have 94 Angus x Holstein females that are being individually fed to determine the influence of ration changes at certain physiological stages in the cows life.

### Feeding

The feeding regimen has been fairly standard. In the main, rations of coarsely chopped hay, grain and protein supplement in various mixtures have been allowed *ad libitum* for 2 hours in the morning and 2 hours in the afternoon. Each cow was tied to an individual self-feeder starting at 168 days of age. The progeny were also individually fed in a like manner from 28 days of age until slaughter. All progeny within an experiment were fed alike. Ration changes were made for the breeding females as necessary until they were 15 months of age; no changes were made therafter. Individual feed consumption data were recorded for all animals. Growth measurements of weight, height, length, etc. were taken every 28 days on the breeding females and their progeny. At least nine body and head measurements were taken.

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Reproduction

All females were bred at the first estrus after 15 months of age and at all postpartum estrous cycles, except in the last experiment the heifers were bred at puberty. The breeding females were palpated once a week as necessary to determine uterine involution, ovulation and pregnancy.

The use of bulls varied over the years. In the first years all females were bred to one bull and in the most recent experiment monogamous matings were made to 64 unrelated sires. Females within twin sets were always mated to the same sire.

The cows were allowed to have three calves or were kept on the projects until they were 5 years of age.

Milk Production

Estimates of milk production early in lactation were made each week and at least once a month later in lactation (after the peak of milk production).

Twice during 24 hours, half the udder was either machine or hand milked while the calf nursed the other half. Butterfat content of the milk was determined by the Babcock test.

Slaughter of Progeny

Slaughter and carcass data were obtained from all progeny. Numerous measures of carcass merit, composition and quality have been taken. The slaughter endpoint in earlier experiments was an estimated grade; in recent years slaughter has been a constant age.

Lifetime efficiency measurements have been calculated to several end points -- weaning, slaughter and trimmed wholesale cuts. Measures were made including and excluding cow salvage value. In one analysis, a herd study base included replacement animal inputs and reproductive rates; the second included only those cows that had three progeny.

## Results

Efficiency of Weaning

Influence of Dam's Level of Nutrition - Cows fed the high energy diets weaned heavier calves and because of their heavier weights had greater salvage value. The cows fed the low energy diet produced less milk and therefore their calves consumed more creep feed to compensate for the lower milk supply.

Cows fed the low energy diets were generally more efficient especially if salvage value of the cow was not a part of the ratio, indicating that continuous feeding a diet high in energy may not be economical. It may be more efficient to feed the calf directly rather than to feed the dam to increase milk production.

Influence of Breed of Dam or Sire on Breed of Dam - Holstein cows managed as beef cows and bred to Hereford bulls weaned calves that were approximatly 100 pounds heavier than Hereford cows bred to Holstein bulls. The Holstein cows produced more milk and their calves ate less creep feed and due to their heavier weight they had more salvage value than the Hereford cows. In spite of these greater outputs the Holstein cows were not as efficient as the Herefords because of their greater feed intake and probably because of their longer postpartum anestrus especially after first calving.

The 1974 crossbred cows, the result of breeding Holstein cows to Hereford, Angus, Simmental and Chianina bulls, showed no significant differences in progeny weaning weight but generally the heavier breeds, Simmental- and Chianina-sired cows weaned heavier calves than cows sired by Hereford and Angus and they had greater salvage value.

TABLE 1. PROPORTIONATE CONTRIBUTION OF EFFICIENCY COMPONENTS TO TOTAL INPUTS AND OUTPUTS TO WEANING

| | Mean Mcal | Proportion (%) of progeny and dam input and outputs |
|---|---|---|
| Metabolizable energy consumed | | |
| Progeny 1 | 1,224 | 3.3 |
| Progeny 2 | 1,226 | 3.3 |
| Progeny 3 | 1.328 | 3.3 |
| Total | 3,778 | 10.0 |
| Metabolizable energy consumed by dam | | |
| Birth to 240 days of age | 1,639 | 4.4 |
| 240 days of age to weaning first calf | 13,379 | 35.5 |
| Weaning first calf to weaning second calf | 9,321 | 24.7 |
| Weaning second calf to weaning third calf | 9,545 | 25.3 |
| Total | 33,884 | 90.0 |
| | Overall Mean, kg | |
| Weaning Weight | | |
| First calf | 255 | 22.3 |
| Second calf | 280 | 24.5 |
| Third calf | 292 | 25.5 |
| | | 72.2 |
| Salvage weight of dam x (.5714)[a] | 318 | 27.8 |

[a]Assuming cow weight has a value 4/7 that of a weanling calf.

The Angus and Simmental crossbreds tended to produce more milk than the Hereford and Chianina sired cows.

The larger crossbred cows consumed more feed on both levels of nutrition so that there were no differences between breeds of sires of cows in weaning efficiencies by any efficiency measures. The Hereford x Holstein crossbreds tended to be more efficient than the larger slower maturing Chianina x Holstein crossbreds. The latter reach puberty at older ages and may have been at a disadvantage because of their large size and therefore higher maintenance requirements.

In table 1 are presented the proportions of inputs and outputs attributable to the progeny and dams. Residual correlations reveal that dams that consumed the most feed were least efficient. When cows were bred at the puberal estrus those reaching puberty at younger ages were most efficient and those calving at younger ages at first, second and third calvings enhanced efficiency.

Cows that were heavier, taller at the withers and fatter were less efficient than lighter, shorter and thinner cows. Within the Hereford breed, cows that produced more milk were more efficient than low milk producers but the opposite was true within the Holstein breed.

Postweaning Efficiency

Influence of Dam's Level of Nutrition -- The diet of the dam had very little effect on postweaning gain, feed consumption and feed efficiency of the progeny and there were no significant effects on slaughter weights, carcass weights or trimmed retail cut weight.

Influence of Breed of Dam or Breed of Sire of Dam -- Progeny of Holstein dams made more rapid postweaning gains, ate more feed and produced heavier slaughter, carcass and trimmed wholesale cut weight than progeny of Hereford dams. Since they consumed more feed they were, therefore, no more efficient than progeny of Hereford dams. Recall, however, that the progeny in both cases were 50% Hereford and 50% Holstein.

The progeny of the larger crossbred dams (Simmental x Holstein and Chianina x Holstein) tended to gain faster, consume more feed and be more efficient than progeny of cows sired by smaller breeds of bulls. The larger breeds of dams also produced progeny with heavier slaughter and carcass weights and greater weights and percentages of trimmed wholesale cuts.

Life Cycle Efficiency

Influence of Level of Nutrition -- The cows fed the low energy diet were generally equal to or superior to those fed the higher energy diet. This was due to the high feed intake of the dams fed the high energy diet. The influence of diet was not apparent in the 1974 data set, as in that experiment the heifers were bred at the puberal estrus and those fed the high energy diet reached puberty and conceived at younger ages than the heifers on the low energy diet.

Influence of Breed -- The breed differences and breed of sire of dam differences were much like those observed in the preweaning data. However, because of the more rapid growth of the progeny of the large breed and large breed of sire groups, the magnitude of the differences between mean efficiencies was narrowed. The efficiency of production improved as the number of progeny slaughtered increased.

The proportions of inputs and outputs of the progeny and the dams are presented in table 2. Sixty-five percent of the Mcal of total energy consumed can be charged to the cow and about 78% of the output value comes from the slaughter of the progeny. The importance of early and frequent calf production cannot be over emphasized.

TABLE 2. PROPORTIONATE CONTRIBUTION OF EFFICIENCY COMPONENTS TO TOTAL SLAUGHTER WEIGHT OUTPUTS AND FEED

| Inputs | | | Percent of total |
|---|---|---|---|
| Progeny preweaning feed | $PF_1$ | | 2.4 |
| | $PF_2$ | | 2.4 |
| | $PF_3$ | | 2.6 |
| | Total | | 7.3 |
| Progeny postweaning feed | $PPF_1$ | | 9.0 |
| | $PPF_2$ | | 9.1 |
| | $PPF_3$ | | 9.3 |
| | Total | | 27.4 |
| Dam's feed | $DF_0$, Birth to 240 days | | 3.2 |
| | $DF_1$, 240 days to weaning calf 1 | | 25.8 |
| | $DF_2$, Weaning calf 1 to weaning calf 2 | | 18.0 |
| | $DF_3$, Weaning calf 2 to weaning calf 3 | | 18.4 |
| | Total | | 65.3 |
| Outputs | | Wt., kg | |
| Progeny weight output | $SLP_1$ | 408 | 24.3 |
| | $SLP_2$ | 450 | 26.5 |
| | $SLP_3$ | 462 | 27.1 |
| | Total Progeny | | 77.8 |
| Dam's output | | 381 | 22.2 |

## Predicting Cow Efficiency

The prediction equations derived from the data collected from the various types of cattle used in these experiments are presented in the following table.

TABLE 3. EFFICIENCY PREDICTION EQUATIONS

| | | | $R^2$ |
|---|---|---|---|
| **Beef** | | | |
| Lifetime efficiency | = | $-.000021^{**}DW^a + .00042^{**}PW^b$ | .49 |
| Annual efficiency | = | $-.000176^{**}DW + .000401^{**}PW$ | .66 |
| **Beef x Dairy** | | | |
| Lifetime efficiency | = | $-.000015AC^c$ | .43 |
| Annual efficiency | = | $-.000076DW + .000342PW$ | .79 |
| **Dairy** | | | |
| Lifetime efficiency | = | $-.0000323^{*}AP^d - .0000219AC$ | .67 |
| Annual efficiency | = | $-.000167DW + .000229PW$ | .90 |
| Annual efficiency | = | $-.000160DYH^e + .000280PW$ | .90 |

[a]DW = dam weight.
[b]PW = progeny weight.
[c]AC = age at calving.
[d]AP = age at puberty.
[e]DYH = dam yearling height.

The prediction equations for lifetime and annual efficiency for Hereford cattle included dam weight and progeny weight, indicating that small cows producing heavy progeny were most efficient. For the beef x dairy crossbreds that were bred at the puberal estrus, age at calving was the best predictor of lifetime efficiency and for annual efficiency, dam weight and progeny weight accounted for almost 80% of the variation in efficiency. For the Holsteins, heifers that reached puberty at young ages were less efficient but those that calved early were more efficient. These females were bred at the first estrus after 15 months of age and all of the Holsteins had attained puberty prior to that time. The ones that reached puberty earliest were the fastest growing, therefore, had the most weight to maintain and were least efficient. Had the heifers been bred at the puberal estrus, those attaining puberty at young ages would have been more efficient. Again, in the Holstein prediction equation for annual efficiency dam weight and height had negative associations with efficiency.

## References

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

Davis, M. E., J. J. Rutledge, L. V. Cundiff and E. R. Hauser. 1983b. Life cycle efficiency of beef production: II. Relationship of cow efficiency ratios to traits of the dam and progeny weaned. J. Anim. Sci. 57:852.

Davis, M. E., J. J. Rutledge, L. V. Cundiff and E. R. Hauser. 1984b. Life cycle efficiency of beef production: III. Components of postweaning efficiency and efficiency to the slaughter end point. J. Anim. Sci. 58:1107.

Davis, M. E., J. J. Rutledge, L. V. Cundiff and E. R. Hauser. 1984b. Life cycle efficiency of beef production: IV. Cow efficiency ratios for progeny slaughtered. J. Anim. Sci. 58:1119.

Hohenboken, W. D., E. R. Hauser, A. B. Chapman and L. V. Cundiff. 1973. Phenotypic correlations between dam traits of progeny in cattle. J. Anim. Sci. 37:1.

Kirkpatrick, B. W., C. A. Dinkel, J. J. Rutledge and E. R. Hauser. 1984. Prediction equations of beef cow efficiency. J. Anim. Sci. (submitted).

Kress, D. D., E. R. Hauser and A. B. Chapman. 1969. Efficiency of production and cow size in beef cattle. J. Anim. Sci. 29:373.

# IMPACT OF SELECTION AND CROSSBREEDING IN COW EFFICIENCY

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## Summary

The beef breeding project at Michigan State University is designed to evaluate the genetic change in commercial beef herds that occurs by means of: using bulls from breeders selecting for growth rate (Group 2); and rotational crossbreeding (Groups 3 and 4). An unselected grade Hereford herd is maintained as a control (Group 1).

Compared to Group 1, Group 2 showed a significant increase in weaning weight, birth weight, calving difficulty, dam weight, average daily gain (ADG) in the feedlot, slaughter weight and dressing percent. There was a decrease in number of calves weaned as a percent of cows wintered.

Compared to Group 2, the crossbred groups showed a significant increase in weaning weight, percent calves weaned, birth weight, dam weight, ADG, final weight, cutability, and dressing percent. There was a decrease in calving difficulty and carcass outside fat.

There were only small differences in efficiency. The crossbreds involving Holstein blood (Group 4) did appear to be more efficient at weaning.

## Introduction

The Michigan contributing project to the NC-1 Regional Project was designed to evaluate what Michigan commercial beef producers could do to improve their cattle genetically. There are only two ways that a population can be changed genetically. First, the gene frequency can be changed. For commercial producers, this is primarily accomplished by the selection practiced within purebred herds from whom producers buy their bulls. Second, the genotypic frequency can be changed by the mating system. For cattle, the primary mating system used to increase productivity is crossbreeding.

Any breeding program should have objectives. In terms of the total beef industry, we feel the ideal cattle are those that: 1) grow as rapidly as possible to market weight of approximately 1200 lb for steers; 2) produce carcasses that grade low choice with a yield grade of 2; 3) produce as many calves as possible per cow wintered; 4) and accomplish these objectives with a minimum of dollar input.

The Michigan project was designed to evaluate change due to selection within bull producing herds and change resulting from a continued rotational breeding program.

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## Procedure

A herd of Hereford cows given to Michigan State University by the Ford brothers in 1967 were divided into four groups at random, stratified within age groups, to form four 50-cow breeding groups at the Lake City Experiment Station. The four breeding groups were:

1. Unselected Hereford controls.
2. Hereford cows mated to sires from Hereford breeders selecting for growth.
3. Crossbreeding: Hereford, Angus and Charolais.
4. Crossbreeding: Hereford, Angus and Holstein-Friesian (In 1977 Simmental was added to the rotation in Groups 3 and 4).

The cows were bred AI for about 6 weeks starting in April. Much of the semen was donated by Select Sires Inc., Plain City, OH. In Groups 3 and 4, cows were mated to bulls from breeds that were least related. The cows were turned to pasture with cleanup bulls in late May for about 4 weeks. The calves were dropped primarily in February, March and April. At birth they were ear tagged, tattooed, dehorned and castrated, except for four bull calves which were kept in Group 1. The oldest bull calves from each of the 4 bulls used the previous year were saved as replacement sires. In the early years, the calves were creep-fed but this practice was discontinued in the early 1970's. The calves were weaned in September, at which time they were weighed and scored for conformation and frame. The steer calves were shipped to East Lansing for finishing at the Beef Cattle Research Center (BCRC). Fifteen replacement heifers were saved in each group. the heifers in Groups 2-4 were selected on actual weight and soundness. The fifteen oldest heifers in Group 1 were saved. These replacement heifers were fed a growing ration at Lake City.

At weaning time all cows were pregnancy checked. Ten replacement heifers were selected from each group - first on pregnancy and then on weight. Older cows were saved on the basis of: first, soundness; second, pregnancy; and third, calf weights. The exception to this was in Group 1 where there was no selection for weight.

At BCRC, the steers were assigned to two nutritional treatments at random within breeding groups. The treatments were usually a high and low amount of corn silage plus corn and supplement. There were 8 steers assigned to each nutritional treatment from each breeding group. The steers were slaughtered at a commerical slaughter plant when it was estimated 80% would grade choice.

## Results

In the crossbred groups, Simmental bulls were included in the rotation for calves born from 1978 to 1982. The data from these five calf crops will be covered in this paper. The use of bulls from herds selecting for growth and selecting replacement heifers on growth (Group 2) will be referred to as Selection. We will look at the data in two parts - at weaning time and in the feedlot.

### Weaning time

The calves in the Selected group (Group 2) were 81 lb heavier (471 vs 390) in their adjusted weaning weights than Group 1, as shown in table 1. However, we experienced problems with fertility and calf survival in the selected group.

They weaned only 81 calves per 100 cows wintered compared to 87 calves in the control group. This was accompanied by an increase in calving difficulty score of .39 (1.54 vs 1.15). There was a slight increase in conformation score and a larger change in frame score (3.7 vs 2.7). The associated changes in weight were also major. Selection increased birth weight by 19 lb (83 vs 64), a surprisingly large change. This large a change in birth weight indicates a genetic correlation between weaning weight and birth weight of greater than 1, which is biologically impossible. Dam weight increased by 142 lb (1113 vs 971). These base data were combined in several ways to look at efficiency in different ways, as shown in table 2. Weight of calf weaned per cow wintered was 43 lb heavier for the selected group. However, there were essentially no differences when lb of calf weaned per cow wintered was divided by either weight of the dam or estimated TDN requirements.

Crossbreeding increased both weight and fertility when compared to the selected group. The weight of individual calves was increased by 114 lb (585 vs 471) (table 1). The number of calves weaned was increased by 4 (85 vs 81). Other related changes included an increase of: 1.2 in frame score, 8 lb in birth weight and 57 lb in cow weight. Calving difficulty score decreased by .18 (1.36 vs 1.54) even though birth weight increase. The various expressions of efficiency (table 2) included an increase of 118 lb (500 vs 382) for lb of calf weaned per cow wintered, .08 for weight of the calf divided by weight of dam, and 1.2 for lb of calf weaned per cow wintered divided by TDN.

TABLE 1. BIRTH AND WEANING DATA FOR CALVES DROPPED AT LAKE CITY (1978-82)[a]

| | Breeding group | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Item | Uns Her | Sel Her | Sim-Char-Ang-Her | Sim-Hol-Ang-Her |
| Birth wt, lb | 64 | 83 | 89 | 92 |
| Calving score[a] | 1.15 | 1.54 | 1.45 | 1.27 |
| Weaning data: | | | | |
| % weaned[b] | 87 | 81 | 83 | 88 |
| Adj wean wt, lb | 390 | 471 | 558 | 611 |
| Conf score | 11.2 | 12.0 | 12.5 | 12.6 |
| Frame score | 2.7 | 3.7 | 4.7 | 5.1 |
| Dam wt, lb[c] | 971 | 1113 | 1170 | 1170 |

[a]1 = no difficulty.
[b]Number of calves weaned per 100 cows wintered.
[c]Average weight of cows in May each year.

TABLE 2. WEANING EFFICIENCY VALUES FOR CALVES WEANED AT LAKE CITY (1978-82)

| | Breeding group | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Item | Uns Her | Sel Her | Sim-Char-Ang-Her | Sim-Hol-Ang-Her |
| Lb calf weaned/ cow wintered | 339 | 382 | 463 | 538 |
| Wean wt/dam wt | .35 | .34 | .40 | .46 |
| Dam's est TDN, lb[a] | 3690 | 4143 | 4789 | 4829 |
| Wean wt/TDN[b] | 9.20 | 9.22 | 9.92 | 11.14 |

[a]Annual estimated TDN requirements based upon cow weight and milk production (NRC, 1984).
[b]Pounds calf weaned/cow wintered/lb TDN X 100.

## Feedlot Results

As shown in table 3, selection caused an increase in average daily gain (ADG) of .3 lb from weaning to market (2.54 vs 2.21), an increase in slaughter weight of 182 lb (1172 vs 990), and a higher dressing percent (61.3 vs 60.5). Only small differences were present for most other carcass traits.

Compared to selection, crossbreeding increased ADG by .22 lb (2.76 vs 2.54) and slaughter weight by 163 lb (1335 vs 1172). There was a slight decrease in carcass grade (11.3 vs 11.6) but a major reduction in outside fat (.43 vs .59 in), dressing percent (62.2 vs 61.3%) and cutability (56.8 vs 53.9%).

TABLE 3. FEEDLOT AND CARCASS DATA FOR LAKE CITY STEERS (1978-82)

| | Breeding group | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Item | Uns Her | Sel Her | Sim-Char-Ang-Her | Sim-Hol-Ang-Her |
| ADG, lb[a] | 2.21 | 2.54 | 2.77 | 2.76 |
| Slaughter wt, lb[b] | 990 | 1172 | 1310 | 1359 |
| Dressing, % | 60.5 | 61.3 | 62.3 | 62.1 |
| Quality grade[c] | 11.6 | 11.6 | 11.2 | 11.4 |
| Outside fat, in | .58 | .59 | .45 | .41 |

[a]Average daily gain was calculated from weaning weight to slaughter weight.
[b]Cattle from all groups were slaughtered on same dates - usually two kill dates per year. End point was 80% estimated to grade choice.
[c]12=low choice.

