Agricultural research: impact on beef cattle

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AGRICULTURE AND HOME ECONOMICS EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology
Ames, Iowa ................................................................. June, 1976
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By Ruth Steyn
Associate Experiment Station Editor
Historic oil painting of Hereford from early 19th century. Introduction of large numbers of Herefords to the United States began in the 1870s. (Courtesy of The American Hereford Association)
When Columbus brought the first cattle to the New World, he could hardly have envisioned the important role they would play in America's history. From the early Spanish-settled ranches of the Southwest, to the vast roundups and cattle drives that we now know only in legend, to the sophisticated practices of modern producers, beef cattle have formed a major segment of American agriculture.

Today, beef cattle are vital to Iowa's integrated crop and livestock production. About one-third of Iowa's farmers keep beef cow herds, producing calves and feeder cattle that are fed out for market by one-quarter of Iowa's farmers. Despite the millions of acres of corn and soybeans in Iowa, some 25-30 percent of the state's farmland is in pasture or forage crops. Without a flourishing cattle industry, these acres would be largely unproductive and useless for food production.

Iowa has all the ingredients for a diversified cattle industry—tremendous feed-grain and roughage supplies to feed cattle for market, sufficient pasture and forage resources to support a large cow herd for production of feeder cattle, slaughtering and processing facilities to prepare beef for consumers, and a location reasonably close to major consumer markets.

But if Iowa is to maintain its position as a leading beef-producing state, continued efforts are needed to improve all aspects of beef production. Future supplies of beef at reasonable consumer prices also depend on increasing the efficiency of beef production. And the oft-voiced criticism that cattle compete with people for limited grain supplies suggests the need for additional research on utilizing the unique ability of cattle and other ruminants to convert many plant materials that people cannot digest into nutritious and palatable meat products.
Scientists at the Iowa Agriculture and Home Economics Experiment Station are working to answer many questions facing today's beef producers and consumers. How to improve the genetic potential of beef cattle? How to increase the reproductive performance of beef cows? How to use Iowa's abundant feed resources most efficiently? How to control cattle growth to produce more lean meat and less fat? How to treat and recycle animal wastes in safe and environmentally sound ways? How to measure meat tenderness and produce tender meat products? How to reduce processing and marketing costs?
Since the domestication of animals during the New Stone Age, farmers have tried to improve the genetic potential of their livestock. Recognition that offspring tend to resemble their parents and other near relatives occurred so early in human history that proverbs expressing this idea are found in the languages of even the most primitive peoples. Early references in biblical, Hindu, and Roman writings give evidence that castration of animals was common and that selection for desired traits was practiced several thousand years ago.

Despite the long history of animal breeding, people did not understand the scientific basis for the genetic improvement of crops or livestock until early in the 20th Century when rediscovery of Mendel's laws paved the way for development of modern theories of population genetics. Application of genetic knowledge to the improvement of livestock was pioneered by Professor Jay Lush at Iowa State University, starting in the 1930s.

Regional Breeding Research

The expense involved in research on cattle breeding prohibits any one experiment station from conducting projects in all areas that could benefit beef producers. Because of this, scientists at the Iowa Experiment Station work with researchers in other north-central states and in the USDA Agricultural Research Service in planning and carrying out a regional research program on beef cattle breeding.

The basic objective of this research is to obtain information that cattle producers can use to maximize genetic improvement in all traits of economic importance. By sharing research results, by carefully pinpointing the most critical research areas, and by spreading out the costs of breeding research among several states, the regional approach permits more rapid accumulation of relevant knowledge than would be possible if each experiment station worked independently.
The various studies conducted as part of the regional program are designed to: (1) determine the traits that contribute to net merit in beef cattle and their relative economic values, (2) develop the most effective methods for evaluating these traits and obtaining estimates of their heritabilities, (3) evaluate the effects and uses of inbreeding and crossbreeding, (4) evaluate the importance of genotype-environment interactions, (5) compare the effectiveness of different breeding and selection procedures for making genetic improvement, (6) determine the mode of inheritance of hereditary defects and develop methods for controlling them in beef cattle.