Neither selection nor crossbreeding improved feed per unit of gain, as shown in table 4. In this study, the cattle from all groups were started on feed and slaughtered at the same age; therefore, the selected and crossbred groups were heavier throughout the feeding period than the controls. The increased maintenance requirements offset the advantage of the faster ADG for Groups 2, 3 and 4. As long as cattle are marketed on a live weight basis and fed during the same age periods, it appears there will not be an improvement in feed efficiency due to selection or crossbreeding.

An attempt was made to evaluate efficiency of lean growth in the feedlot (table 4). The lean growth produced was calculated as live weight x dressing percent x cutability minus lean at the start. Lean in the cattle at the start was calculated as .40 x weaning weight (Merkel, 1984). Efficiency was defined as lean growth divided by feed consumed. On this basis, neither selection nor crossbreeding had a significant effect on efficiency.

TABLE 4. CARCASS YIELD DATA AND EFFICIENCY VALUES FOR LAKE CITY STEERS, 1978-82

| | Breeding group | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Item | Uns Her | Sel Her | Sim-Char-Ang-Her | Sim-Hol-Ang-Her |
| Cutability, %[a] | 53.7 | 53.9 | 56.6 | 57.1 |
| Total feed DM, lb | 3871 | 4541 | 5292 | 5353 |
| Feed DM/gain | 5.83 | 6.02 | 6.36 | 6.56 |
| Est lean gain, lb[b] | 191 | 226 | 270 | 266 |
| Lean gain/feed DM | .049 | .049 | .051 | .050 |

[a]Cutability based on Nebraska formula (Koch, 1979): Cutability = 57.6 + (.6 X LEA)-(13.03 X fat thickness)-(1.23 X % KHP).
[b]Lean gain calculated as follows: (% cutability X dressing % X slaughter weight) - (.4 X weaning weight) (Merkel, 1984).

## Conclusions

Selection resulted in increased growth rate to weaning time and in the feedlot. It was also associated with heavier calves at birth and heavier dams.

Crossbreeding increased pre- and post-weaning growth as well as percent of calves weaned, which increased efficiency of calf production to weaning time. Rotational crossing that incorporated Holstein-Friesian blood tended to be the most efficient system.

Crossbreeding also increased dressing percent and decreased the amount of outside fat even though the steers were 160 lb heavier when marketed. There was more lean meat produced by the crossbreds, but neither selection nor crossbreeding increased efficiency of lean production in the feedlot.

## Literature Cited

Koch, R. M. 1979. Personal communication.

Merkel, R. A. 1984. Personal communication.

NRC, 1984. Nutrient Requirements of Domestic Animals. No. 4. Nutrient Requirements of Beef Cattle. Sixth Revised Ed. National Academy of Science - National Research Council, Washington, D.C.

# FACTORS AFFECTING COW-CALF UNIT EFFICIENCY

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## Summary and Conclusions

Growth rate, defined in pounds, of the calf is highly related to efficiency of beef production. The correlation between 180-day calf weight and efficiency of the cow-calf unit at weaning was .81. Therefore, there is an economic need to emphasize improved growth rate within a breed and mating system in our breeding and selection programs. If efficiency of the cow-calf unit has a hereditary basis, selection for increased weaning weights and post-weaning growth rate would be helpful in improving productivity. However, the need for calving ease should temper selection for maximum growth rate. Since frame size is an estimate of mature size and feed requirements for body maintenance are related to mature size, selection for growth rate to improve efficiency should occur within a frame size. Optimum frame size should be determined by feed and management resources available to a specific operation and the reproductive performance of the herd under those conditions. Measures of mature cow size, including hip height and weight, appear to have small but unfavorable relationships with biological efficiency of the cow-calf unit, indicating that selection for frame size per se may have a negative effect on cow-calf efficiency.

Crossbreeding per se may have little effect on cow-calf unit efficiency beyond its heterotic effects on fertility and calf livability. However, crossbred systems that utilize sire breeds equal to or larger in mature size than the dam breed(s) may have the potential to improve efficiency an additional 2.5 to 10.0%.

The sound management and breeding program will be one that emphasizes a systems approach and maximizes fertility, percent calf crop and growth rate while minimizing calving difficulties, maintenance costs and excessive finish on slaughter cattle.

## Introduction

As an industry, I think it is time we begin to think about optimizing beef production. One of the things that has concerned me about our industry is that we have constantly worried about how we can improve our prices. I do not believe that consumers are going to be willing to spend a great deal more for beef in the future which suggests to me that if we want to make this industry more profitable, we must improve efficiency. Do you realize that in the poultry industry it takes about 7 weeks to produce a 4-lb bird on 2 lb of feed per lb of gain? Thirty years ago, it took 4 lb of feed per lb of gain and 12 to 16 weeks to produce a 4-lb bird. That is tremendous progress, and they have accomplished this because as an industry they decided what was ideal - and growth rate had a

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high genetic correlation with feed efficiency. Pounds gained and less feed made money in the poultry industry. In my opinion, we have been guilty of not doing our homework in the beef cattle industry and we have not been concerned enough about improving efficiency of production.

I believe biological efficiency of the cow-calf unit has a hereditary basis, and genetic improvement must start with the seedstock industry. From time to time, I think it is important for us to step back and take a look at what we are doing and ask the question - am I getting done what I set out to do? Am I solving the problem or adding to the problem? As cattlemen, our concern should be for the future of the beef cattle industry! Do performance testing programs that emphasize growth rate improve efficiency of beef production? Perhaps, more importantly, do programs such as central bull tests which have a tendency to emphasize larger mature size (both frame and weight and some of the things that go with larger mature size) contribute to an improvement in efficiency of beef production?

If one considers a group of calves, the faster growing individuals within a breed and mating system tend to be more efficient if fed to the same compositional end point. This is because they are putting on more weight relative to their weight maintained than the poorer gaining individuals - thus resulting in lower relative maintenance requirements. Within frame size, and remember frame size determines logical slaughter weight, is it not reasonable that the faster growing individuals are going to be more efficient because they will reach their logical slaughter weight in fewer days - again lowering percent maintenance. Perhaps selection should be for gain within frame size rather than frame size or gain alone. There is a difference! Selection of gain within frame would hold mature size relatively constant while decreasing time in the feedlot because of higher average daily gains. Selection for growth will increase mature size because of a high genetic correlation with mature size. Selection for frame will increase mature size and increase time on feed. In our bull test stations this might mean that ratios should be calculated within frame size.

## Materials and Methods

Now, I wish to examine the results of a project that was conducted at the Livestock and Range Research Station at Miles City, which was designed to evaluate some of the factors that might contribute to cow-calf unit efficiency The results presented come from two research projects that were conducted using the same data base (Urick et al., 1984; Wagner et al., 1984).

Data were collected on individually fed cows for approximately one year and on their calves from birth to slaughter over a four-year period. Cows completed the study only if they had a live calf. This included 140 cow-calf records at weaning and 137 records at slaughter. The cows were mature Angus, Hereford, Charolais, and reciprocal crosses of these breeds. Calves produced were straightbred, two-breed backcross and three-way crosses. All calves were fed until they were estimated to grade low choice which required 168 to 309 days on feed following weaning. Initial and final cow weights were calculated as the average of two weights taken on consecutive days.

## Results and Dicussion

### Weaning

In the first study, traits of the cow which were studied included hip height, cannon bone length and circumference, and cow weight within 24 hours after calving and at weaning. Calf traits studied included: birth weight, 180-day age adjusted weight, preweaning average daily gain, and relative growth rate, postweaning average daily gain and relative growth rate, average daily gain and relative growth rate from birth to slaughter, final live weight, weight of lean cuts, weight of lean cuts per day of age, age at slaughter, and percent cutability.

Efficiency at weaning was defined as 180-day age adjusted calf weight divided by TDN intake of the cow for a year adjusted to a 180-day lactation and TDN intake of the calf on creep adjusted to 180 days. Efficiency at slaughter was defined as weight of lean cuts produced divided by TDN intake of the cow for a year and the calf from birth to slaughter.

Within breed or breed cross of the cow, the relationship between efficiency of the cow-calf unit at weaning and various traits of the calf and cow are shown in table 1. The correlation of .83 between 180-day calf weight and efficiency of the unit indicates that 180-day weight was a very good predictor of cow-calf unit efficiency at weaning. In fact, it was nearly as good as a formula which was used to predict efficiency. This formula (180-day calf weight ÷ metabolic cow weight at weaning) used metabolic cow weight as a predictor of feed requirement of the cow in the denominator. The correlation between this predictive formula and efficiency of the cow-calf unit was .85.

TABLE 1. RESIDUAL CORRELATIONS BETWEEN EFFICIENCY OF THE COW-CALF UNIT AT WEANING AND VARIOUS TRAITS OF THE CALF, COW, AND THE COW-CALF UNIT

| Trait | Efficiency of cow-calf unit at weaning |
|---|---|
| Calf | |
| Birth weight | .38 |
| 180-day weight | .83 |
| Preweaning average daily gain | .83 |
| Preweaning relative growth rate | .68 |
| Cow | |
| Hip height | -.02 |
| Cannon bone length | -.12 |
| Cannon bone circumference | -.26 |
| Weight within 24 hrs. after calving | -.24 |
| Weight at weaning | -.30 |
| Cow-calf | |
| (180-day weight) ÷ (metabolic cow weight at weaning) | .85 |

The correlation between efficiency and calf birth weight (.38) indicates that there was a small but positive relationship between birth weight and efficiency (as efficiency of the unit increased, birth weight of the calf increased slightly). The correlation between preweaning relative growth rate and efficiency was .68. However, the correlation between efficiency of the cow-calf unit and measures of cow size were generally small and negative. The correlation with hip height (-.02) and cannon bone length (-.12) suggest there was no relationship between efficiency of the unit and linear measures of mature cow size. Also, the correlations between weight of the cow and efficiency of the unit indicate that as cow weight increased, efficiency declined slightly. The correlations between efficiency and cow weight within 24 hours after calving and cow weight at weaning were -.24 and -.30, respectively.

These correlations do not suggest that taller cows were less efficient, but they do indicate that large and small cows may be equally efficient or equally inefficient. In other words, I am suggesting that an efficient cow (or an inefficient cow) could have several different physical descriptions.

Slaughter

The relationship between efficiency of the cow-calf unit at slaughter and traits of the calf are shown in table 2. The correlations between measures of

TABLE 2. RESIDUAL CORRELATIONS BETWEEN EFFICIENCY OF THE COW-CALF UNIT AT SLAUGHTER AND VARIOUS TRAITS OF THE CALF, COW, AND COW-CALF UNIT

| Trait | Efficiency of cow-calf unit at slaughter |
|---|---|
| Calf | |
| Birth weight | .36 |
| 180-day weight | .40 |
| Postweaning average daily gain (ADG) | .47 |
| Postweaning relative growth rate (RGR) | .23 |
| ADG (birth to slaughter) | .62 |
| RGR (birth to slaughter) | .38 |
| Weight of lean cuts[a] | .72 |
| Weight of lean cuts/day of age | .81 |
| Percent cutability | .37 |
| Calf age at slaughter | -.15 |
| Cow | |
| Hip height | -.06 |
| Cannon bone length | -.12 |
| Cannon bone circumference | -.17 |
| Cow weight within 24 hrs. after calving | -.13 |
| Cow weight at weaning | -.13 |
| Cow-calf | |
| Efficiency at weaning | .53 |
| (Weight of lean cuts) ÷ [(metabolic cow weight at weaning) + ((metabolic calf weight at slaughter) x (age at slaughter ÷ 365))] | .80 |

[a]Percent cutability x cold carcass weight.

The results of the Miles City study indicate little or no overall heterosis for cow-calf unit efficiency. But, remember the cows were Angus, Hereford, Charolais and reciprocal crosses of these breeds and they were mated to produce two-breed backcross and three-way cross calves. That means some large cows were being mated to some relatively smaller bulls. Even though the number of observations per group are small, some interesting observations can be made. The information in table 3 is listed by breed of calf with the first line representing the only three-way cross system which utilizes a sire breed larger than the dam breed. The next line represents the other two three-way cross systems found in this study. The next group represents the two rotational crosses in which both breeds are similar in mature size. The last two groups are backcross systems in which the two breeds differ widely in mature size.

TABLE 3. COMPARISONS OF CROSSBRED SYSTEMS BY RELATIVE SIRE AND DAM SIZE FOR COW-CALF EFFICIENCY AT WEANING AND SLAUGHTER

| Breed of calf[a] | Relative dam size | Relative sire size | Cow-calf efficiency at weaning (% heterosis + complementarity) | Cow-calf efficiency at slaughter (% heterosis + complementarity) |
|---|---|---|---|---|
| (AH) C | S | L | 10.3 | 8.4 |
| (HC) A<br>(AC) H | M | S | -2.8 | -3.2 |
| (AH) A<br>(AH) H | S | S | 5.7 | 2.5 |
| (AC) C<br>(HC) C | M | L | 4.1 | 5.9 |
| (AC) A<br>(HC) H | M | S | -4.3 | -2.2 |

[a]Breed of calf's dam is in parenthesis followed by breed of calf's sire. A = Angus, H = Hereford, C = Charolais, AH = Angus-Hereford reciprocal crosses, etc.

The first column indicates the percent superiority in cow-calf unit efficiency at weaning of the crossbred combination compared to the average of the parental breeds. The second column indicates the percent superiority in cow-calf unit efficiency at slaughter of the crossbred combination compared to the average of the parental breeds. Only one combination of the three-breed cross systems utilizes a sire breed larger than both of the dam breeds. That combination (A-H reciprocal cross cows mated to a Charolais bull) was 10.3 and 8.4% more efficient at weaning and slaughter, respectively, than the average of the parental breeds. On the other hand, when Hereford-Charolais reciprocal cross cows were mated to Angus bulls and Angus-Charolais reciprocal cross cows were mated to Hereford bulls, the crossbred system was 2.8 and 3.2% less efficient than the average of the parental breeds at weaning and slaughter, respectively. When Angus-Hereford reciprocal cross cows were mated to Angus and Hereford bulls, heterosis for calf growth rate and efficiency of the unit were favorable and moderate to high, but the correlations between efficiency of the unit and measures of mature cow size were small and negative.

As a trait of the calf, weight of lean cuts/day of age would be the best predictor of cow-calf efficiency at slaughter. The correlation between weight of lean cuts per day of age and cow-calf unit efficiency at slaughter was .81. Weight of lean cuts per day of age is an expression of a combination of factors including: growth rate, rate of maturity or days to slaughter weight where cattle were killed at a low choice carcass grade, and percent cutability or lean to fat ratio.

The correlations between cow-calf unit efficiency and traits of the calf were all favorable. That is to say that cow-calf unit efficiency at slaughter increased as calf growth rate and percent cutability increased and calf age at slaughter declined. the correlations between efficiency at slaughter and 180-day age adjusted calf weight, postweaning average daily gain (ADG), and ADG from birth to slaughter were .40, .47 and .62, respectively. Percent cutability and calf age at slaughter, as independent traits, were relatively less important than the growth traits as indicated by the magnitude of the correlations, .37 and -.15, respectively. These correlations indicate that within a herd and breed the desirable calf would be one that grew rapidly to slaughter weight, reached the low choice carcass grade at a relatively young age, and had a high yield of lean to fat.

The correlations between cow-calf unit efficiency at slaughter and measures of mature cow size are shown in table 2. The correlations with hip height, cannon bone length and circumference, cow weight within 24 hours after calving and cow weight at weaning were -.06, -.12, -.17, -.13 and -.13, respectively.

The correlation between efficiency of the cow-calf unit at weaning and slaughter was moderate (.53) and indicates a favorable relationship between the two traits. Cow-calf units which were more efficient at weaning tended to be more efficient at slaughter.

Several predictive measures of efficiency at slaughter were also evaluated including: (weight of lean cuts) ÷ (metabolic cow weight at weaning + (metabolic calf weight at slaughter x (age at slaughter ÷ 365))). This formula includes a measure of metabolic cow weight as a predictor of nutrient requirements of the cow, and metabolic calf weight weighted by age as a predictor of nutrient requirements of the calf. The correlation between this predictor and efficiency was .80 which is of about the same magnitude as the correlation with weight of lean cuts per day of age.

Heterosis

Now I wish to discuss that portion of the study which examined heterosis effects on cow-calf unit efficiency. Crossbreeding has been recommended as a mating system commercial producers can use to improve productivity. But, just crossing breeds is not the answer - they must be crossed in a logical sequence. There are basically two crossbreeding systems to be concerned with here - rotational and terminal. In a rotational system, the breeds used should be of a similar mature size if our objective is to maximize efficiency. However, to maximize efficiency in a terminal system, the size of sire breed should be somewhat larger than that of the cow breed(s).

efficiency at weaning and slaughter was 5.7 and 2.5%, respectively. This was the only reciprocal cross system that used breeds which were similar in mature size. When Angus-Charolais and Hereford-Charolais reciprocal cross cows were mated to Charolais bulls, heterosis for efficiency at weaning and slaughter was 4.1 and 5.9%, respectively. On the other hand, when reciprocal crosses were made and the two breeds differed widely in mature size and the sire breed represented the smaller of the two breeds, (Angus-Charolais reciprocal cross cows mated to an Angus bull and Hereford-Charolais reciprocal cross cows mated to a Hereford bull), there was negative heterosis for cow-calf efficiency at weaning and slaughter of -4.3 and -2.2%, respectively. .

## Literature Cited

Urick, J. J., O. F. Pahnish, G. V. Richardson and R. L. Blackwell. 1984. A comparison of crossbred and straightbred cow-calf pairs. I. Heterosis effects on total feed efficiency. J. Anim. Sci. 58:1151.

Wagner, W. R., J. S. Brinks, J. J. Urick, O. F. Pahnish and G. V. Richardson. 1984. A comparison of crossbred and straightbred cow-calf pairs. II. Biological efficiency of the cow-calf unit. J. Anim. Sci. 58:1160.

# RELATIONSHIP OF LINEAR MEASUREMENTS TO BEEF COW EFFICIENCY

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## Introduction

Linear measurements of skeletal size, scrotal circumference and body composition (fatness) are used most frequently by cattle producers and researchers to partially evaluate beef cattle productivity and efficiency. This discussion will focus primarily on these three measurements with minor reference to a few other linear measurements.

## Skeletal Size

Height at the hip, taken at approximately a year of age, is the most commonly used measure of skeletal size. Hip height measurement can be converted into frame scores (1 through 7 and higher) or major size categories, e.g. small, medium and large.

Measurement of frame size appears to be most useful in evaluating the optimal slaughter weight of steers and heifers (Dolezal, 1983) and also in predicting the mature weight of cows. The carcass trait preferences, which have high economic values, are: carcass weight of 600 to 800 lb, yield grade 2 and choice quality grade. The carcass weight range is determined primarily by size of cut and preferences in the boxed beef market, where carcass size is generally dictated primarily by box size. The 600 to 800 lb carcass weight implies a live weight range of approximately 950 to 1300 lb.

These desired carcass weights and live weights, with the preferred quality and yield grades, can be projected into a skeletal frame size range of approximately 4 to 6 in slaughter animals. These weights and frame sizes are primarily for slaughter cattle which are placed on feed at weaning and slaughtered at 14 to 16 months of age. Cattle which are backgrounded on high roughage feeds for 6 to 12 months after weaning will be 50 to 150 lb heavier than those finished at 14 to 16 months of age, when slaughtered at a similar compositional endpoint (Dolezal, 1983). Thus, linear measurement of skeletal size can be used to predict the desired slaughter endpoints of steers and heifers as it relates to rate of compositional maturity.

Even though research data verifies that no one cow size is more efficient than another, there are ways cow size can be managed for improvements in efficiency. Cow size and calf weight must be matched to feed resources or reproductive performance declines (Kress et al., 1983). Skeletal size at a year of age gives a rough estimate of mature cow size (Brown et al., 1983) as shown in table 1.

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TABLE 1. RELATIONSHIP OF YEARLING FRAME SIZE TO MATURE COW WEIGHTS

| Yearling Frame Size | Mature Cow Weight (lb) |
|---|---|
| Small | Under 1000 |
| Medium | 1000-3000 |
| Large | Over 1300 |

The weights in table 1 are only rough estimates since the environment where the cows are raised can result in 100 to 200 lb difference in weight within similar frame classification.

Carcass size preferences should be critically evaluated when considering a mating system to be used. A straight breeding or rotational crossbreeding program would need to use medium-frame size (average of 5) cows and bulls. The terminal crossing system not only contributes maximum heterosis but also permits the use of smaller cows and larger bulls which can enhance efficiency of the total system. For example, frame size 4 cows (selected primarily for maternal traits) mated to frame size 6 or 7 bulls (selection preference for calving ease, growth rate and carcass traits) will moderate the maintenance requirement of the cows while still meeting the carcass preferences in the slaughter offspring.

## Scrotal Circumference

Scrotal circumference is a highly heritable trait which is favorably correlated with age of puberty in the bull and the semen quality traits. Also, the genetic correlation is high (-.80) between scrotal circumference and age at puberty in half-sib heifers. Selection for each centimeter of scrotal circumference superiority of bulls above the population average would give an expected .25 cm increase in scrotal circumference in the bull offspring, with a 4-day earlier puberty in the heifer offspring (Brinks, 1983).

The improvement in semen traits associated with increased scrotal circumference has been shown to improve up to approximately 38 cm, then level off. The response of improved puberty in heifers has not been evaluated as critically; however, one might expect a similar optimum level of scrotal size as that shown with semen quality.

Scrotal circumference is easily measured and would be considered a low cost input for the anticipated economic improvements in reproductive performance. Early puberty in replacement heifers of moderate size, when associated with heifers capable of calving at two years of age, can reduce replacement heifer cost in the herd. Early puberty and early breeding of heifers, which results in early pregnancy, gives some assurance of efficient reproductive performance throughout the lifetime of the cow.

## Body Composition

Body composition has been shown to have high economic importance, as fatness (body condition) is important in determing the carcass yield grade and the postpartum interval of cows.

Fatness in slaughter cattle can be estimated with a high accuracy if the evaluator has been properly trained (Daley et al., 1983). Fat thickness, which has a high heritability, can be economically measured with a mechanical probe in yearling bulls and used as a component of selection for genetic superiority.

Body condition of cows at calving is correlated to the length of the postpartum interval (Bartle et al., 1984). A visual scoring system (1 to 9) has been shown to predict the postpartum interval, and the visual scores are more accurate than weight to height ratios in measuring body fat (Dunn et al., 1983).

## Other Linear Measurements

Pelvic size, pelvic angles and other pelvic measurements have been shown to be poor predictors of dystosia (Lasater, 1974). Birth weight of the calf and age of dam at calving are the most important factors influencing calving difficulty. While pelvic area has a high heritability and large variations are observed in yearling heifers, there is not substantial evidence to show how selection for pelvic area can be effectively used to improve cow efficiency.

Even though many beef producers feel strongly that shape of calf has a significant effect on dystocia, there is little research data to support this opinion (Lasater, 1974). There is some evidence which suggests that shape of calf might be important in dystocia once a certain threshold level of birth weight (85 to 90 lb??) has been reached (Gregory et al., 1982).

## References

Bartle, S. J., Males, J. R. and R. C. Preston. 1984. Effect of energy intake on postpartum interval in beef cows and the adequacy of the cow's milk production on calf growth. J. Anim. Sci. 58:1068.

Brinks, J. S. Genetics of Reproduction. Proc., The Range Beef Cow Symp. VIII, Dec. 1983, Sterling, Colorado.

Brown, C. J., Brown, A. H., Jr., and Z. Johnson. 1983. Studies of body dimensions of beef cattle. Arkansas Agr. Exp. Sta. Bull. 863.

Daley, D. A., Tatum, J. D. and R. E. Taylor. 1983. Accuracy of subjective and objective preslaughter estimates of beef carcass fat thickness. J. Anim. Sci. 56:1.

Dolezal, H. G., Jr. 1983. Effects of feeder cattle frame size, muscle thickness and age class on growth and carcass traits. Ph.D Thesis. Colorado State University.

Dunn, T. G., Riley, M. L., Murdoch, W. J. and R. A. Field. 1983. Body condition score and carcass energy content in postpartum beef cows. J. Anim. Sci. 57 (Suppl. 1):391.

Gosey, J. 1983. Linear measurements and productivity in beef cattle. Beef Briefs, American Simmental Association.

Gregory, K. E., Cundiff, L. V. and R. M. Koch. 1982. Characterization of breeds representing diverse biological types: Preweaning traits. Beef Research Program Prog. Rpt. No. 1, U. S. Meat Anim. Res. Center, Clay Center, NE.

Jacobs, V. E. Cost behavior ... and optimal size in beef cows. Farm Management Newsletter, May 6, 1983.

Kress, D., Doornbos, D. and D. Anderson. 1983. Effect of calf breed on beef cow productivity. Montana Agr. Exp. Sta. Res. Rep. 123.

Lasater, D. B. 1974. Factors affecting pelvic size and dystocia in beef cattle. J. Anim. Sci. 38:496.

Taylor, R. E. 1984. Beef Production and the Beef Industry: A Beef Producer's Perspective. Burgess Publishing Co., Minneapolis.

# ECONOMIC EFFICIENCY IN BEEF PRODUCTION

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"Economic efficiency," as a fundamental article of faith, is the sine qua non of survival in competitive business enterprises--of which beef production is certainly a representative. It is the stated objective of most applied research into alternative production technologies. It most certainly is the stated objective of modern beef cattle selection. At this altar, worship both the economist and the biologist--even if at times they may seem to be from different planets. Whether the bottom line is improved feed efficiency or maximum residual return to a constraint set in linear programming, either represents more product from some measure of inputs.

While we all share the objective of enhanced economic efficiency, our varied definitions of the problem and of efficiency, our diverse disciplinary approaches, our differing fundamental assumptions, all occasionally lead to conflict, inconsistency, and disagreement.

## The Blind Men and the Elephant Syndrome

Despite a common subject (the beef industry) and a common purpose (improved efficiency), we often resemble the fable of the blind men describing the elephant--based on the particular portion of the elephant's anatomy each had examined. A critical observer might conclude either that we are describing different industries--or that we are approaching our subject from different perspectives. Some stress production per cow while others stress product per ranch or per ton of feed. Some never tire of reminding that we "still sell 'em by the pound"--while others stress that a "small live calf sells for a lot more than a large dead one." Some want a calf that can be backgrounded while others brag that theirs "don't need it." To some, the rancher's panacea is maximum weaning weight per cow while others say a cow can milk too much. Steer judges select for cattle others say won't fit the box. While many assume larger is more efficient, others stress the independence of size and efficiency and seek optimums. While many breeds claim superior maternal traits, most select primarily for the terminal cross bull. Despite the generally accepted importance of maternal qualities, the highest priced heifers are placed in transplant before we even know whether they can calve without assistance, claim and clean their calf, or milk adequately to support him. To some the showring is the root of all evil while to others it is a necessary merchandising activity that creates interest and is highly educational.

We could go on ad infinitum with these apparent conflicts without resolving a single one. Alternatively, allow me to first enumerate what I feel are a few major causes of these seeming conflicts, (with an eye to their resolution) then

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proceed to a more direct discussion of economic efficiency--as applied to the beef industry. First, however, here are some of my nominees as major causes of confusion and disagreement:

-- The mis-understood economics of the industry

First, the beef industry is composed of two very unlike sectors-forage or range-based feeder cattle production and confined feedlot finishing. The first sector is small-scale, extensively managed, "natural" production, based primarily on fixed inputs and left over resources not demanded for more intensive higher value production. In direct contrast, the feedlot sector is extremely large scale, "hot-house" production produced on variable inputs bid away from competing uses. It is very intensively and professionally managed with liberal use made of advanced technology. Where management intensity may approach "benign neglect" in the cow-calf sector, professional nutritionists, marketing consultants, and other expertise is lavished on the feedlot sector. Management approaches and the intensity of application of technology that are required in the feedlot sector usually fail when applied to the cow-calf sector. Neither the perennial forages nor the natural "one-calf-per-year" production of the beef cow offer the economic responses to technology that most hothouse production does--whether it be major grain or horticultural crops, dairy cows, poultry, or cattle in a feedlot. Space will not permit rigorous proof of these assertions, but any long-time observer will likely agree that intensity of application of technology and management in the cow-calf sector is--and probably must be--at a far lower level than in "hot-house," intensive enterprises.

Another much misunderstood part of the beef industry includes the linkages and relationships among the component sectors. A case in point is backgrounding --in particular that part based on perennial pastures and hay. Some look at backgrounding as an obsolete, outdated, and inefficient function. What they fail to perceive or understand is its role and purpose. Backgrounding is the beef industry's adjustment mechanism. Whether it is more efficient to grow out a calf during feedlot finishing--or to grow him out on forage prior to feedlot placement--depends quite simply on which has the greatest value--the cost of gain in the feedlot--or the calf production which must otherwise be "given up" to grow him on pasture and hay. With a 15:1 beef steer:corn price ratio in 1975, giving up 0.8 lb of production of 25 to 30¢ calves was far cheaper than paying a feedlot cost of perhaps 50 to 55¢ per lb with the then $2.70 corn. In marked contrast, with a near 30:1 beef steer:corn price ratio in 1979, giving up 0.8 lb of $1.00 calves was far costlier than the 45 to 50¢ gain cost in feedlots with $2.36 corn. In 1975, cow-calf producers were led by price relationships to conclude that they could "buy them cheaper than they could raise them"--and a sufficient number shifted to backgrounding to reduce calf crops and set the stage for 1979's high prices. In 1979, backgrounders were led to the conclusion that "they couldn't afford to buy them and would have to raise them"--and enough of them purchased females to produce a turn-around in calf crops.

In short, backgrounding's importance depends on rather simple economic questions. For the feedlot operator it's "how much more (or less) can (or must) I pay for lighter, younger animals requiring longer finishing gains?" His answer depends on how much higher (or lower) fed cattle prices are than the cost of feedlot gain. For the grass operator it's "which will return most for my feed--backgrounding or cow-calf?" His answer depends on the feedlots' relative bid prices for light calves and heavier yearlings. Backgrounding will remain a viable economic option until such time as all our forage base can be employed producing calves and all the product still sell well above the cost of feedlot gain.

Recent trends in beef demand suggest that backgrounding will be around for a long, long, time!

-- The power and predispositions of the show ring

Despite all the advances of performance testing and of all our protestations that we are immune to showring fads and fancies, I submit it is still a most powerful influence in the breeding and selection of beef cattle. And, despite the $180^{o}$ about-face in showring standards in the last couple of decades, I submit that it still shows a strong predisposition toward extremism, single-trait emphasis on whatever is easily visualized, and perpetuates the myth of an "ideal animal" for all systems, managements, and environments.

As to it's "power." all one has to do is look to the high selling animals--and the bases on which those prices were paid. Observe the $80,000 untried heifer that is placed in embryo transplant before anyone knows whether she can calve safely, clean and claim her calf, milk adequately, or need a nurse cow to raise her calf. Observe even the bull that tops the state performance tested bull sale. Was it because of his weaning weight, yearling weight, fat-free body, index, ADG--or his height and frame and conformance to showring standards? Ask any breeder who really selects for the multiple traits needed by the commercial cow-calf producer whether he's taking the low or the high road in terms of selling prices? The showring still exerts enormous power.

In terms of the showring's predispositions, I submit it tends toward single-trait extremism. When was the last time you saw a judge place one in second place because he was "too big"--to be followed in third place by one that was "too small"? How many steers are placed down because they're "too big for the box"? Demands for consistency (biggest to smallest, or smallest to biggest) almost inevitably lead ultimately to extremism--even in traits for which an "optimum" is better than either maximum or minimum. Are not judging team aspirants taught to visualize the "ideal animal." Ideal for what management level, which environment, or for which production system? And, what of reproduction, milking ability, calving ease--and a host of other attributes not evident in visual inspection?

-- Conceptual ambiguity

There has, I feel, been much confusion, "fuzzy logic," and outright error in the relationships some have assumed between body size and type, gain, maturity rate, and energetic efficiency. I feel it is imperative that these relationships be sorted out and understood on a more solid scientific basis. As an economist, I am perhaps not qualified as a physiologist, ruminant nutritionist, or as a specialist in bio-energetics. I have, however, been a student of such relationships for a number of years. Therefore, immodesty aside, let me give a few examples.

First, rate of gain was a good proxy for energetic efficiency when comparisons were made among cattle of similar genetic size with similar initial on-feed weights. When cattle of different frame and genetic size were compared in the pioneering Wisconsin frame size research (Brungardt, 1979), only a half percent of the feed efficiency differences between subgroups were explainable by differences in absolute rate of gain. A more solid 58 percent of the variance in efficiency was explained by their percentage increase in weight. A still more useful 70 percent of the efficiency variance among groups was explainable by "gain per unit of metabolic size." Clearly some measure of "relative gain," (or gain relative to maintenance energy) was far, far superior to absolute ADG--which was essentially useless.

Secondly--maturity rate has been much misunderstood by many. In the early 1970's, "early maturity" became a damning phrase in cattle breeding circles. The real problem, however, was not that they matured too early--but that they matured at too small a size to "fit the box" while still at desired body composition. To be sure, as Brody (1945) demonstrated four decades ago, smaller animals do tend to mature earlier and larger animals later ($t = 13.775 \cdot W^{.294}$). But, it is extremely important to recognize that "too small" is the sin--not too early maturing. Analysis of the 15 sire breed crosses at Clay Center (MARC) indicates real efficiency advantages for the earlier maturing crosses--whether measured by age at puberty, shortness of gestation or rate of gain relative to either birth weight or mature size.

Finally, we have (hopefully) gotten the "terminal point" issue well in hand. Early comparisons, where large and small cattle were fed to the same weight, led some to think "larger" and "more efficient" were identical twins. Surely we all know by now that what those trials really showed was that "immature and underdone" are more feed efficient than "mature and overdone."

-- Disciplinary inbreeding vs. intellectual heterosis

When really pressed, I suspect many would agree that most of the larger real world problems are broader than any single academic discipline or department. Thus--the age-old lament that "farmers have problems while universities have departments." Yet, even after over 30 years of administrative "lip service" to the need for interdisciplinary problem-solving, I honestly suspect it becomes more rare, more superficial, and more difficult to attain each passing year. These are the assessments of one who has been interdisciplinarily involved for the past several decades. Now note, I'm not talking about crossing two closely-related disciplines like nutrition and physiology. I'm talking about a much "wider" cross--which hopefully would produce real intellectual heterosis--like between economics and biology.

Why is such a conceptual intermarriage so difficult? Is it because university administrators have effectively given their evaluative proxies to the manuscript review committees of the academic professional associations? Is the "refereed publication" of one's own professional association the only "hard currency" that's acceptable at salary determination time for faculty members? Are these "refereed" professional journals really open to truly interdisciplinary problem-solving articles?

We could argue for days (even months) over the causes--but more important is the sterility I feel is creeping (or galloping) into some of our efforts. In my own discipline, I fear I see a good deal of what might be called "technocratic exhibitionism"--or "conspicuous obfuscation"--or "playometrics" (playing with numbers on computers). The imbalance or assymmetry involved is often one of merely using some purported "problem" as an excuse for exercising some sophisticated technique or expensive instrumentation. While the technique may be highly sophisticated, the problem specification may be unbelievably naive.

Back to the subject! I have heard and read a great deal about how beef cattle are belatedly but surely being selected for "economic" superiority. Can you even name a single competent economist who has been importantly involved in the process of identifying, defining, weighting, and evaluating these "economic" traits?

The causes of disciplinary inbreeding are many. I do hope, however, that some of you will go back to your institutions and (figuratively at least) drag some competent economist--"kicking and screaming," if need be--into enough biological competence to effectively work with you in dealing with the bio-economic issues of the beef industry. Or, failing that, I hope all of you will make a strenuous effort to understand the important economic relationships in the beef industry.

## Economic vs. Biological Efficiency

The use of physical or biological input-output ratios as proxies for, or indicators of, economic superiority is widespread. Examples include beef per acre, feed efficiency ratios, milk per cow, etc. How accurately do they proxy for economic superiority? In what situations and under what conditions do they truly gauge economic efficiency? How can they be improved? These are particularly crucial questions when selection parameters are chosen for livestock with long generation intervals like beef cattle. The adequacy of the selection parameters employed today will be influencing the competitive position of the beef industry several decades from now--just as the selection excesses of the 1940s and 1950s still haunt today's beef industry.

Why physical proxies anyhow? Why not directly assess the economic efficiency and net economic worth of animals? One reason, of course, is impracticality. Weighing a bull is a lot easier than determining his net economic worth. A second reason is that his net--or even relative--economic worth changes as relative prices change--as they most assuredly will. His genetic size and growth characteristics will not.

Thus, let's look at some of the relationships between economic and biological efficiency.

### The "Aggregation" Problem

If there were only one input employed to produce but one product--and if both the input and product were "homogeneous"--that is each unit exactly like any other--a purely physical input output ratio would substitute perfectly for economic efficiency. Unfortunately, that is seldom (if ever) the case in the real world. More typically we deal with: (1) multiple inputs and (2) multiple products--or (3) heterogeneous inputs and/or (4) heterogeneous products. Thus, we are in a situation where we must somehow add up "apples and oranges."

Economists faced this problem a couple of centuries ago when they attempted to "explain" market value based on cost of production. At first they attempted a single input approach--the "labor theory of value." They attempted to value the cost of capital inputs as so many units of "stored-up labor." More skilled or educated labor had to be viewed as also representing "stored-up labor." Land cost posed a problem not at all amenable to such an appraoch. Interest on investments ultimately required a different approach. Ultimately this simplistic approach simply had to be scrapped. Engineers and others almost trod the same mistaken paths in the mid-70's--when many came close to attempting an "energy" theory of cost or value. But again, the "apple-and- oranges" non-equivalence of a calorie in wood and one in natural gas, and the problems of" stored-up" or previously invested energy in steel and other inputs resulted in a gradual abandonment of such approaches.

Now, what do we face in evaluating efficiencies of alternative systems, technologies, and individual animals in beef production? The following are a few examples of crucial problems in aggregating apples 'n oranges.

-- Heterogeneous inputs.

It obviously takes more TDN, ME, NE, or whatever to produce a pound of backgrounding gain on pasture and hay than it does on a high energy ration when the steer is on full feed in a feedlot. Some, therefore, conclude that range-based backgrounding is too slow and automatically inefficient. Such a conclusion is most premature, since TDN (or other energy units) are not homogeneous units, and do come at different prices and costs from different sources.

For instance, if 8 lb TDN is required per pound of gain in backgrounding vs. only 5 lb in the feedlot, the slow gains will be most cost-efficient if its TDN costs less than 62 1/2 percent as much per unit than the TDN employed in the feedlot. If most of it comes from pasture and the total yearly blend cost is only 3 1/2¢/lb TDN while that in the feedlot costs 9¢--it is much the more economical--costing 28¢/lb gain vs. 45¢/lb in the feedlot.

On the other hand, if the backgrounding TDN costs more than 62 1/2 percent of the unit cost of TDN in the feedlot, it will represent higher cost gain.

Another example of this problem of non-additivity of energy units can be found in evaluating alternative milking abilities of beef cows. While the highest milking cow probably produces the most weaning weight per unit of feed energy--if fed well enough to ensure reproduction--she may not be economically more efficient. If her 3 1/2 to 4¢ TDN (from pasture and hay) must be supplemented (and partially replaced) with 9¢/lb TDN to ensure reproduction, she may well be the high cost producer of weaning weight.

-- Heterogeneous products

Nor is a pound (or kg) of production economically equivalent to every other unit of product. While an early maturing-high milking cow may wean more pounds per unit of energy than her herdmate, it does not necessarily mean she weans more dollars per unit of energy. Because her calf appears fleshier and more mature--and perhaps too small framed--he may well sell for $5 to $7 less per cwt. The buyer bids on the basis of expected future performance and ultimate sale price.

And, where a "threshold" trait such as size and frame is involved, too large-framed or late-maturing a calf may also sell at a discount. Even color, and its perceived association with marbling, may influence selling price. The point is--pounds become dollars only through multiplication by price--which can vary substantially with size, type, condition, sex and even color.

-- Multiple products

While beef cattle are not plagued with the "lamb vs. wool" problem of sheep, different sizes, types, and maturities may well present similar problems. As proposed by Hauser and Kress (1969) larger-later maturing cows may be less energy-efficient per pound of calf weaned--but be equally or even more efficient when their larger salvage weight and value at sale time is considered. In short, cow-calf production produces a joint product of calves and slaughter cows. While the cull cow's weight may sell for only 55 to 60 percent of the steer calf price, further adjustment for capital gains tax treatment raises its effective after-tax value. Again, however, an important "apples and oranges" problem of aggregation --whenever the product mix (cow weight vs. calf weights) varies substantially among breeding types.

-- Multiple inputs

If inputs were always required in the same proportions, then a single input (i.e., feed) could be used as a proxy for all inputs. While more will be said about this later, it should be evident that input proportions are not necessarily the same for all types, sizes, and breeding systems.

A simple example: One breeding system produces more pounds of calf per unit of feed by employing large terminal cross sires on smaller maternal line dams. But, it perhaps gains feed efficiency at a cost of higher management and labor requirements and larger veterinary costs because of increased dystocia. Or, greater concern over calving difficulty may cause the farmer to opt for later spring calving, with his larger "adjusted" weight advantages dissipated via later dropped-younger calves at sale time. Or, the larger management input may come at the neglect of more important sources of income--such as corn or soybean crops or his hogs.