Results in many phases of the regional program come slowly because of the long generation interval and low reproductive rate of cattle. Experiments often must be continued for several years to obtain any reliable data at all. Results obtained in one project at one experiment station provide only partial answers and generally must be considered and compared with other results to be most useful.

Despite these difficulties, animal scientists have accumulated comparative data on breeding systems and procedures, selection methods, and estimates of genetic response to long-term selection that producers can apply in improving the genetic potential of their cattle.

Crossbreeding Raises Questions

Crossbreeding in commercial hog production became common soon after World War II, but it gained widespread acceptance in the cattle industry only during the past decade. The importation of semen or breeding stock of numerous European breeds, such as the French Charolais, Simmental, Limousin, and Chianani, un-
doubtlessly stimulated interest in crossbreeding. Some of the imported breeds have the potential for rapid growth rate, leanness in the carcass, and extra milk production in cows—traits that could improve productivity and carcass merit in commercial beef enterprises.

Although the potential advantages of crossbreeding are substantial, not just any crossbreeding program will reap profits for producers. The rapid influx of exotic breeds and adoption of crossbreeding brought to the fore many unanswered questions:

**Which breeds should be used as dams and sires?**
**How much benefit comes from using crossbred cows?**
**What value do the newly imported breeds have in U.S. beef enterprises?**
**What effects do management and environment have on the performance of different crossbreeds?**
**Is there any advantage in using some dairy breeding in beef cow herds?**
**Which crossbreeding systems are practical and profitable in different sized herds under various management conditions?**

In recent years, cattle breeders at the Iowa Experiment Station have tried to answer some of these questions relating to crossbreeding. They began evaluating the effects of introducing dairy breeding into an extensive beef production system in 1967. Recently, they undertook another project, which is still in progress, to determine the lifetime production of crossbred cows that differ in the amount and kind of dairy breeding.

*The growth potential, carcass merit, and general performance of various types of crossbred calves are compared with those of straightbreds at McNay Farm.*
Beef-Dairy Crossbreds Show Potential Payoff

In their initial study, Station scientists measured the growth potential, carcass merit, and maternal performance of straightbreds and crossbreds involving two beef breeds (Angus and Hereford) and two dairy breeds (Holstein and Brown Swiss). All 16 possible combinations of single-cross calves from mating the four breeds were produced.

The crossbred calves were compared with straightbreds for growth potential and carcass merit. Only the steers were slaughtered for carcass data. Heifers were grown out after weaning and mated so that the fertility and mothering ability of crossbred heifers could be compared with that of straightbreds.

Scientists found that yearling weights of single-cross calves from matings of dairy bulls on either breed of beef cow averaged 100 pounds higher than straightbred beef calves. Carcass weights for the dairy-beef calves showed a 45-pound advantage over straight beef calves. In general, dairy-beef crosses performed somewhat better than the beef-beef crosses. The extra growth potential of single-cross calves is profitable because the cost of maintaining a cow is nearly the same whether she has a crossbred or straightbred calf at side.

By using dairy-beef cross cows instead of straight beef cows, additional growth potential was obtained in the calves. At a year's age, calves from dairy-beef cows weighed about 43 pounds more than similar calves from straight beef cows. The amount of retail product was decreased slightly, but the quality grade was increased slightly for calves out of dairy-beef cows compared with the same type of calf out of straight beef cows.

The calf-crop percentage for dairy-beef cows averaged about 10 percentage points higher than for straight beef cows, but these results were obtained on young cows only. Other data suggest that the calf-crop percentage for beef cows increases as they age, while for dairy cows, it decreases. What actually happens to the reproductive performance of dairy-beef cows as they age is currently under study by Station scientists.

Crossbreeding generally affects any one trait, such as weaning weight or percentage calf crop, by only a few percentage points. But the cumulative effect of these relatively small changes can amount to a 15-25 percent increase in beef output per cow bred.
Although dairy-beef cows cost somewhat more to maintain than straight beef cows, they probably would be profitable in many Iowa enterprises, especially if real improvement exists in average calf-crop percentage throughout the lifetime of crossbred cows.