Somehow all inputs or costs must be considered in evaluating efficiency whenever the input mix varies with types or sizes of cattle or breeding systems.

## Aggregation and "Bottom Line" Economic Efficiency

What should we do when we are faced with multiple inputs and products produced or used in varied proportions--or where the inputs or products are heterogeneous units with respect to unit costs or values? As a professional economist I am tempted to simply say something like--"the bottom line can only be reached through competent economic pricing, valuation, and analysis." And, in any specific application or decision questions, that conclusion is valid. In short, economic superiority or inferiority can only be definitely demonstrated by applying appropriate prices and values to each input and each product and comparing the aggregated returns with the aggregated costs.

Yet, I am troubled by this conclusion. To be quite candid, I "cringe" every time I hear a farmer's question about alternative practices or technologies answered with a ". . . It paid (or didn't pay) in research in South Dakota (or Missouri, or where ever) to do thus-and-such." And, my concern is not just with the competency of the economic assessment being cited. The statement may well be true for the particular matrix of prices and costs then existing. But, being a long-time student of the cyclical nature of agricultural markets, I'm only too aware that the same results, analyzed with today's prices, could well yield quite different inferences.

A case in point with respect to the importance of changed relative prices: Coming off the 10 to 15:1 beef steer-corn price ratios in the 1940s (and of prior decades), much research emphasis was on maximal forage use (deferred feeding systems, etc.). This emphasis carried well into the 50s after these price ratios had substantially changed. Gradually, some hardy souls suggested it was "no sin" to feed corn to cattle. And, as this ratio consistently topped the 20:1 level during the '60's and early '70's, the revolutionary growth of the feedlot industry was accompanied by research emphasis on all (or high) concentrate rations, plastic "rumen scratchers", antibiotics, liver abscesses, etc. Predictably, when that same beef steer-corn price ratio precipitously dropped from around 30:1 (at its peak in '72) to 10:1 (for a few months in '74-'75), a "re-invention of the wheel" was suddenly in order and research emphasis abruptly shifted to something entitled "forage-fed beef," which was then predictably reportable <u>after</u> the causative conditions had been cyclically remedied.

Similar belated responses to changes in this ratio could also be cited in beef breeding and selection, forage technologies, etc.

The point of all this is that drawing too many inferences based on what are quite temporary price ratios and relationships can be very hazardous.

One of the questions I feel this problem strongly raises is the "what products or inferences should we intend as our research end products?" Should the end product of applied research be the economic superiority or inferiority of particular treatments, technologies, systems, or animal types? Or, if such inferences are too "price-specific" in their validity, should we only report physical input-output results which can be continually re-appraised as price relationships change over time?

Unfortunately, the selection of and value-weighting of particular traits for purposes of breeding stock selection cannot wait for future price relationships to reveal themselves. Rather, best guesses <u>must</u> be made <u>now</u> about future price and cost ratios, and the business of animal selection allowed to proceed. Here, however, I feel it is most important that the best economic knowledge available be employed in identifying normal or equilibrium relationships, the levels around which price cycles tend to fluctuate, and the best possible forecasts made of any crucial market trends. And, even then, we must all stay alert to major changes as they occur.

## <u>Cost Fixities, Constraints to Production, and the Appropriate Units for Comparison and Analysis</u>

A very fundamental question in assessing comparative efficiencies is the selection of the unit of analysis. For instance, in selection, should we attempt to maximize weight weaned per cow, weight weaned per ton of feed, or weight weaned per ranch or business unit? Which ratio will best proxy for bottom line economic efficiency and profitability? It is evident that we have emphasized product per cow up to this point in time--primarily because of ease of measurement. But, are 200 calves averaging 500 lb really economically superior to 250 calves averaging 400 lb? In either case we have 1000 cwt. of calves to sell. Or, are 1300 lb cows weaning 500 lb calves superior or inferior--to 1000 lb cows weaning 450 lb calves?

In this latter question it is evident we can get quite different efficiency assessments--depending on whether we look at product per cow, per ton of feed, or per ranch. Some writers have defended "per cow" criteria by alleging that many non-feed costs are "fixed per cow"--and hence decline on a per unit of product basis as product per cow is increased.

The key to unlocking this paradox lies in identifying the behaviors of other (or non-feed) costs and in identifying what the effective constraints are to levels of total product. If most other costs are "fixed" or constant on a per cow basis, product per cow is the appropriate criterion. If, on the other hand, most other costs are "fixed to," constant with, or directly proportional to feed used, then product per unit of feed is appropriate. Or, if most other costs are essentially fixed to the total ranch or forage unit, product per ranch is the appropriate efficiency criteria. This writer is already on record (Jacobs, 1983) as having described most non-feed costs in calf production as being either proportional to feed used--or "fixed" to the ranch or forage unit.

This conclusion relative to cow-calf production is directly counter to the same writer's conclusions with respect to summer grazing enterprises with steers. Despite forage agronomists' emphasis on "beef per acre", gain per head is made very important by the behavior of the costs incurred in such an operation. In particular--negative price margins on purchased weight. If over the past twenty years the summer grazer had purchased an average 4-5 cwt. steer calf at K.C. in April and sold an average 6-7 cwt. steer in November, the first 72 lb of gain per head was required just to recover the average of 13.7 percent price deterioration (negative price margin) on the initial weight. The buy-sell commissions, two-way transport, and other "per head" costs claimed a second 70 to 75 lb of gain. Thus, the "fixed per head" costs claimed the first 140 to 150 lb of gain <u>per head</u>! The effective yield remaining to pay for use of the pasture was <u>only the surplus</u> gain per head <u>in excess of</u> the first 140 to 150 lb required just to <u>recover</u> the above <u>described "per head"</u> costs.

With the cow-calf enterprise, many fewer of the non-feed costs are incurred on a flat or constant per head basis. Most are fixed either to the total forage unit (fencing and equipment costs)--or are proportional to feed used (i.e., harvesting, handling, feeding, and storage costs on hay). Also, the per ton of feed and per total ranch unit criteria resolve to essentially the same thing. Each ton of forage required really amounts to a fractional unit of the total ranch. Thus, maximizing weight weaned per unit of forage amounts also to maximizing product per total ranch unit. This is very fortuitous as it much simplifies our challenge. In the case of the cow-calf operation it means that maximizing feed efficiency essentially means maximizing total ranch efficiency. And, if not offset by reduced selling price or by inflation in particular non-feed costs (such as vet and labor costs via dystocia)--it amounts to simultaneously maximizing economic efficiency in total.

Unfortunately, we have not yet generally agreed on selection parameters that we can confidently use in maximizing feed or energetic efficiency in the beef cow. Let us now turn to that question.

NEEDED: Physical Measures That DO Proxy for Energetic Efficiency

If, as hypothesized above, most "other" or non-feed costs in cow-calf production are essentially allocable on a per feed unit basis, then energetic efficiency is an excellent indicator of economic efficiency. This assumes, of course, that the other cost levels are not substantially affected by the genetic and breeding system alternatives. This includes the assumption that levels of required concentrate supplementation are not affected. It also assumes that selling prices and product mixes are either unaffected by our alternatives--or are adjusted for variations in average product sale price to equal value equivalency.

Given these assumptions, however, it is fortuitously simplifying that energetic efficiency can thus be an accurate proxy for economic efficiency.

But, how do we routinely measure or estimate energetic efficiency in breeding animals? An obvious approach is to evaluate gains (ADGs) in "relative" terms--relative to whatever we feel is a good indicator of maintenance requirement. If the 0.75 power of body weight is not a suitable indicator of true metabolic size or maintenance requirement--then by all means let's find whatever fractional power is better.

Where cow efficiency is at issue, let's indeed find some suitable proxy variable for the cow's feed requirement or maintenance cost and use it in evaluating her weaning performance. Dinkel and Brown (1978) found little or no advantage in explaining beef cow efficiency in use of the .75 power of the cow's weight to the cow's "metabolic" weight (or $W^{.75}$). Does this mean that big cows consume the same feed as small cows--or does it mean they didn't consume as much more feed as their conventionally calculated metabolic weight would suggest?

I can only conclude the latter, that $W^{.75}$ over-estimated large cow feed requirements and/or under-estimated small cow requirements. Thus, Dinkel and Brown's work indirectly suggests that 0.75 is too large. More direct evidence of that can also be developed.

In their study of differing cow sizes, Klosterman and Parker (1976) reported the feed requirements and productivities of cows averaging 874, 1022, and 1210 lb. If one relates the reported TDN requirements to average cow weight by Least Squares method, the fractional power that emerges for best fit to their data is 0.505. (Their calves' weaning weights, in turn were related to the 0.42 power of the cows' average weights). Klosterman et al. (1979) subsequently reported voluntary intake studies with two cow breeds varying in size. Pooling the data from four separate comparisons, and re-analyzing group means results in a voluntary intake that was proportional (among cow sizes) to the 0.48 power of cow weight. Another study of energy requirements as related to cow weight and level of milk production was reported by Ewing et al. (1969). While they apparently chose to estimate purely linear equations, relating energy and the 1.0 power of cow weight, their reported maintenance energy estimates by cow weight were re-analyzed by this writer for their exponential equivalent. When this was done, their linear estimates imply that maintenance requirements were proportioned to the 0.47 power of body weight.

Thus, while Dinkel and Brown's work only indirectly suggests a fractional power less than 0.75, more direct analysis of data reported by others suggests a fractional power closer to 0.50.

It is not suggested that 0.50 is the "right" fractional power for estimating energy requirements of mature beef cows. Rather, it is suggested that if .75 isn't good enough to use, then let's go to work and find one that is. It is a bit surprising that so few cow size researchers have even asked the question. It is also surprising that several have opted to force fit their estimating equations as pure linear relationships--when most theory relating energy to body size will relate metabolic requirements to at least some fractional exponential power of body size.

It should also be pointed out that employment of fractional power exponents is the simplest of mathematical transformations with todays' electronic calculators--let alone with modern computers. Any fractional power can be obtained in a second or two on a $20 scientific calculator. No burdensome looking up numbers in 8-place logarithm tables and calculation of "proportional parts" is required in today's electronic world. Given the basic nutritional and energetic concepts, I fail to understand our reluctance to apply fractional power relationships in relating energy and body size. It seems to me to be a simple but very necessary step if we are to transform absolute animal weights into something more meaningful in terms of energetic efficiency--and correspondingly--in terms of economic efficiency. Most of what we need requires no new animal research--only a re-analysis of research already abundantly reported in the literature.

## Some Thoughts on Pricing and Costing of Inputs and Products

One of the characteristics of the beef-forage industry that made it "interesting" to this economist originally was the pricing and costing difficulties associated with it. In fact, much of the ambiguity and disagreement about what "good management" really is, traces directly to these pricing and costing difficulties. Wide ranging disagreements and disparate beliefs with respect to such practices as creep feeding, pasture fertilization, etc., are cases in point. Let's look at a few of these difficulties.

-- Valuation of "gain" vs. "whole animals". Interestingly enough, two thirds of the cattle industry (feeders and backgrounders) produce a product (gain), for which there is no quoted market price. Its value is easily calculated as the difference between the values of two whole animals. As an example, if, during the 15 years 1965-80, a backgrounder had purchased an average 450 lb choice steer in the second quarter and sold him at 650 lb during the fourth quarter, what did he get for his gain? At an average second quarter price of $45.54, the 450 lb cost $204.93, while the 650 lb steer in the fourth quarter brought $39.53/cwt.--for a total sale price of $256.95. The difference--of $52.02 for 200 lb gain--represents a gain price of $26.01 per cwt. of gain--or 57 percent the price paid for the stocker steer. Had he instead bought the 4.5 cwt. in the fourth quarter and sold 6.5 cwt. in the second quarter, he would have bought at $43.42, sold at $43.64, and received $44.13 per cwt. for his gain. In short, the "market works"! Everyone knows the cheap gain (from pasture) occurs from second to fourth quarters--and the higher cost period (on hay or silage) is from fourth to second quarters.

The market also works in reflecting differing relationships between grain prices and cattle prices. With low beef steer-corn price ratios (and thus cattle prices well below costs of feedlot gain), feeder steers sell below fed steers--and these "positive price margins" in feeding then permit a gain price or value above the selling price of the fed steer. With high beef-steer corn price ratios, feeder steers sell well above fed cattle prices, and gain prices are thus competitively driven down to the level of feedlot costs of gain.

-- <u>"Intermediate product" pricing</u>. Feeder calves and feeder cattle are "intermediate products," the market value of which reflects buyers' expectations about their future performances, costs, and selling prices. An example can be seen with respect to the old "creep vs. non-creep" issue. One of the negatives in creep feeding is the possibility (even probability) that selling price will suffer. In short, the buyer (usually a backgrounder)--knows that fleshier creep-feds will negatively "compensate"--and reflects that belief in his bidding practices. Thus, while he may bid $70 for a 400 lb calf, he may only bid $65 for a calf carrying an extra 50 lb of fed-on fleshing. In such a case, what does the calf producer get for his fed-on weaning weight? A 450 lb calf at $65 grosses $292.50, while a 50 lb lighter calf at $70 grosses $280. The difference of $12.50 for an added 50 lb means a gross return of only $25/cwt for the extra fed-on weight!

Unfortunately, such crucial price effects are not easy to evaluate, since our grading and reporting system ignores condition as a price-determinant. Feeder prices are reported by weight (not condition) and "quality" (No. 1 muscled medium frame).

In addition to condition as a determinant of price we must add maturity. In the Wisconsin frame size experiment, their residually estimated initial values per cwt. were best explained by their initial weight as a percent of their finished weight. While subgroup differences in estimated break-even value were only 28 percent explainable by initial weight <u>per se</u>, this variance in per cwt. value was 98 percent explained, however, by <u>initial</u> weight divided by finished or final weight adjusted to 63.4 percent dressing percent. The inherent value of a calf per cwt. can be shown to be closely related to his "maturity" (or immaturity)--and especially so whenever fed cattle prices are substantially higher (or lower) than the per cwt. cost of feedlot gain.

## <u>Costing of Inputs: Problems of Fixity, Joint Products and Behavioral Differences</u>

If all inputs were regularly purchased with an explicit transaction price, were divisible into small units employed in direct proportion to level of product; were employed only in production of a single product; and were used up in one production period; the costing of a product would be simple. Unfortunately, there is often no regularly recurring transactions to price some inputs (operator's labor, land), some inputs are lumpy (tractors, corrals, etc.) some are durable--and of uncertain useful life; are used to produce two or more products, and may be "fixed" or constrained in quantity available. These latter conditions challenge all the ingenuity and understanding of the economist and accountant if defensible cost estimates are to be made for a product for which most inputs are of these types.

Feeder cattle production commonly poses all the above challenges, and cost of production estimates can range all over the economic map. One of the big reasons (or "culprits") is pasture and forage. Out-of-pocket or annual transaction costs are commonly a small proportion of the total cost. Most of the cost of pasture or range is land cost. Let's look at a realistic example. In Missouri, in recent years, it would not be unusual to find an acre of pasture land that might sell for $500 per acre--yet cash rent for only $20 to $25 per acre. If one starts with a $500 land value, charges a 12 percent mortgage rate of interest, we quickly have a $60 per acre cost just in interest on land value. Add in another $10 per acre for labor, mowing, fence upkeep, and real estate taxes, and we're up to $70/acre/year.

Now, it may take four acres of this land to produce the pasture and hay for one cow for a year. If we take this $70 per acre times four acres we quickly have what amounts to a prohibitive land cost per cow of $280--before paying interest on the cow, labor for feeding and handling the cows, veterinary costs, supplemental feeds, hay harvest, nor general farm overhead. In short, we are soundly-whipped before we even get started.

In contrast to the above approach, if we take the market cash rental price of, say, $20 to $25 per acre, then we start with a land cost of only $80 to $100 per cow. Now, we at least have a chance.

<u>But, which is right?</u> First, we have to ask ourselves a very crucial question. Why did we--or would others--willingly pay $500 for an acre that yields an annual service that the market values at only $20 to $25? If we were to capitalize this gross rent at a 12 percent rate of return, we'd have a capitalized value estimate of only $167 to $208 per acre (or $20 to $25 ÷ 0.12)! Why then does (or did) it have a value of $500? Unless the buyer was motivated by some non-economic objectives, or was irrational, he evidently believed there was some other "product" or "economic gain" above and beyond the present cash pasture lease rate. The most likely candidate was probably land price appreciation. In short, he may have paid $200 for its present value-product--and $300 for rights to future gain in land value. Or, looking at it another way, after 30 to 40 years of land price inflation, he may have "expected" 10 percent annual un-taxed gain in value per year, deducted that from a 12 percent total rate of return desired, leaving 2 percent to be gained from annual product. And, a 2 percent return on $500 is only $10 per acre--which added to $10 other costs sums to $20 cash lease price.

In short, pastureland became (and still is) a "growth stock"--with a market valuation well above what its present productivity would justify. Whether its future price performance will ultimately fulfill people's apparent expectations is truly the $64 billion question! Recent land price declines have to gradually weaken such bullish expectations, but who among us can confidently say what will be occurring in another 5 to 10 years?

Now, getting back to the problem at hand, what do we do in the meanwhile? Here I want to end with what I feel are three simplifying truths:

-- <u>"Cost is what you give up to do it!</u>

This is only another way of citing the old "opportunity cost" principle in economics. It is, however, a very safe, simple, yet totally comprehensive approach. In the above example, if selling the land is a viable alternative actually under consideration, and if the decision-maker feels future price appreciation would be zero, and if he thinks he can get $500 per acre and 12 percent on the proceeds, then he really "gives up" 12 percent on $500 plus continuing to incur the $10/acre other costs. In short, he "gives up" this $70/acre by keeping as opposed to selling. Unless he expects some imminent and substantial price rise on cattle, he should sell the land.

Altering this situation just a bit, another owner might feel the market value had already dropped to $400; that realtor fees, sale costs, and capital gains taxes would claim another $80 per acre; that he's debt-free and not paying 12 percent interest; and that his own money would only net an 8 percent return, and $7 of the other $10 costs per acre were fixed. Now, we have only $320 to invest ($400 - 80); at only an 8 percent return (yielding $25.60/acre); and a reduction in "other" costs of only $3 per acre ($10 - $7). Adding his expected net investment income ($25.60) to his reduction in other costs by selling ($3.00) means he would recover ony $28.60 per acre per year if he sold. Thus, he's "giving up" only $28.60 per acre by "not selling" vs. $70 per acre in the first case. Again, it's a matter of what the decision-maker best perceives that he actually "gives up" to conduct (or not conduct) a particular activity.

For most, however, sale of the land is not an option under consideration. Either because the pasture is an inseparable part of a larger unit--or for whatever set of reasons--selling the land is not an option under consideration. For one, the acceptable set of options include only run cows or rent it to some other cowboy. For him, the "what he gives up" to run cows is whatever price he could have rented it to another for. In his case, he perhaps "gives up" the $20 to $25 market cash lease price per acre. For yet another operator, the most likely alternative is to run a steer (or backgrounding) operation. The real cost of the forage base to his cows is whatever he could have received from running steers instead. That's what he gives up.

For pasture that is at least marginally cropable, the best alternative being considered is whatever the operator "gives up" from not producing crops. Thus:

-- <u>"Cost" is alternative-specific</u>. The "what is being given up" (or the opportunity cost) depends on what other alternatives can, or will, be considered. Land price, for instance, is irrelevant in costing a product unless sale or exchange of the land is one of the alternatives under consideration. Otherwise its cost for one purpose is whatever was given up by not using it for the best of the remaining alternatives under consideration.

And Finally:

-- <u>Think in terms of cost and income "BEHAVIOR"</u>! Profitability of a proposed adjustment depends on whether increases in income (plus decreases in costs) are greater than increases in costs (plus decreases in income). Look at the <u>changes</u> in income and the <u>changes</u> in costs.

It is convenient to classify costs as fixed or variable, but such categorization seldom describes their <u>behaviors</u> for all alternatives. While depreciation of either a feed wagon or a concrete feeding floor may be categorized as fixed cost, they are not equally fixed. The feed wagon can be easily sold--and its costs suddenly made "variable" in terms of its behavior. On the other hand, the concrete feeding floor--or other assets strongly attached to the real estate--may be necessarily "fixed" so long as you own the land.

In short--whether a particular cost is "fixed" or "variable" depends on the alternatives the operator is able or willing to consider. Again, their "behaviors" are alternative specific. Again, one needs to look and see what a cost is "fixed to." Fence depreciation is a "fixed" cost and can be "expressed" on a per cow basis. Its behavior, however, is one of being fixed to the forage unit--not to the cow. If more, but smaller cows are run on that forage unit, fence depreciation becomes "variable" with number of cows--and hence with cow size. Do not become intimidated by the arbitrary cost categorizations someone adopts for his accounting convenience. Always look to see what the expected behavior of cost and income items are likely to be with the particular set of alternatives actually under consideration.

## Literature Cited


Brody, Samuel. 1945. Bioenergetics and growth. Reinhold Publishing Corp., New York.

Brungardt, V. H. 1979. Efficiency and profit differences of Angus, Charolais, and Hereford cattle varying in size and growth. Univ. of Wisconsin Res. Rep. R2398.

Dinkel, C. A. and M. A. Brown. 1978. An evaluation of the ratio of calf weight as an indicator of cow efficiency. J. Anim. Sci. 46:3.

Ewing, S. A. and L. Smithson, C. Ludwig, and D. Stephens. 1969. Energy requirements of mature beef cows as influenced by weight and level of milk production. In Animal Science Research: A Progress Report. Okla. Agr. Exp. Sta. Misc. Rep. 80.

Hauser, E. R. and D. D. Kress. 1969. What about cow size? Unpublished Mimeo.

Jacobs, V. E. 1983. Cost "behavior. . . and optimal cow size." Missouri Coop. Ext. Service Farm Mgmt. Newsletter F83-4.

Jacobs, V. E. 1984. Economics and beef cattle selection; Have we really discovered the "promised land"? Missouri Coop. Ext. Service Farm Mgmt. Newsletter FM84-3.

Klosterman, E. W., F. M. Byers, and C. F. Parker. 1979. Voluntary feed intake of mature cows as related to breed, type, condition, and forage quality. In beef cows and calves--1979: A summary of research. Ohio Agr. Res. Dev. Center Res. Circ. 251.

Klosterman, E. W. and C. F. Parker. 1976. Effect of size, breed, and sex upon feed efficiency in beef cattle. Ohio Agr. Res. Dev. Center Res. Bull. 1088.

# THE MEANING AND EXPECTATIONS OF TOTAL MANAGEMENT BEEF SYSTEMS

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There are several levels at which efficiency can be measured in beef cattle. At the most basic level is the efficiency of energy metabolism. A next step up from metabolic efficiency is the efficiency of a cow-calf unit. Beyond cow-calf unit efficiency is the efficiency of an entire cattle operation -- total system efficiency. In going from metabolic efficiency to system efficiency, we move further away from physiological processes, but closer to practical application.

Total system efficiency differs from cow-calf unit efficiency in that it is the efficiency of an entire herd over a complete life cycle, rather than of a single cow-calf pair at one point in time. Total system efficiency takes into account a number of factors which cow-calf unit efficiency measures often ignore. Once factor is herd size; fewer highly productive cows can be run on a fixed land area than less productive cows. A second consideration is the age structure of the herd -- how many replacement heifers, two-year olds, threes and so forth. Reproductive rate is taken into account since it has an effect on total efficiency which measures of feed consumption and weight gain alone cannot assess. To measure system efficiency, the value of all products of the system must be considered, including product derived from cull cows. Mating system is also important; the efficiency of a cow-calf unit can be dramatically changed by breeding a large sire to a smaller cow. Finally, total system efficiency takes into account the relationship between fixed costs (costs associated with the ranch or farm unit) and variable costs (costs apportioned on a per head basis).

There are four general categories of variables associated with beef production systems: 1) genotype, 2) natural environment, 3) management system/mating system, and 4) economics. Because the number of potential combinations of variables within and among these categories is very large, systems research can be conducted in only a limited way with conventional beef cattle facilities. Instead, we must rely on computer simulation techniques. Simulation programs provide an inexpensive way to study and make sense out of the multitude of interactions among these variables.

There are problems with employing computer models to do systems research. Naturally, results will only be as good as the biological and economic models used. Typically, these models are complex, and so are the input variables required by them. Even so, generalization is unavoidable, and there is always a trade-off between exactitude and simplicity. Of the models I am aware of, none incorporates adequate risk analysis. The computer programs simulate static rather than dynamic environments, and in so doing, they promote genotypes and management alternatives that are optimal for very specific situations, but which may not be optimal over the range of situations encountered in reality. The various models and versions of models now in use often contain widely varying assumptions. Because of this, conclusions from different models may be

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inconsistent and even contradictory. Before accepting or rejecting the results of a systems model, it is most important to understand the underlying model assumptions.

The major assumptions of the Texas A & M -- Colorado State University beef production model are:

1. Northeastern Colorado range environment
2. Fixed land base
3. Winter supplement levels appropriate to genotype
4. No terminal sires or heifer bulls
5. Slaughter at 30% empty body fat
6. Open cows culled -- pregnant replacement available

The CSU model has not been adapted for different mating systems and has not yet been used to simulate different natural environments, so the comparisons that follow are among genotypes, management systems and economic scenarios. Simulated effects of changing from a management system in which weanling calves are fed out in the feedlot to a stocker type of system (calves enter the feedlot in September of their second year) are listed in table 1. The stocker program resulted in reduced herd size and greater slaughter ages and weights. Stocker programs were generally less biologically efficient in terms of TDN input per unit of empty body weight produced, but were uniformly more economically efficient in terms of dollars per unit of output and net profit. Smaller genotypes benefitted most from a stocker system of management, due primarily to a large increase in slaughter weights. Larger genotypes also gained in economic efficiency, but to a lesser degree. Market weights of the largest steers produced with this system were outside current market requirements (900+ lb carcasses).

TABLE 1. EFFECTS OF CHANGING TO A STOCKER SYSTEM FROM A SYSTEM IN WHICH WEANLING CALVES ARE CUSTOM FED

| | | Slaughter Steers | | | | | |
|---|---|---|---|---|---|---|---|
| Genotype | Herd size (%) | Sl. age (mos) | Time on feed (mos) | Sl. wt. (%) | Biol. eff. (%) | Econ. eff. (%) | Net profit ($) |
| Large cow (1404 lb) | -15 | +6.7 | -2.3 | +21 | -4 | +4[a] | +4,598[a] |
| Medium cow (1179 lb) | -15 | +7.6 | -1.4 | +32 | -1 | +5 | +7,892 |
| Small cow (955 lb) | -13 | +8.2 | - .8 | +43 | +2 | +8 | +12,217 |

[a]Steer slaughter weights above market requirements.

Tables 2 through 5 demonstrate the effects that economic scenario can have on the efficiency of various genotype-management system combinations. The simulated genotypes were "best" in the sense that they incorporated smaller birth weights, larger yearling weights, somewhat greater milk production, leaner body composition and more insulation from hide and hair than was considered normal; all these traits had been shown to be generally beneficial in earlier comparisons. The optimal management system for these genotypes was a stocker program for all but the large type steers, which entered the feedlot at weaning.

TABLE 2. "BEST" GENOTYPE-MANAGEMENT SYSTEM COMBINATIONS FOR THREE COW SIZES

1. BIOLOGICAL EFFICIENCY

| Genotype | Management system | Herd size | Total EBW production (1000 kg) | Biol. effic. (TDN/EBW) | Rank |
|---|---|---|---|---|---|
| Large | Stocker operation for heifers, Weanling steers fed out | 222 | 101.3 | 9.87 | (1) |
| Medium | Stocker operation | 204 | 88.3 | 10.35 | (2) |
| Small | Stocker operation | 284 | 96.7 | 10.69 | (3) |

TABLE 3. "BEST" GENOTYPE-MANAGEMENT SYSTEM COMBINATIONS FOR THREE COW SIZES

2. ECONOMIC EFFICIENCY WITH STANDARD COST/PRICE RELATIONSHIPS

| Genotype | Economic efficiency ($/100 kg EBW) | Net profit ($) | Rank |
|---|---|---|---|
| Large | 146.40 | 24,510 | (1) |
| Medium | 149.28 | 18,825 | (2) |
| Small | 154.05 | 15,990 | (3) |

TABLE 4. "BEST" GENOTYPE-MANAGEMENT SYSTEM COMBINATIONS FOR THREE COW SIZES

3. ECONOMIC EFFICIENCY WITH DOUBLED HAY COSTS

| Genotype | Economic efficiency ($/100 kg EBW) | Net profit ($) | Rank |
|---|---|---|---|
| Large | 175.50 | -4,973 | (2) |
| Medium | 173.48 | -2,552 | (1) |
| Small | 191.44 | -20,157 | (3) |

TABLE 5. "BEST" GENOTYPE-MANAGEMENT SYSTEM COMBINATIONS FOR THREE COW SIZES

4. ECONOMIC EFFICIENCY WITH DOUBLED CONCENTRATE COSTS

| Genotype | Economic efficiency ($/100 kg EBW) | Net profit ($) | Rank |
|---|---|---|---|
| Large | 186.20 | -15,819 | (3) |
| Medium | 181.90 | -9,986 | (1) |
| Small | 182.32 | -11,336 | (2) |

Large cattle produced the greatest amount of empty body weight and were the most biologically efficient despite small herd size relative to the smallest genotype (table 2). The improvement in biological efficiency with increased cow size was largely a result of increased product per cow. When "standard" cost/price relationships were simulated (table 3), the different cow sizes ranked similarly for biological and economic efficiency. Larger cows were more economically efficient because they produced more income per cow with which to offset fixed costs and other costs associated with maintenance of the cow herd.

When hay costs were doubled (table 4) to represent expensive wintering costs for the cow herd, and when concentrate costs were doubled (table 5) to represent expensive feedlot costs, the medium sized animals were most economically efficient. Small cows were most disadvantaged by increased hay cost due to large total hay consumption -- a result of large herd size. When concentrate costs were doubled, large genotype animals were least different because of their greater requirements for time and feed in the feedlot.

One way to evaluate individual traits using computer simulation is to calculate weightings for changes in those traits. The weightings are simply the changes in overall efficiency resulting from independent changes in trait breeding values. Weightings per genetic standard deviation, increase in breeding values for birth weight, yearling weight, mature weight and milk production when weanling calves are fed out are listed in table 6. Because the weightings for the four traits have been standardized, they are all directly comparable. Positive values are favorable.

The weightings for birth weight in table 6 are uniformly negative, indicating the increased birth weight decreases overall system efficiency. This result is not surprising since heavier birth weights contribute to greater calving difficulty and smaller weaned calf crops. The largest weightings were calculated for yearling weight, suggesting that rapid early growth is of prime importance in selection.

TABLE 6. WEIGHTINGS PER GENETIC STANDARD DEVIATION INCREASE IN EACH OF FOUR TRAITS[a]

1. WEANLING CALVES FED OUT

| Trait | Biological efficiency | Economic efficiency: Standard costs | Economic efficiency: Doubled hay costs | Economic efficiency: Doubled conc. cost |
|---|---|---|---|---|
| Birth weight | -.09 | -1.58 | -3.65 | -1.44 |
| Yearling weight | .24 | 4.76 | 8.74 | 4.76 |
| Mature weight | -.01 | .48 | .57 | -.51 |
| Milk production | -.09 | -.17 | -1.45 | 2.79 |

[a]Listed values represent changes in efficiency per genetic standard deviation increase in a trait, where biological efficiency is measured as kg TDN/kg EBW and economic efficiency is measured as $/100 kg EBW. Positive values are favorable indicating increased efficiency.

Weighting for mature weight were generally small, and greater mature weight appears to have both disadvantages and advantages. The disadvantages are due to increased feed consumption. The advantages result from heavier slaughter weights of both calves and cull cows. The negative weighting for mature weight when feedlot costs were high reflects the increased feed required to finish later maturing animals.

Increased milk production was biologically inefficient, but economically ambivalent when "standard" costs were simulated. However, when wintering costs for the cow herd were high, the increased supplement required by heavier milking cows cost more than was justified by the increased milk. On the other hand, when feedlot costs were high, increased milk was favored because calves that were heavier and in better condition at weaning required less time and feed in the feedlot.

Table 7 is similar to table 6 except that the management system simulated is a stocker operation. As in table 6, the weightings in table 7 for birth weight are consistently negative, but as a rule more highly negative than before. This is because calf slaughter weights are greater in a stocker operation, with the result that product derived from calves (as opposed to product derived from cull cows) is responsible for a greater proportion of total income. Each individual calf is then relatively more important, making any trait associated with calf survival more critical.

TABLE 7. WEIGHTING PER GENETIC STANDARD DEVIATION INCREASE IN EACH OF FOUR TRIALS[a]

2. STOCKER OPERATION

| Trait | Biological efficiency | Economic efficiency: Standard costs | Economic efficiency: Doubled hay costs | Economic efficiency: Doubled conc. cost |
|---|---|---|---|---|
| Birth weight | -.13 | -2.30 | -3.02 | -3.89 |
| Yearling weight | .17 | 3.40 | 5.89 | 5.21 |
| Mature weight | .00 | .15 | .30 | -1.07 |
| Milk production | -.02 | -.18 | -.25 | .69 |

[a]Listed values represent changes in efficiency per genetic standard deviation increase in a trait, where biological efficiency is measured as kg TDN/kg EBW and economic efficiency is measured as $/100 kg EBW. Positive values are favorable, indicating increased efficiency.

Weightings for yearling weight in table 7 are positive, but generally not so highly positive as in table 6. This is probably due to the fact that growth of yearling animals in a stocker operation is a function not just of the preyearling growth curve, but of the postyearling growth curve as well. The weightings for mature weight did not change appreciably with management system. I should note, however, that genotypes with particularly small mature weights relative to yearling weights were especially inefficient under stocker management. This result was likely caused by suppressed postyearling gaining ability.

Weightings for milk production in a stocker operation followed the same pattern as when weanling calves were fed out. However, milk level appeared to have less influence on overall efficiency. This can be expected since weight and condition on weanling calves will have less effect on slaughter weight if those calves are pastured for ten months before entering the feedlot.

Reproduction is an area of growing concern, especially among breeders of "systems" cattle. There are two aspects of reproduction: cow fertility and calf survivability. Survivability is of critical importance to total system efficiency; the weightings for birth weight in tables 6 and 7 reflect the impact of relatively small changes in weaning rate. Inherent fertility is also important. Genetic ability to cycle and conceive serves as an insurance policy in bad years and harsh environments, and enables cows to get by on less feed. I wish to show, however, that high levels of phenotypic fertility are not necessarily of value.

TDN consumption and empty body weight gains of several classes of cattle are listed in table 8. If these figures are summed to as to represent the consumption and production over a two-year period of a mature cow versus a replacement heifer, the replacement heifer turns out to be more efficient (10.0 to 11.5% more efficient for empty body weight production -- depending on management system; 18.0 to 20.8% more efficient for fat free weight production). The replacement heifer raises one calf to the mature cow's two calves, but the heifer is herself gaining weight where the mature cow is only maintaining weight. The conclusions to be drawn from table 8 are that maintaining mature cows is biologically inefficient, and, at least from the standpoint of biological efficiency, cow herds should be kept young.

TABLE 8. TDN CONSUMPTION, WEIGHT GAINS AND BIOLOGICAL EFFICIENCES OF REPLACEMENT HEIFERS VERSUS MATURE COWS OVER A TWO-YEAR PERIOD

| Class | TDN consumed (kg) | EBW gain (kg) | Biol. eff. (TDN/EBW) | Advantage (%) |
|---|---|---|---|---|
| Mature cow | 2,502 | 0 | | |
| Her steer calf | 1,318 | 399 | | |
| 2-year old cow | 2,253 | 43 | | |
| Her steer calf | 1,351 | 399 | | |
| Replacement heifer | 1,590 | 171 | | |
| Total mature cow[a] | 7,640 | 798 | 9.57 | |
| Total replacement[b] | 5,194 | 613 | 8.47 | 11.5 |

[a]Includes annual inputs and outputs for two mature cows plus inpugs and outputs for two steers from birth to slaughter.
[b]Includes annual inputs and outputs for one replacement and one two-year old cow plus inputs and outputs for one steer from birth to slaughter.

The economic efficiency of phenotypic fertilty and of other determinants of longevity is another question. Because open cows can be replaced with pregnant heifers, it is possible to have low pregnancy rates and still maintain high weaning rates. Lower pregnancy rates imply not a loss of product (as would be the case with death losses), but a change in the relative amounts of products derived from cows and calves; as pregnancy rates decline, cull cows are substituted for slaughter heifers that are now needed as replacements. The immediate economic value of phenotypic fertility will, therefore, be a function of: 1) costs of raising replacements relative to costs of maintaining mature cows, and 2) relative contributions of calf product and cow product to total income. Phenotypic fertility will be especially important when replacement costs are high relative to the costs of maintaining mature cows, and when calf product represents a relatively large proportion of total income. When these conditions are not met, the biological inefficiency of maintaining mature cows causes phenotypic fertility to be less important.

A simulated example of optimal pregnancy rates is presented in table 9. Assuming a "standard" relationship between prices for cull cows and fed calves and a management system in which weanling calves were fed out, the optimal pregnancy rate for 3 to 10-year old cows was only 78%. When prices for cull cows declined, calf product was responsible for a large share of total income, and the optimal pregnancy rate increased 5%. With a stocker operation, slaughter weights for fed animals were heavier, calf product made up a larger proportion of the total, and the optimal pregnancy rate was 83% assuming standard price relationships. When prices for cull cows decreased, the optimal pregnancy rate increased further.

TABLE 9. OPTIMAL PREGNANCY RATES -- 3 TO 10 YEAR OLD COWS

| Management system | Economic scerario | Pregnancy rate |
|---|---|---|
| Weanling calves fed out | Standard price relationship | 78% |
| Weanling calves fed out | Cull cow prices decreased 25% | 83% |
| Stocker operation | Standard price relationships | 83% |
| Stocker operation | Cull cow prices decreased 25% | 88% |

Summary of results of the CSU model

1. Stocker operations are generally less biologically efficient, but more economically efficient than systems in which weanling calves are fed out.
2. The increased slaughter weights achieved by a stocker operation benefit smaller genotypes most.
3. Larger genotypes are more biologically efficient and often more economically efficient than smaller genotypes.
4. High wintering costs for the cow herd and/or expensive feedlot costs favor genotypes of moderate size over other types.
5. Rapid early growth (yearling weight) followed by calving ease (birth weight) should receive the most attention in selection.
6. Mature weight should be proportional to yearling weight (not too high, not too low). High feedlot costs favor lower mature weights.
7. For the enviroment simulated, ample milk production was favored.
8. More milk is indicated when feedlot costs are high, and less milk is indicated when wintering costs for the cow herd are high.
9. For a stocker operation, calving ease is relatively more important, early growth somewhat less important, and milk production less influential than for a system in which weanling calves are fed out.
10. Maintaining mature cows is biologically inefficient.

11. Phenotypic fertility is especially important when replacement costs are high relative to the costs of maintaining mature cows, and when calf product represents a relatively large proportion of total income. When these conditions are not met, the biological inefficiency of maintaining mature cows causes phenotypic fertility to be less important.

# INCORPORATING BEEF COW EFFICIENCY INTO TOTAL MANAGEMENT SYSTEMS

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## Introduction

Objective evaluation of beef cow efficiency from a total management systems viewpoint involves the recognition that cow efficiency is not an innate, invariant characteristic of an individual or a genetic type. Instead, cow efficiency should be viewed in terms of the ability of the cow to interact with the physical environment and with the imposed breeding and management system in a way that allows the economic efficiency of the entire production system to be maximized. Thus, any discussion of cow efficiency must be prefaced by a description of the production system.

## The Crossbred Perspective

It is particularly important that we discuss cow efficiency from a crossbred perspective. Heterosis in the cow and calf, coupled with the potential to combine complementary breed effects from the sire and dam, indicate that the advantages of crossbreeding are too large to ignore and suggest that cow efficiency should be evaluated in terms of the maternal role in crossbreeding.

The effects of heterosis on several measures of productivity are shown in table 1 for systems using crossbred calves nursing purebred cows and for systems using three-way-cross calves nursing crossbred cows. The values in table 1 are all relative to a system using purebred calves nursing purebred cows and involve only the effects of heterosis; the breeds being crossed are assumed similar in size, growth rate and milk production. Cundiff and Gregory (1977) reported that the pounds of calf weaned per cow exposed was increased by 8.5% by use of the crossbred calf and by 23.1% in crossing involving both crossbred cows and calves. Notter et al. (1979c) noted that on an industry basis all matings could not be crossbred because a certain fraction of the population was required to produce the parent purebreds but concluded that the pounds of calf marketed per cow exposed (including both crossbreds and associated purebreds) could still be increased by 6.5% by use of the crossbred calf and by 18.9% by use of the crossbred cow and calf. Notter et al. (1979c) also estimated that the cost per pound of weanling calf marketed could be reduced by 5.4% through use of the crossbred calf and by 11.8% through use of the crossbred cow and calf. In a similar study, Kearl (1975) estimated that the return per dollar invested to weaning could be increased by 8% through three-breed rotational crossing and that this relatively small improvement in economic efficiency would be expected to increase net ranch income by 57.3%. When calves are evaluated at slaughter, Notter et al. (1979c) estimated that the cost of production per cwt at slaughter would be reduced by 2.5% through use of the crossbred calf and by 4.7% through use of both the crossbred cow and calf. If one assumes a profit margin of $5/cwt in purebred production, these cost reductions would translate into increases in net income of 22.9% crossbred calf and 55.1% for the crossbred cow and calf.

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TABLE 1. EFFECTS OF HETEROSIS IN CROSSES INVOLVING BRITISH BEEF BREEDS

| Item | Percentage change[a] |
|---|---|
| Pounds of calf weaned per cow exposed[b] | |
| Crossbred calf | + 8.5% |
| Crossbred cow and calf | +23.1% |
| Pounds of calf marketed per cow exposed[c,d] | |
| Crossbred calf (56%) | + 6.5% |
| Crossbred cow and calf (62%) | +18.9% |
| Cost/lb weanling calf marketed[c] | |
| Crossbred calf | - 5.4% |
| Crossbred cow and calf | -11.8% |
| Return/dollar invested to weaning[e] | + 8.0% |
| Net ranch income[e] | +57.3% |
| Cost/lb at slaughter[c] | |
| Crossbred calf | - 2.5% |
| Crossbred cow and calf | - 4.7% |
| Net income at slaughter[c,f] | |
| Crossbred calf | +22.9% |
| Crossbred cow and calf | +51.5% |

[a]Relative to purebred herds.
[b]Cundiff and Gregory (1977).
[c]Notter et al. (1979c). Includes both crossbreds and necessary associated purebreds.
[d]Values in parentheses are the fraction of the total matings that can be of the most desired type.
[e]Kearl (1975) for three-breed rotational crossing.
[f]Assumes a profit margin of $5/cwt in purebred production.

Several studies (Smith, 1976; Notter et al., 1979c) have also suggested that the economic efficiency of beef production can be increased through the use of large, terminal sire breeds on smaller, well-adapted cow breeds. However, these studies have also recognized that the advantages of crossbreeding can be lost because of excessive calving difficulty and calf death losses if the divergence in size between sire and dam is too large. Thus, effective use of crossbreeding involves maintenance of a maximum tolerable size divergence between sire and dam types in order to maximize the rate of calf production in relation to cow maintenance costs without incurring unacceptable amounts of calving difficulty.

Notter et al. (1979c) described breed differences in size in terms of the mature cow weight of the alternative types and reported that a difference of no more than 200 lb between sire and dam types was acceptable if heifers were to be bred to the terminal sire breed. However, Notter also reported that much larger size differences could be tolerated if young cows were bred to a sire type of moderate size, leaving only older cows to be mated to the terminal sire breed. Under this system differences in mature size of at least 400 lb between sire and dam types apparently can be readily tolerated. For example, these results would suggest that cows with a mature size of 1,000 lb could be mated to a similar sire type for two calf crops and then mated to bulls of a 1,400 lb type for subsequent calvings.

This maximum tolerable size divergence of perhaps 400 lb in mature weight for terminal crossing can be combined with existing market specifications for slaughter cattle to delineate desirable cow types in terms of their size and calving ease. Carcasses outside the weight range of 550 to 850 lb are difficult for the packer to merchandise; thus, slaughter cattle outside a live weight range of 900 to 1,350 lb are likely to receive substantial price discounts, even if those cattle are properly finished. Figure 1 shows the relationship between sire breed size and cow breed size as a function of market demand and the maximum tolerable size difference.

As an example, assume that cows of an 1,150 lb mature weight type are bred to bulls of a similar type for the first two calf crops and are then bred to a 1,500 lb sire type for subsequent calvings. Also assume for purposes of illustration that the target slaughter weight for steers is equal to the mature weight of a cow of the same type (i.e., that steers of a 1,150 lb mature weight type reach choice grade at 1,150 lb) and that heifers weigh 100 to 150 lb less than steers at slaughter. In this system, calves from the first two calf crops would go to market at weights of about 1,150 lb for steers and 1,000 lb for heifers. Calves from the terminal cross would go to market at weights of about 1,350 lb for steers = 1/2(1,150 + 1,550) and 1,200 lb for heifers. This sytem would produce cattle covering almost the entire range of acceptable slaughter weights, but with very few cattle outside this range. Note that an increase in cow size would result in production of terminal-cross steers that would be outside the acceptable weight range (>1,350 lb) or would necessitate use of a smaller terminal sire type which would in turn reduce the desired divergence of 400 lb between sire and dam types. Thus, little would be gained by increasing cow size. Note also that increases in sire breed size above 1,550 lb would likewise result in production of animals outside the acceptable market weight range unless the increases were accomplished without increased calving difficulty in order to allow compensating reductions in cow breed size.

The above example, coupled with the concepts shown in figure 1, suggest the following conclusions: 1) the desired mature weight for commercial cows is likely to be in the range of 900 to 1,150 lb and should increase only as the market becomes willing to accept heavier carcasss, and 2) increases in sire breed size above those shown in figure 1 are also not indicated unless market weights can be increased or unless calving difficulty can be controlled to allow increases in sire size to be accompanied by decreases in dam size, with 900 to 950 lb as a practical minimum size.

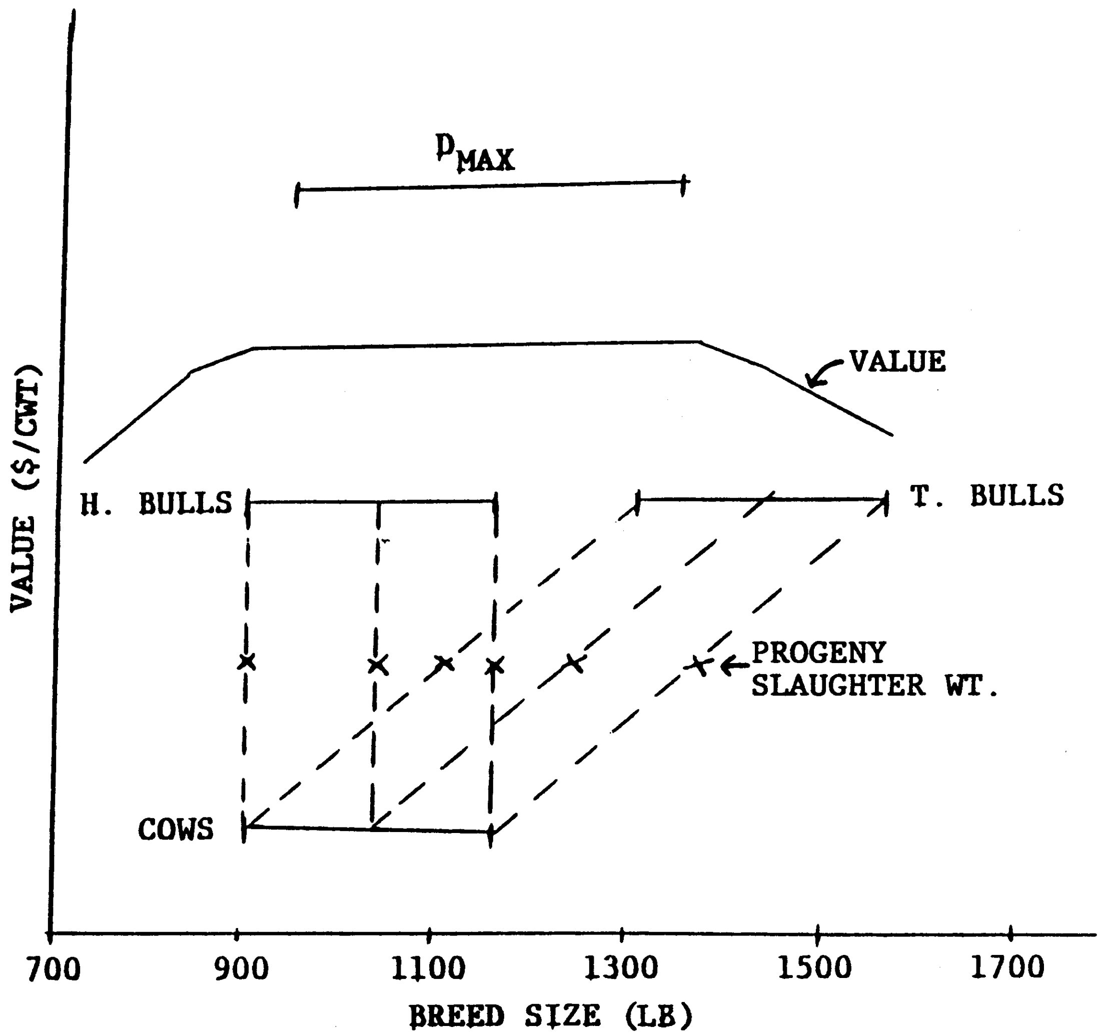


Figure 1. Options for production of crossbred slaughter progeny in crossbreeding program as a function of product value, sire breed size, dam breed size and the maximum acceptable size divergence between sire and dam ($D_{MAX}$). The system involves use of both moderate-sized sires (H or "heifer" bulls) for use on younger cows and large terminal (T) sires for use on older cows to produce the market progeny (X).

## Selection Criteria

Given the above considerations regarding the desired characteristics of maternal types for use in crossbreeding, let us now consider the traits that could be used in selection programs to improve cow efficiency.

Size. Although figure 1 suggests an intermediate optimum cow size range, there is still opportunity for selection for (or against) size within this range. Also, future increases in cow size are not precluded so long as three conditions are met: 1) terminal sire size must also increase to maintain the size divergence desired in crossing, 2) acceptable market weights must increase, and 3) increases in cow size must be economically efficient. It is the last condition that will be considered here.

A number of studies (Smith et al, 1976; Cundiff et al., 1981, 1984) have indicated that the efficiency of individual calf growth to a condition-constant endpoint (such as Choice grade) is essentially independent of the mature size of the breed or cross. However, most theoretical studies that have attempted to evaluate the likely effect of increasing size on economic efficiency have concluded that larger cows should be more efficient than smaller cows on a total production system basis (Morris and Wilton, 1975; Notter et al., 1979b). This result has occurred in part because of the assumption that many fixed, nonfeed production costs accrue on a "per head" basis and are therefore spread over more units of product by larger cows, although both Notter et al. (1979b) and Jacobs (1983) have suggested that this assumption is probably not correct. More importantly, most theoretical studies have used the general, interspecific rules of Taylor (1980) to estimate the additional time required for larger cattle to reach acceptable slaughter finish. These rules suggest that a 50% increase in size could be accompanied by a 34% increase in growth rate and a 12% increase in the time required to reach Choice grade. If we assume a 365-day calving interval for both large and small types (the theoretical size scaling rules suggest that larger cows might have longer calving intervals, but this has not been documented), these assumptions allow a higher annual rate of calf production for larger cows and would be predicted to increase efficiency by 3.5% for every 50% increase in size. However, the accumulating published information on beef cattle breed difference from the U.S. Meat Animal Research Center provides a somewhat different picture of the relationship between size and productivity within cattle breeds. That data on steer growth (Smith et al., 1976; Cundiff et al., 1981, 1984) and mature cow size (U.S.D.A., 1978, 1980, 1982) suggests that a 50% increase in mature size is associated with only a 23% increase in growth rate but with a 30% increase in time to reach a constant composition, and that these changes do indeed lead to almost exact equality among size classes in the annual efficiency of the cow-calf unit.

Changes in cow size must also be considered in terms of the adaptation of different cow size classes to specific environments. Although experimental data is scanty, the opinion is common that large cows cannot function as well in areas of sparse vegetation where a premium is placed on foraging ability. In a classic Australian study, Frisch (1981) found that cattle selected for growth in a dry, tropical climate were smaller at birth than control cattle and were not superior in growth to control cattle when both were evaluated in an improved environment. These results suggest that the more rapid growth of selected cattle in this environment was a function of improved adaptation, not increased mature size. Likewise, Demment and VanSoest (1983) suggested that under extensive grazing conditions, larger animals may be forced to consume lower quality forages than smaller animals in order to meet their requirements.

Taken together, these results provide little support for an association between size and efficiency other than that imposed by market demands and environmental adaptation.

Milk Production. Notter et al. (1979a) discussed relationships between milk production and economic efficiency and concluded (figure 2) that for any environment there is likely to be a feasible range of milk production levels that are potentially optimum in that environment. The lower limit of the feasible range is the minimum amount of milk consistent with calf health and survival; the upper limit is reached when the nutritional stress of lactation precludes satisfactory rebreeding. In practice, the lower limit generally corresponds to maximum weaning rates (high fertility with acceptable calf growth and survival) and the upper limit corresponds to the maximum pounds of calf weaned per cow exposed (rapid calf growth with acceptable fertility). The feasible range varies with the environment, being wide in good environments and narrow in poor environments, and will probably have to be experimentally determined for each major production system. Within the feasible range, the economically optimum milk production level for slaughter calf production depends primarily upon the relationship between postweaning and preweaning feed costs. The optimum milk production level is near the upper limit of the feasible range when feed for the cow herd is cheap in relation to the feedlot ration and near the lower limit when feed for the cow herd is relatively expensive. For weanling production, optimum milk levels were near the top of the feasible range, even after correction for the lower sale prices ($/cwt) expected for the fatter weanling calves (Seldin, 1983).

Thus, milk production, like cow size, appears to have an intermediate optimum level that is best set in commercial beef production by crossing among existing breeds with subsequent selection directed toward fine-tuning and maintaining this intermediate production level.

Fertility, Fitness and Functionality. The preceding discussion has emphasized that changes in size and milk production are unlikely to be economically advantageous if they compromise the environmental adaptation of the cow herd. The keys to cow efficiency may well lie in traits that we often take for granted: the ability to breed quickly, calve easily, rebreed readily and forage well and widely. Selection for these functionality traits in commercial herds is often intense; the culling of all open cows represents extreme selection pressure for fertility. However, the expanded use of A.I. with the attendant use of popular sires on a national scale mandates increased attention to fertility and functionality traits in seedstock herds as well. If cow efficiency is to be more than a synonym for milk production, we must bring these true cow efficiency measures under the umbrella of national sire evaluation. This needs to be done not only to facilitate within-herd selection but also as a merchandising tool to document that a sire of medium-sized, fertile, functional females may be fully as valuable to the industry as the large-framed terminal sire.

## Literature Cited

Cundiff, L. V. and K. E. Gregory. 1977. Beef cattle breeding. U.S.D.A. Agriculture information Bull. No. 286.

Cundiff, L. V., R. M. Koch, K. E. Gregory and G. M. Smith. 1981. Characterization of biological types of cattle--Cycle II. IV. Postweaning growth and feed efficiency of steers. J. Anim. Sci. 53:332.

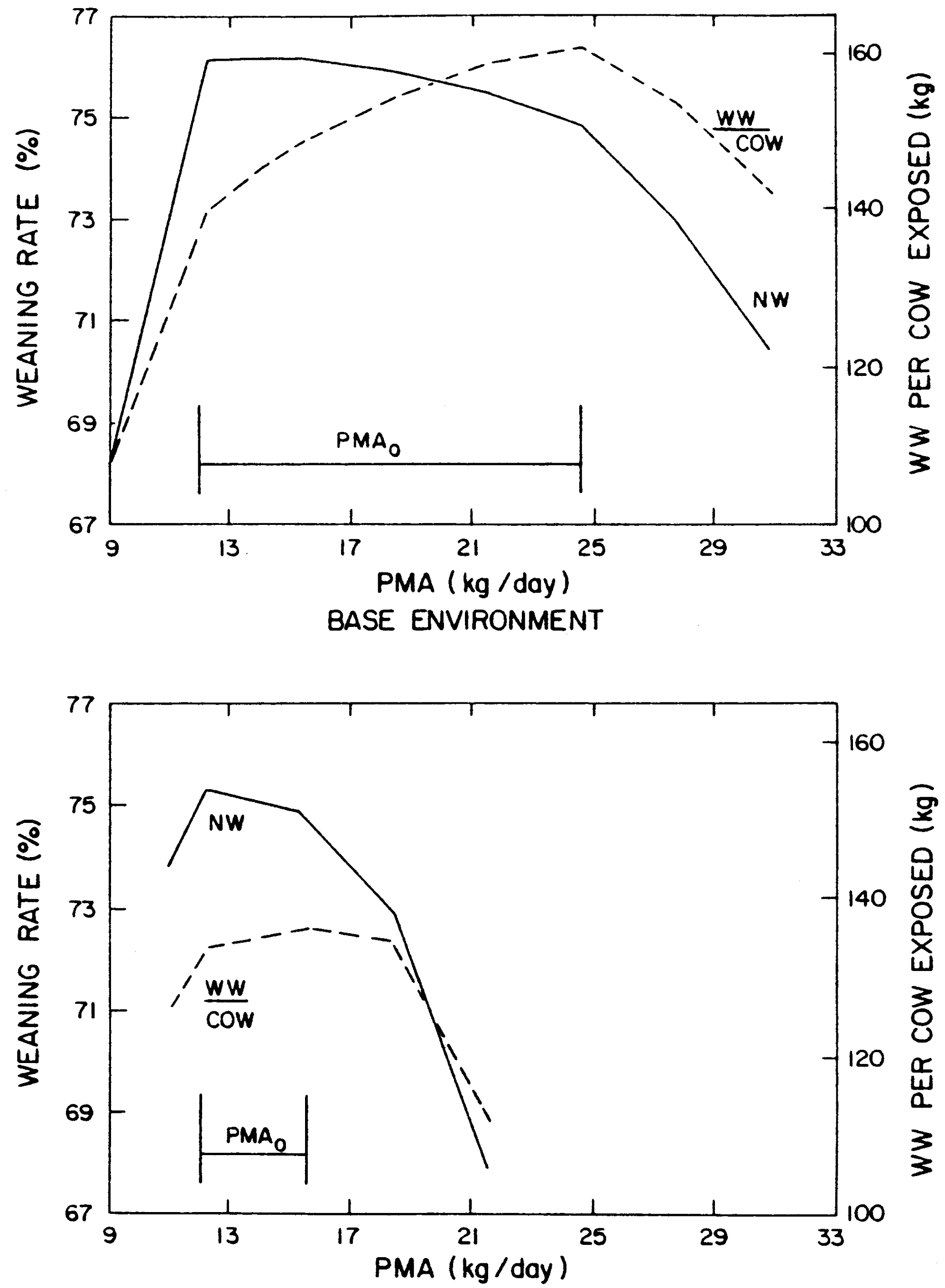


Figure 2. Definition of the feasible range in milk production potential ($PMA_0$) for a high-quality (base) environment and a less-favorable environment in terms of number of calves weaned per cow exposed (weaning rate; NW) and weight weaned per cow exposed. PMA values (in kilograms) are maximum daily milk production potentials at peak lactation in an unrestricted environment. PMA levels range from about the level of the Hereford x Angus (PMA = 11) to the level of the Hereford x Holstein (PMA = 26).

Cundiff, L. V., R. M. Koch and K. E. Gregory. 1984. Characterization of biological types of cattle (Cycle III). IV. Postweaning growth and feed efficiency. J. Anim. Sci. 58:312.

Demment, M. W. and P. J. VanSoest. 1983. Body size, digestive capacity, and feeding strategies of herbivores. Winrock Int. Livestock Res. & Training Center, Morrilton, AR.

Frisch, J. E. 1981. Changes occurring in cattle as a consequence of selection for growth rate in a stressful environment. J. Agr. Sci. 96:23.

Jacobs, V. E. 1983. Cost "behavior". . . and optimal size in beef cows. Missouri Coop. Ext. Service Farm Mgmt. Newsletter FM83-4.

Kaerl, W. G. 1975. Adoption, management and returns in crossbreeding English cattle. Wyoming Agr. Exp. Sta. Res. J. 54R.

Morris, C. A. and J. W. Wilton. 1975. Influence of mature cow weight on economic efficiency in beef cattle production. Can. J. Anim. Sci. 55:233.

Notter, D. R., J. O. Sanders, G. E. Dickerson, G. M. Smith and T. C. Cartwright. 1979a. Simulated efficiency of beef production for a Midwestern cow-calf-feedlot management system. I. Milk production. J. Anim. Sci. 49:70.

Notter, D. R., J. O. Sanders, G. E. Dickerson, G. M. Smith and T. C. Cartwright. 1979b. Simulated efficiency of beef production for a Midwestern cow-calf-feedlot management system. II. Mature body size. J. Anim. Sci. 49:83.

Notter, D. R., J. O. Sanders, G. E. Dickerson, G. M. Smith and T. C. Cartwright. 1979c. Simulated efficiency of beef production for a Midwestern cow-calf-feedlot management system. III. Crossbreeding systems. J. Anim. Sci. 49:92.

Seldin, R. M. 1983. Estimation of economic weights for a beef cattle selection index. M.S. Thesis, Virginia Polytechnic Institute and State Univ., Blacksburg.

Smith, G. M. 1976. Sire breed effects on economic efficiency of a terminal-cross beef production system. J. Anim. Sci. 43:1163.

Smith, G. M., D. B. Laster, L. V. Cundiff and K. E. Gregory. 1976. Characterization of biological types of cattle. II. Postweaning growth and feed efficiency of steers. J. Anim. Sci. 43:37.

Taylor, St. C. S. 1980. Genetic size-scaling rules in animal growth. Anim. Prod. 30:161.

U.S.D.A. 1978. Germ Plasm Evaluation Program Progress Report No. 6. ARM-NC-2.

U.S.D.A. 1980. Germ Plasm Evaluation Program Progress Report No. 8. ARM-NC-13.

U.S.D.A. 1982. Germ Plasm Evaluation Program Progress Report No. 10. ARM-NC-

# EVALUATING BEEF MANAGEMENT SYSTEMS

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The Beef Cow Efficiency Forum has been originated with recognition that many factors interplay to affect efficiency of a beef cow, and that the cow is the most important of the three animal components of beef production systems (cows, bulls, and steers plus excess heifers).

The cow's importance is placed into perspective by considering the basic functions of beef cattle:

I. Reproductive phase - increase numbers
II. Growth phase - increase weight and finish

Cow-calf operations account for all of the reproduction and about one-half of the weight production in the form of weanling calves and cull cows. There is little question about the importance of cow efficiency in the total beef production system (Cartwright, 1970).

However, there is concern about the economic efficiency, or lack of it, of cow-calf production. In order to put the cow efficiency question in an economic context, the results of a detailed economic analysis of a cow-calf operation in Texas (Doren et al., 1984) illustrates a dimension that should not be overlooked. These results are from a Texas Agricultural Experiment Station research project cooperating with a large ranch where forage and cattle production data were collected over a number of years. We simulated productivity of this herd as part of our systems analysis research (Sanders and Cartwright, 1979a,b), first validating the observed production as a baseline and then examining the effect of a number of different production management practices. Table 1 summarizes some of the economic analysis.

Two points are apparent at least for this ranch in 1982. One is that there was no apparent way to make a profit with this cow-calf operation if all expenses were considered. A second is that the practices employed have a large effect on return; that is, the practices employed do make a difference.

A third point that may be inferred is that beef cattle production is not necessarily entered into as a commerical enterprise separated from other interests. Of course we all hope for better times, but we should be realistic and acknowledge that there are some extraneous elements holding cow--calf enterprises together. These include use of land to provide speculation and personal satisfactions. These factors may not directly affect production efficiency, but it is useful to recognize the base for which economic return is contemplated since this base conditions management decisions. There are changes

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in the ranking of different management practices for net return depending on the basis for figuring net revenue return (see table 1). There are also changes in ranking based on net revenue return versus cattle production measures such as sale weight/cow or sale weight/feed utilized, whether the ratio is put in $ terms or left as weights. That is, if we define efficiency in terms of net revenue, then a thorough economic analysis is required or we may be misled. Nonetheless, it appears clear that as much or more emphasis needs to be placed on keeping variable costs or expenses minimal as on increasing output or production.

TABLE 1. NET RETURNS SIMULATED FOR COW-CALF OPERATION: 400 ACRE RANCH, APPROXIMATELY 100 COWS; CALVES SOLD AT WEANING; BASED ON 1982 PRICES[a]

| Net revenue returns[b] | Net revenue range for different production practices |
|---|---|
| Over total production costs | -$9,800 to -$7,720 |
| To land | -$4,620 to -$2,520 |
| To land and livestock | $2,220 to $4,940 |
| To land, livestock, labor and mangement | $7,820 to $10,840 |

[a]Taken from Doren et al. (1984). These figures are scaled down to a 400 A. ranch for convenience of presentation and may be slight over estimates.
[b]The first line indicates returns when all production costs are included (prevailing rental fees were used for land cost); the second line is return when all costs except land are included; livestock are included, etc.
[c]The practices included different winter feed supplementation and breeding/calving season. In every case the lower figure was for the practices actually employed on the ranch.

Having the right kind (or kinds) of cattle is an important first step. The right kind of cows may vary with each area and production system, but generally cows must be easy keepers that tend to be trouble-free; cows that tend to require minimal dollar input. For convenience I have divided traits into two categories (Cartwright, 1982):

Primary Traits
- Size/age
- Maturing rate/size
- Milk production
- (Muscularity/fat deposition)

Secondary Traits
- Anatomical Soundess
  - Reproduction
    - Sex organs
    - Calving ability
  - Muscle and Bone
    - Structure
    - Ratio or balance
  - Color
  - Horned/Polled
  - Genetic Defects

| Primary Traits | Secondary Traits |
| --- | --- |
| | Physiological Soundness |
| | Adaptability to production resource |
| | Climate |
| | Nutrition |
| | Range area |
| | Disease/parasites |
| | Reproduction |
| | Hormonal balance |
| | Calving ability |
| | Temperament |

Muscularity and muscle/fat proportions and distribution should perhaps be listed under primary traits, but for this discussion I am avoiding that issue and looking at it only from the soundness point.

Primary traits tend to predominate or overwhelm many other traits. They have pervasive, important correlated effects; that is, they affect, or are affected by, many other characters. Size is a composite character conveniently characterized by body weight at maturity, at a given body composition, especially fat and fill. Generally, as genetic size potential increases, rate of gain potential increases and degree of maturity, including degree of finish, at any age, decreases. Cow size is important because of effects on her growth rate, maturing rate and weight, and, therefore, on feed requirements (stocking rates) for maintenance and growth and age at first calf. The nutrients consumed (including pasture/range) by cows are the major expense related to beef production (see article by D.E. Johnson in the proceedings of this forum). Cow size is genetically important because of its effect on growth and maturing rates on her progeny. Level of milk production affects nutrient requirements, degree of fatness, breed-back of the cow, weaning weight, and finish of her calf. Maturing rate, independent of size, affects age at puberty and degree of finish at any age and, therefore, age at first calf and breed-back.

Size and milk production potentials can be relatively easily changed by selection. Maturing rate, independent of size, is much more difficult to change by selection. Breeds exist which combine various size and milk production potentials and to some degree maturing rate (e.g., differences in maturing rates of Zebu and European breeds of approximately the same mature size).

The traits listed as secondary are intended to reflect mostly structural and physiological soundness and are secondary because of generally more limited or confined effects (fewer correlated effects) and not necessarily secondary in importance.

It is relatively easy to change cattle by selection and choice of breeds for the primary traits of size/age and milk production; that is, heritability tends to be relatively high. Maturing rate, independent of size, is much more difficult to measure and to change by selection. The various breeds available in the U.S. combine these three traits in various combinations.

Traits that contribute most to efficiency of the reproductive phase of cow production are often not the same and may be antagonistic with those traits that contribute to growing and finishing steers. If the sire breed in a terminal crossing program is thought of as contributing to desired slaughter progeny traits, and the dam breed is thought of as contributing to reproduction, the traits desired tend to contrast (Cartwright, 1970):

| Sire Breeds | Dam Breeds |
|---|---|
| High rate of gain | High fertility |
| Efficient feed conversion | Desired milking qualities |
| High cutout percent | Early puberty |
| Tender, palatable beef | General soundness |
| | Adaptability |
| | Easy calving ability |
| | Low feed requirements |
| | Longevity |

Generally speaking, The Texas Agricultural Experiment systems analysis research that has examined total offtake of a herd in relation to the production resource (characteristics of the geographic area, management, etc.) indicates that as the level of nutrition increases in both quality and quantity, as well as the stability of nutrition through the seasons of the year, that the size/age, maturing rate and milk production level that are best, or optimal, tend to increase and vice versa. That is, there is a size, maturing rate and milk production level that best fits each set of conditions and production system (e.g., cow-calf vs cow-calf-stocker-finisher, straightbreeding vs crossbreeding, intensive vs extensive). Figure 1 illustrates this point (Baker, 1982). Of the two breeds illustrated, the breed (B) with the lower "productive potential" was more efficient in total herd offtake under the more limited nutrition. When the nutrition was improved to a level that better supported a faster maturing, larger cow that gave more milk, the breed ranking reversed the breed (A) with the higher potential was more efficient. The management, breeding and production system must be synchronized. Probably no agricultural commodity is produced under a wider array of conditions than beef cattle, especially the cow herd production. No single set of recommendations is best for every producers.

In general terms it seems safe to recommend placing emphasis on getting cattle in the correct range for the primary traits for the production conditions; that is, select cattle so that they are close to the best or optimal size, maturing rate and milk production. Then begin shifting emphasis to the secondary soundness traits thinking about cutting production costs with easy keeping or low-care cattle. For example, calving difficulty present at even a low level can overwhelm breeding improvements we may make for other characters.

I have only touched on breeding to include some of what may be considered breeding management. The major effects interacting with breeding are nutrition, weather and market. The weather and market (or price of cattle) are extraneous effects in that they don't respond to individual producer efforts; the producer must respond to them. A cow-calf producer can only develop a strategy to attempt to cope with these facts of life; generally that means reducing his risks.

The producer can manage his nutritional program, but still the greatest nutritional problem in cow-calf operations is planning the best crop with the seasonal nature of feed (pasture/range) supply. As the prices for grain and other harvested feeds (e.g., hay and silage) become more expensive relative to the price of cattle (which is the likely long term trend), then the problem becomes greater.

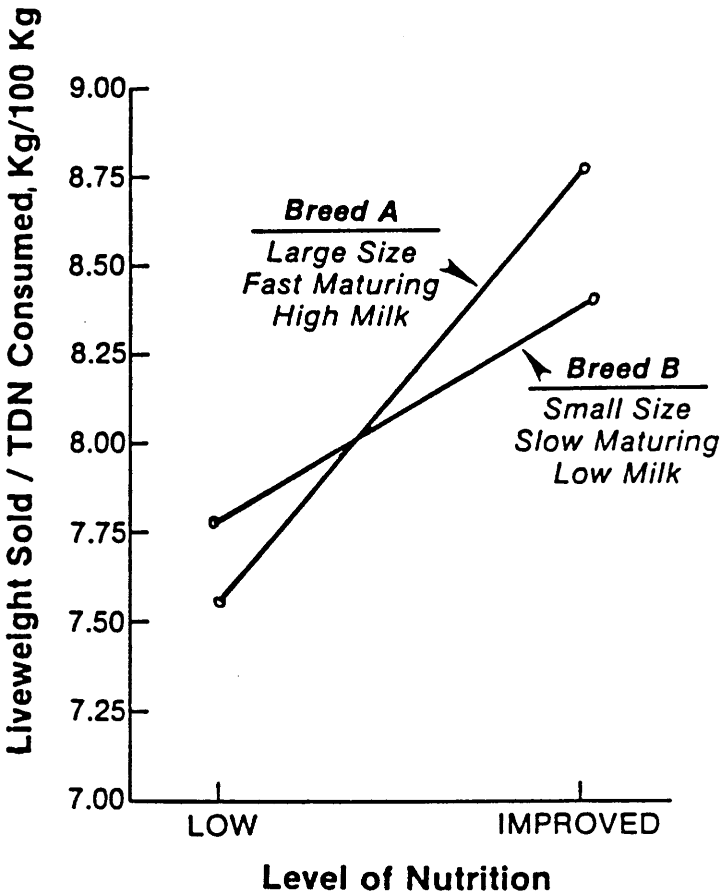


Figure 1. Simulated net herd efficiency, as measured by liveweight offtake per 100 kg of TDN consumed, of two breeds contrasting in genetic potential for three primary characters, simulated as breed A and breed B kept on a generally low quality, seasonally variable range and then again on the same range with modest feed supplement added during the period of lowest quality and lowest production of forage. The data for the simulations were taken from a ranch in the Gulf Coastal Plains area of Texas.

Winter feeding is the problem of most concern for a large portion of Texas producers and I think most other producers. We have examined through our system analysis research the best level of winter hay feeding in several areas. One is northeast Texas where a lot of coastal bermudagrass hay is grown and winter hay feeding is almost universally practiced. Data were taken from experiments at the Texas Agricultural Experiment Station Research Center at Overton (Nelsen et al., 1982). The effects of feeding hay at levels from almost starvation to ad libitum during the winter were simulated. The effects of different winter hay feeding on cow herd production are shown in table 2. The hay quality chosen for study was the low qaulity typically produced in that area; the digestibility of the hay was approximately 55% as fed. Price relationships were compiled for a long term extending from the 1950's through the 1970's. Feeding cows at the level of about 80% of ad libitum (about 18-20 lb/day for a mature cow) was the most economical practice. It is evident from the conception rates and weaning weights that the cows on this pasture resource could not recover sufficiently from a large winter weight loss in order to produce efficienly. An interesting observation was that the herds on lower nutrition required a much larger fraction of heifers as replacments and a larger function of the offtake was cull cows as compared to weaned calves.

TABLE 2. SIMULATED AVERAGE COW HERD PRODUCTION FROM DIFFERENT LEVELS OF WINTER HAY FEEDING[a,b]

| Cow herd performance | Level of hay feeding Unlimited | 80% | 60% | 40% |
|---|---|---|---|---|
| Pregnancy, % | 92 | 88 | 73 | 57 |
| Weaning weight, lb. | 465 | 460 | 435 | 300 |
| Liveweight sold, lb/acre | 364 | 353 | 296 | 179 |

[a]The hay was coastal bermudagrass hay of approximately 50% digestibility; the level of feeding was ad lib or unlimited, 80% of the ad libitum amount, 60% of ad lib and 40% of ad lib.
[b]Taken from Nelsen et al. (1982).

Another study examined efforts of hay quality and management practices in an area of Texas where a lot of hay is grown, but wet weather usually presents a problem during harvest time. Therefore, producers customarily produce mature, low quality hay. We utilized data from the Texas Agricultural Experiment Station at Angleton to simulate the effect on herd productivity of feeding options in this area of mild winters in pasture overseeded with rye grass and fallow cultivated fields seeded to rye grass. The results in table 3 again emphasize the effect of feeding during the winter on total offtake of a herd. We are in the process of completing the economic analysis but I want to make a point here.

TABLE 3. SIMULATED HERD OFFTAKE FROM FOUR WINTER FEEDING PRACTICES[a]

| Winter Feed Supplement | Sale Weight Per Cow[b] |
|---|---|
| Low quality hay 45% Digestibility | 387 lb |
| Low quality hay +2 lb cubes[c] | 420 lb |
| Higher quality hay 55% Digestibility | 417 lb |
| Rye grass pasture[d] | 524 lb |

[a]Source: Texas Agricultural Experiment Station, Angleton.
[b]Sale weight includes weaned calves and cull cows.
[c]Cubes were 75% digestibility and 20% crude protein.
[d]Rye grass varied according to stage of growth, but always exceeded 65% digestibility and 18% crude protein.

The capability now exists for examining or predicting the effects of different management practices on production systems by use of computer simulation models. These types of systems are now being employed with soybeans, cotton, corn and sorghum crops. Beef cattle producers, who have a more complex production system then crop producers, could certainly increase their management efficiency by being able to accurately predict the effect of changing various management practices on an economic as well as production basis. Such a decision support system needs to be available on a current basis - not long after the fact. A producer asks himself many different questions and often is not comfortable with the basis of his answer. Some questions relate to longer term, advance planning. When is the best calving season? How long should the bull be left out? What is the best cross breeding system? What are the best breeds to fit my production resource, management capability, capital resources and market?

Then there are questions that are unique for each year and season; that is, they are reactive to recent events. For example: this has been a dry year, my hay is low quality and short supply; how should I stretch this hay? What will happen to next year's calving percentage if I simply cut the amount fed? Should I buy cubes, how much? Buy hay? Sell cows?

These types of "what if" questions always require experience-based, sound judgement, but the decisions can be aided immensely by examining predicted outcomes, and economics, on a quantitative basis; that is, the fact and figures as best as can be predicted for your specific area and situation. The computer hardward and a good deal of the software to do this presently exists.

One last example to illustrate the planning aspect. A study in a mixed cropping area of Central Texas examined alternative production systems and market time for that farming area. Data from the Texas Agricultural Experiment Station Research Center at McGregor were used to represent this area (Cartwright et al., 1981). Native summer pastures and winter oat grazing are common. Large, medium and small cattle of high, medium and low milk production (9 types) were included as options. Selling calves at weaning, after stocking or after owning them through custom feeding was examined. A ten-year base of economic data was used to establish price relationships. The results of this study (table 4) indicated that eight years out of ten, the system that had the greatest net return was large cattle with low milk production and calves going directly into custom feedlots after weaning. That is, this strategy resulted in the greatest net returns for this area for the time examined.

## Summary

Good management of cow-calf herds requires that the total system be considered as a whole because there are many interacting trade-offs. First, the breeding or genetic potential should be matched with the production conditions, market and resources. Seek the genetic potential for optimal growth, maturing and milking and then concentrate on improving the physical and physiological soundness traits. Generally the better the nutritional environment, the higher the level of genetic potential that is optimal. Be critical of measures of production such as cow herd production efficiency; production measures may not be closely correlated with net return (profit) to your desired base (e.g., returns over total costs: to land; to land and cattle; to land, cattle, labor and management).

TABLE 4. SIMULATED PERFORMANCE OF NINE CATTLE HERDS OF THREE DIFFERENT GENETIC SIZE AND THREE DIFFERENT GENETIC MILK PRODUCTION POTENTIALS FOR A RANCH LOCATED IN CENTRAL TEXAS

| | Genetic potential[b] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Large size | | | Medium size | | | Small size | | |
| Herd performance measures | Heavy milk | Moderate milk | Light milk | Heavy milk | Moderate milk | Light milk | Heavy milk | Moderate milk | Light milk |
| Av. 8-yr old cow wt., lb | 1142 | 1142 | 1144 | 1036 | 1036 | 1039 | 928 | 928 | 930 |
| Av. calving percent | 73.0 | 74.4 | 76.1 | 72.6 | 73.4 | 74.1 | 70.2 | 71.6 | 72.3 |
| Av. 8 mo. wean wt., lb | 538 | 496 | 467 | 501 | 474 | 445 | 476 | 450 | 421 |
| Av. finished wt., lb[c] | 1028 | 1058 | 1080 | 990 | 1001 | 1025 | 915 | 944 | 964 |
| Av. profit per acre, %[d] | 1.84 | 4.39 | 9.70 | 1.03 | 5.49 | 5.35 | -1.33 | 2.85 | 7.01 |

[a]Adapted from Cartwright et al. (1981). These simulated output figures depend on the prevailing production and market and are presented for illustrating differences in net productivity possible for different practices.

[b]These sizes may be characterized by mature cows with 25% body fat: large = 1200 lb, medium = 1100 lb, and small = 1000 lb. These milk potentials may be characterized by the production a well-fed, mature cow at peak day lactation: heavy = 30 lb, moderate = 24 lb, and light = 18 lb.

[c]Feedlot steers; all finished to same grade: "mostly" (60 to 70%) choice.

[d]The years examined were 1972 through 1978, but profit figures for the first year only are presented.

A systemic method of examining the total herd effects of inputs on outputs in needed. This can be approached informally with pencil and paper, but computer programs are being developed and employed that systemtically organize and process production input and output information. These programs will be useful for long term planning of such things as breeding programs and winter feed supplementation in "normal" years. These programs can be even more useful for responding to short term planning such as "emergency" drought measures. There are some programs already available, but during the next two years they will become more common place and more useful. Livestock extension specialists will become expert in their application of programs designed for home micro-computers. Some producers will utilize these programs directly. These computer programs do no more than assist in organizing and using information for making predictions, but they can do it vastly better than pencil and paper. I do not think it will be long before we have available to us current decision support systems to help make long term and short term decisions for each production area. These will not replace the value of experience, good judgement, attention to detail and skilled work, but I hope that they will enhance the personal satisfaction of being a beef cattle production by enhancing the potential for making a profit with cow-calf operations.

## Literature Cited


Baker, J.F. 1982. Evaluation of genotype-environment interactions in beef cattle production systems using a computer simulation model. Ph.D. Dissertation. Texas A & M Univ., College Station.

Cartwright, T.C. 1970. Selection criteria for beef cattle for the future. J. Anim. Sci. 30:706.

Cartwright, T.C., K.W. Stokes, J.W. Stuth, T.C. Nelsen and D.E. Farris. 1981. Evaluation of effect of cow size and milk production on herd productivity in Central Texas. Texas Agric. Exp. Sta. CPR 37.

Cartwright, T.C. 1982. Objectives in beef cattle improvement. Proc. World Congress on Sheep and Beef Cattle Breeding. Vol. II, p. 19. Denmore Press, Palmerston North, N.Z.

Doren, P.E., C.R. Shumway, M.M. Kothmann and T.C. Cartwright. 1984. An economic evaluation of simulated biological production of beef cattle. J. Anim. Sci. (Prepared for submission).

Nelsen, T.C., T.C. Cartwright, A.K. Angirasa and F.M. Rouquette, Jr. 1982. Simulated effects of calving season and winter hay feeding level on cow herd productivity. J. Anim. Sci. 54:29.

Sanders, J.O. and T.C. Cartwright. 1979a. A general cattle production systems model. I. Structure of the model. Agr. Sys. 4:217.

Sanders, J.O. and T.C. Cartwright. 1979b. A general cattle production systems model. II. Procedures used for simulating animal performance. Agr. Sys. 4:289.

# EDUCATOR'S REACTION

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The concept of "Cow Efficiency" is certainly a topic of widespread interest in a cow-calf industry that is struggling to create a profitable economic atmosphere. Cow-calf producers have analyzed critically the four factors that influence profitability; those being:

1. Weaning weight of the calves.

2. Percent of cows weaning calves.

3. Annual cost of maintaining the cow.

4. The price of those calves.

In evaluating the research that's been presented on cow efficiency, it becomes very apparent that one of the most important factors that influences the overall productivity and efficiency of a commercial cow herd is reproductive efficiency.

A recent analysis conducted by Cattle Fax (the marketing organization of the National Cattlemen's Association) outlined various factors that can influence the profitability of a commercial herd. In looking at how those factors impacted on the profitability of a cow herd, no factor had a greater influence than the percent of cows weaning calves. Thus, as we strive to improve growth rate in the cattle industry and to make the commercial cow more efficient from the standpoint of utilizing nutrients, we must insure that we do not deviate from the goal of maintaining an optimum level of reproductive efficiency.

The recent research being done on modeling and a systems approach to cow productivity and cow efficiency is generating helpful answers while identifying where additional research is still needed.

In conclusion, the economic climate of the commerical beef cow industry is prime for evaluating efficiency. Hopefully, the end result will be a productive, profitable cow for the entire cattle industry.

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# EDUCATOR'S REACTION

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Cattlemen have a strong desire for common goals and common selection criteria for their cattle; however, given the diverse conditions in which we raise cattle, a common goal (outside of net profit) is not realistic. We should not be alarmed that variable definitions of "the profitable cow" are emerging. There always have been and always will be numerous pathways to profit.

Cattlemen are essentially risk managers who merchandise feed and forage resources through their cattle. The primary resource is not the cattle, but is the feed and forage.

In most situations, there is a tendency to concentrate our effort on "changing" the genetics of the cattle as the fastest route to increase net profit; however, on many farms and ranches, the first limiting factor to improved economic efficiency may not be cattle genetics at all. Recommendations regarding "changing" cattle genetics should only be made after a thorough review of the resources and environment in which the cattle are expected to produce.

Beef production systems that stray far from the economically available feedstuffs best suited to their home farm or ranch will do so at substantial risk. It makes more sense to fit the cattle to the economically available feedstuffs than to manufacture feed to fit the needs of a type of cattle you may happen to like. The most economical feedstuff may be native grass, improved grass species or even corn silage in some situations.

With respect to the "glamour" topics of cow size and milk, it appears that optimum milk production is quite sensitive to subtle changes in cost inputs; i.e., the optimum level of milk is affected by the price ratio of cow herd feed to feedlot feed. Beyond the need for sufficient size to meet market weight criteria and to suit climatic adaptability, the impact of cow size on economic efficiency is very small. Cattle genetics cannot be changed fast enough in response to these volatile changes in costs, prices and environment. Thus, in my opinion, "flexibiity" in cattle genetics will be a key component of many future production systems. Genetically flexible cows would respond to a good rainfall year with more milk, but in a dry year would have a high rebreeding rate. Genetically flexible cows would have sufficient body fat to survive a hard winter, yet would produce progeny of acceptable carcass merit. It would seem unlikely that genetically flexible cattle would be extreme in any one production trait since an extreme in one trait often results in an important trade-off or sacrifice in another trait.

Certainly, preferred carcass specifications are important and provide a production target for producers. However, all carcasses sell at some price, and if carcasses that fail to meet the ideal carcass specifications can be produced at

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relatively lower costs than the ideal carcass, then they may be more profitably produced by some cattlemen, even though they sell for a lower price per pound.

The beef industry desperately needs to continue efforts to identify the biological components of economic efficiency within various environments and merchandising strategies. Some generalizations can be made regarding profitable production systems, but many of the important aspects of economic efficiency cannot be generalized. Therefore, some form of systems analysis specific to a given operation will be required.

# EDUCATOR'S REACTION

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I appreciate the opportunity to participate in this Beef Cow Efficiency Forum, which could have a significant impact on the future of the industry. This Forum has provided the framework for an excellent exchange of ideas. We've heard 16 scientists supply us with a wealth of research results containing scientific, biologic and economic information. We've heard enough different results that most of us can go home feeling relatively comfortable; i.e., we don't have to sell our cow herd and go out and find smaller cows, larger cows, or even a different breed. Also, depending upon our breed or size biases, we could have found some statistics the past two days to substantiate those biases.

Most of us likely came here hoping to go home with a recipe entitled, "How to Improve Efficiency of Beef Production." But, we heard that E.W. Klosterman said in 1971, "If there was an optimum size in cattle we would have found it by now." I was concerned after the first day's program that the audience may be confused, but the speakers on management systems began pulling things together. I believe that we're at a crossroads and some progressive cattlemen are ready for a change. In fact, the process of directional change already has begun in my opinion.

I will admit that I have told cattlemen that: (1) they needed more milk production in their beef cow herds, (2) their calves should be larger and heavier at weaning, or (3) they should buy a higher performing bull without considering all of the consequences in the total system. Now, it's time to admit that we may have been wrong when giving some of those recommendations if we're to improve efficiency of production. Are you willing to join me in admitting our mistakes of the past? We must drastically slow down, or halt the "speeding train" that implies that heavier, taller or higher ADG is better. For example, look at nearly any breed publication, test station sale catalog or AI sire directory. Martin Jorgensen, well-known Angus breeder from Ideal, South Dakota, stated in 1982 that, "The poultry industry didn't achieve their efficiency of production by selecting for long-legged roosters."

I help coordinate a central bull testing program in Indiana. A Simmental breeder called me the next day after the performance test ended and his first question was, "How tall were my bulls?" He didn't ask about their gain ratio, weight per day of age, or scrotal circumference. The majority of Simmental, Charolais or Maine-Anjou bulls that I've seen do not need additional height or weight for age. Instead, more emphasis needs to be given to structural and breeding soundness, calving ease and disposition.

I'm co-leader of a research study on breeding systems involving Angus, Polled Hereford and Simmental cattle. I arrived at the farm one morning to find a 2-year-old Angus heifer that had major difficulty giving birth to a stillborn,

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purebred Angus calf weighing 110 lb. Two months later, a "22" was used because the cow still was partially paralyzed. That same morning, a thin, 3-year-old Simmental cow had a 102-lb (hard pull) purebred Simmental calf that lived 10 minutes. Our emphasis on increased size and "new" breeds the last 25 years has resulted in greater dystocia in U.S. beef herds. Producers have done what we told them to do; namely, select for more rapid growth and larger size. **WE MUST PLACE MUCH GREATER EMPHASIS ON REPRODUCTION!**

Henry Gardiner, Angus breeder from Ashland, Kansas, told us at the BIF Conference in Atlanta that buyers paid an average of $1,650 for the 10 lightest birth weight bulls in his recent sale as compared to an average of $1,450 for all bulls. No mention was made in the sale catalog or from the auction block calling attention to the fact that those bulls had lighter birth weights than others. So, buyers paid $200 premium for bulls with lighter than average birth weights. In the presentation by Bourdon at this Forum, increased birth weight was negatively related to economic or biological efficiency of the total production system. Ten years ago, G. E. Dickerson recommended an index to give emphasis to rapid early growth but yet select against individuals with heavy birth weights,

$$I = \text{Yearling Weight} - 3.2 \times \text{Birth Weight}.$$

Many cattlemen are frustrated by the various breeds from which to choose, what size cow is best for them and the inconsistencies between the showring and productive efficiency of the total system from conception to consumption. Some cattlemen are in serious financial difficulty. They need our help in use of new technology and methodology to improve efficiency and profit potential.

# PRODUCER/BREEDER REACTION

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"Read not to agree or disagree but to weigh and compare."

Bacon

It is apparent that the beef industry is entering a new era evolving around words such as optimum, systems, inputs and efficiency. It is very critical that in the infancy of this new philosophy that we as seedstock breeders do not draw conclusions too rapidly and that we try to approach research findings unbiasedly, irrespective of conventional wisdom or our personal breed preferences. Following are my reactions as a member of the Beef Cow Efficiency Forum panel.

Growth and efficiency are not as related as once thought. Re-educating the industry that bigger is not necessarily better is one of the current priority challenges.

Feedstuffs used for maintenance of life cycle beef production is estimated at around 71% of total feed consumed. Current research showing differences for maintenance among biological types has to make this area, for increased efficiency potential, of highest priority.

Different production levels and biological types should be matched to compatible environments in the future. It appears that the higher the production level the more intense the management system required. However, this does not say that adequate inventory of lower production animals are not efficient in intense management. It appears that lower production, lower maintenance cattle, may be more versatile than extremely high producing, high maintenance cattle.

Seedstock breeders will be paid in the future for keeping accurate records and offering predictable germ plasm for specific uses and environments, not for simply breeding herds in a direction for maximum growth, milk, height, etc. Merchandising optimal multiple trait germ plasm for maximum net profit within a given environment will be the seedstock breeder's challenge.

It is essential for researchers to attempt within reason to standardize research procedures in regards to a common efficiency definition which should include reproduction and standard end points. A researcher's definition of net merit, appropriate to cattle in different production and market environments would be a logical start.

Efficiency has to be viewed from an operation standpoint and not from a per cow or per steer basis. When looking at inventory, most all costs are fixed to the ranch and not individual cows.

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In conclusion, lowering cost per unit of output seems to be the main key to survival in the beef industry. This means an ever closer look at inputs in the beef system. The beef cow is simply a forage harvesting machine, nothing more. She is a low priority enterprise; lower than the forage she consumes. Thus, simply matching the optimal harvesting machine to the specific operation and having that machine work for the ranch system, not vice versa, is the challenge.

# PRODUCER/BREEDER REACTION

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The Forum has been both great pleasure and pure agony. I appreciate the opportunity to hear and am more than a little awed and amazed by the complexity of the technical research. Also, I am a little more than confused by the apparent contradictions in results or conclusions of capable researchers.

Our family operation started early with commercial cattle. Hereford cattle were added in 1918, and then over 14 other breeds or crosses were added, in an attempt to produce more efficient cattle for our arid range. In these attempts, we have started down some systems roads that are headed in the wrong direction. There has been considerable modification, too many mistakes, and a lot of improvement over the past few years.

Reproduction was found to be essential for the system to have a chance of being efficient (profitable). Our system still needs more options; more cattle with high fertility under range conditions. At present, our best system appears to be our Red Angus x Hereford cross cows bred to Simmental bulls (as terminal cross).

Replacement heifers need to be kept in large numbers. The suggestion that 15% of the weanling heifers are all that is feasible to retain will limit the commercial cattleman's chance for progress and survival. We have saved 15% and we have saved 80% of weaned heifers. The 80% level gives both greater net return annually and has allowed much more progress in producing (finding) the most efficient cows (improved herd fertility and total production).

How much supplemental nutrition is feasible to get more early calves? We believe reproduction has to come first to be a prerequisite to all other measures of efficiency. We need help in the management of the cow herd. We need help in evaluating our options. Supplementing of the range is practiced in hope of a substantial increase in production. But, at what level is the supplementation most likely to be economically efficient?

Some researchers seem to say that cows of all sizes are equally efficient; other researchers indicate small cows bred to larger bulls are more efficient. We seem to be receiving conflicting conclusions. It would be helpful to have the apparent conflicts resolved or explained. We need clearer signals for the industry.

Modeling conclusions are interesting but suspect. We need to have confidence in the builders of the model. Our hope is for clearer signals from the researcher and proven modeling that can be applied to ranch computer systems for improved management.

We do want recipes for success! Researchers, the extension service, and land grant colleges have been very helpful in the past. And, we have come to expect good work. Today, better designed research is needed to clean up the confusion research has generated. The industry does need and expect useable conclusions that will work on the range.

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# SYSTEMS ANALYST'S REACTION

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This conference successfully met its goal of providing state-of-the-art information to serve as the basis for management and genetic decisions to improve beef efficiency. Clearly, there are significant opportunities to change efficiencies of production and maintenance. Just as clearly, we are dealing with complex biological systems with many interacting components.

There are no simple answers to beef efficiency, no single ideals to serve as the standard for the U.S. industry. There is no single ideal cow size or ideal level of milk production; not even a single ideal level of fertility. Instead, performance levels must be matched to cost-effective management practices which will differ across environmental conditions. Thus, there will be different ideal genotypes, different profitable management regimes for different decisions, a systems approach--taking account of all factors involved--is needed.

There are two types of genetic decision makers in the beef industry--commercial producers and seedstock breeders. Both must decide which bulls to mate to which cows. But there are important differences in their breeding objective:

> Commercial Producers--the success or failure of their decisions is determined in the short run (2 to 3 years) when cattle are sold for feeding and slaughter. Commercial cattlemen must be flexible, able to respond quickly to changes in production environment and market requirements.
>
> Seedstock Breeders--the success or failure of their decisions will be determined in the long run (1 to 2 cow generations or 5 to 10 years). Seedstock breeders must anticipate the future needs of commercial producers; they must provide the genetic differences which can be mixed by the commercial producer and matched to his own special requirements. These genetic differences must be predictable. If a producer buys a bull to breed to heifers, predictable calving ease is as important (or more so) than predictable growth rate from a sire used in a terminal cross program.

With increasing emphasis on beef efficiency, there will be more demand for "performance certified" seedstock. Optimal rather than maximal performance will be sought. Seedstock breeders will market predictability rather than color patterns and extremes of frame size.

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# FORUM SUMMARY

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This beef cow efficiency forum held in 1984 at Michigan State University and Colorado State University (and the resulting proceedings) will be recognized in the years ahead as a landmark event. This forum not only provided a compilation of much of the past research on beef cow efficiency but undoubtedly will provide the motivation for an increasing amount of research and education in the future.

It would be appropriate to recognize those who made it happen. Ron Nelson at Michigan State University and Jim Brinks at Colorado State were among those who first visualized the potential of such an event. Harlan Ritchie and Dave Hawkins at Michigan State and Dave Ames at Colorado State did also, and then provided vast amount of work and planning, which resulted in an outstanding event. Congratulations and thanks to them, and to all who made it possible.

The contributors to this forum provided a vast amount of data. Some of it appeared to be contradictory and might be perceived as confusing initially. However, we should recognize that some of the apparent contradictions would likely be explainable if we knew more about the biology of the cow. Then too, the cow does not react the same under all conditions, and different questions were often asked in different research trials.

The approach in this summary will not be to restate and reiterate all of the data presented but rather to provide some perspectives, some stated and some implied, during the forum, and colored in some cases by my personal biases.

Perspective #1: Cow Profit Formula. Any time the matter of cow efficiency becomes overwhelming complex, we should revert to basics, and specifically the basics of what determines profit in the cow-calf operation. The following simple formula tells the whole story:

Profit = weaning weight x percent calf crop x selling price per pound of calf x number of cows - annual cost of the cow-calf operation.

There is nothing else. Any "production" factor, genetic or environmental (including whatever management is imposed), has its influence through one of the items in the above formula.

The formula can be used not only to reduce a complex matter to the essential basic consideration but can also be used by the producer, for example, to evaluate the wisdom (profitability) of changing the genetic makeup of his cows or of changing management procedures. The test is simple: anything done to increase weaning weight must cost less than the value of the additional weight.

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The same can be said o percent calf crop. It has been shown several times during this forum that the imum percent calf crop isn't necessarily the optimum (most profitable) percent ca crop. Similarly, during the period of very low cattle prices in the mid 1970's, it was economically advantageous in many operations dependent on supplemental feeding to produce less than a 90% calf crop (even as low as 80%,or 70%). So we should not remain married to the myth that it is always most profitable to produce the maximum attainable percent calf crop.

And so on with selling price per pound of calf. If a change in the type of calf adversely affects selling price, there may be no net economic advantage, and even an economic disadvantage, even though the weaning weight of the calf is increased.

If weaning weight is increased through larger and/or heavier milking cows, the total economic benefit of a large number of pounds weaned must also more than compensate for fewer cows (calves) possible to carry on the same feed resources.

So until more sophisticated and comprehensive tools (systems analysis computer programs) are available to the producer, he can use this simple formula. It can be useful because in most cases the interested producer has a cow herd and a management system and may be considering only one or two changes which can be appropriately evaluated by the formula to obtain at least a ball park answer.

Perspective #2: Different Ball Game Today. We are in a "new ball game" today in the cow-calf business. Actually it isn't totally new today since it has been with us since 1973. But the cattle industry had grown so accustomed to the "old ball game" that it is difficult to adapt to the "new rules".

The name of the old ball game was maximum production. Almost anything that could be done to increase weaning weight or percent calf crop or pounds of beef produced per acre automatically increased profit because input costs were relatively lo

The name of the game today is optimum (profitable) production. Before weaning weight or percent calf crop is increased through genetic or management change, we should do an economic analysis using the previously discussed formula, or better yet, a more sophisticated computer program when available, to determine if the value of the benefit exceeds cost.

Perspective #3: Biological vs. Economic Efficiency. When research is done on cow efficiency, biological parameters of inputs and outputs must be used. From that point on, however, in research and education we must recognize two things: (1) Biological efficiency does not automatically translate to economic efficiency. In fact, they can be drastically different, partly because there is not uniformity in inputs (the cost of TDN fed to the cow may be drastically different than the cost of TDN fed to cattle in the feedlot) and partly because the economic value of the end product is not considered in many measures of biological efficiency. (2) There is only one kind of efficiency which is important and useful to the producer and of course that is economic efficiency. It is possible for cows differing in type and genetic makeup to be similar in biological efficiency and yet differ as much as $100 to $200 in terms of economic efficiency.

Because of the above, we should not perpetuate the myth that a better environment in terms of availability of forage automatically favors a bigger, heavier milking cow. Remember we are in a different ball game. Considering input costs, including fertilizer, an abundance of forage today may not be cheap.

Perspective #4: Biological Extremes. With 50 or more breeds, tremendous differences are available today in such traits as size, milk production, muscling, and "fleshing ability." It can be rather safely stated that biological extremes are seldom best (most profitable) for the commercial cowman selling calves through normal market channels. On the other hand, biological extremes can often be justified for the seedstock producer. If we have some cattle which are too small (and we do) we can justify some cattle which are "too big," because as these extremes filter down from the seedstock producer to the "national cow herd" there is considerable dilution. If we have cows which produce too little milk (and we do), we have a need for genes for milk production which can be classified as "too high". The same can be said for muscling and other traits. The extremes allow necessary genetic change to occur more rapidly.

The danger comes when the biological extreme is viewed as the industry ideal. This has happened in the past, and may be happening now.

Perspective #5: Need for Industry Goal for Cow Type. Many have stated that we cannot have one ideal cow for the beef cattle industry and that not all cows should be alike. I think everyone would agree. However, is there need for a "national focus," an "industry target" or goal? The industry target could be an average around which the industry could orient. For example, it could be recognized from the outset that specific geographical areas or environments, or specific producers, would "sight" above the target, or below it as appropriate. By the same token, changing economic conditions would dictate some change in the target.

It is stated during the forum that "If you're in a tight, do something even if it's wrong." We would all agree that the beef cattle industry has been in a tight and has been trying to do something. Has it been the right thing? Similarly, the imminent philosopher Yogi Berra stated, "If you don't know where you're going, you're going to end up somewhere else." Does the beef cattle industry know where it is going? Could it end up "somewhere else"?

If the industry target were an average it would likely represent the "middle of the road," with respect to many traits, or it could be a range, in size, for example, or milk production or other traits. An industry target if properly identified and qualified as a national focus and not an ideal might just provide the sense of direction needed during this time of change.

Perspective #6: Help is on the Way. One of the most encouraging and optimistic aspects of this forum was in the presentation of several computer models with sufficient size and power to analyze a total beef industry system. This allows the opportunity to consider a vast number of influencing factors such as genotype, environment as influenced by geographical location, imposed management, market prices and, of course, related costs and returns. Some of the systems analysis models are already very good. They will surely be further improved in the near future. Also, and very importantly, they will be modified and simplified for field use with microcomputers so that they can ultimately be used by or for individual cattlemen. These models will provide useful guidelines relative to projected changes.

We have every reason to believe that because of this form, and future research and applications, it will be possible to make much more meaningful (profitable) judgements about desirable beef cow type than at any time in the past.