**How Much Dairy Breeding?**

In their current research, Station scientists are determining the amount and kind of dairy breeding that will maximize beef production over the life-time of the cow. The earlier work showed definite advantages to half-beef, half dairy cows in calf crop and calf weaning weight for the first and second calves. Scientists now are studying whether these advantages persist throughout the productive life of crossbred cows and whether different amounts of dairy breeding would be more profitable.

The influence of management system on performance of crossbred cows also will be evaluated more thoroughly in the work now under way. The two management systems under study represent the extremes in possible systems available to Corn Belt beef producers.

In the more conventional spring-calving program, calves are

*An Angus-Holstein cow with her Charolais-sired calf. About half of the advantage of crossbreeding comes from the better reproductive and mothering ability of crossbred cows.*
weaned at about 8 months, wintered, and then put on grass for summer gains before going into the feedlot for a short period. In the fall-calving program, calves are weaned at 45 days (before cows are rebred), placed on full feed soon after weaning, and slaughtered at about 12 months of age.

**Using Imported Breeds**

The bulls used in the current crossbreeding project differ from the original four breeds (Angus, Hereford, Holstein, and Brown Swiss). During the first year, when the majority of crossbred cows were young, breeding was to Shorthorn sires to reduce the incidence of calving difficulty.

But as the original cows become older, they will be bred to some of the larger, newly introduced breeds including Simmental, Maine-Anjou, and Limousin. The three-way cross calves from these matings will be used to evaluate the performance of these new breeds as terminal sires for crossbred cows containing different amounts and kinds of dairy breeding.

When cows are eliminated from the initial phase of this project, replacement heifers coming from the original cows and the newly introduced breeds will be added. Thus, in the later part of the project, scientists will evaluate the performance of the newly introduced breeds as part of a crossbred dam.

**Computer Cow Game**

Scientists at the Iowa Experiment Station helped to develop a novel game that aids students and farmers in applying the principles behind genetic improvement. It's a computer game with a herd of “computer cows.” With no worries about money or chores, players can concentrate on evaluating the records that form the basis of selection in beef cow herds.

A typical computer game starts when each player is given a herd of cows, sires mated to those cows, and the calves from the last (hypothetical) mating. More specifically, players are given the records of these animals for several performance traits such as weaning weight, feedlot gain, yearling weight, and carcass quality. The challenge to players is to select which sires to mate with which cows to produce the next calf crop.
Once players select the parents, the computer takes over and, on the basis of known genetic principles, gives birth to the next calf crop. This sequence is repeated for several cycles, each equivalent to a season in real life livestock production. The smart player should have a demonstrably better crop of “computer calves” at the end than at the beginning, even if he can’t market them.

**Controlled Breeding**

Iowa Experiment Station scientists are pursuing several lines of research aimed at improving fertility in beef cattle. Much of this research deals with the intricacies of reproductive physiology and the hormonal, physiological, and behavioral mechanisms involved in the estrous cycle, pregnancy, and lactation. As scientists learn more about the reproductive process in cows, techniques can be developed and applied to control breeding and improve reproductive efficiency.

Synchronizing the estrous cycle of the cows in a herd so they come into heat and ovulate on the same day or within a 2-3 day interval would permit better timing and management of the breeding and subsequent calving season. A fairly uniform calf crop would result from synchronized cows. The similarly aged calves could be managed more effectively and easily during the preweaning and postweaning period. The ability to control when estrus and ovulation occur also would encourage greater use of artificial insemination (AI) in commercial cow herds. To be successful, AI must occur during the brief period when the egg is viable and capable of being fertilized.

An effective synchronization method must induce heat in a large percentage of treated cows within a brief time period and must not significantly reduce the fertility of treated animals below that of untreated ones. Station scientists are testing the use of various hormones and combinations of hormones to regulate the estrous cycle in cows.

Many advances already have been made in this research. In the future, it may be possible to induce ovulation at a predetermined time and then artificially inseminate cows when conditions are optimal for successful fertilization, regardless of whether or not the cow expresses the behavioral symptoms of heat. Application of
These diagrams schematically illustrate changes that occur in the ovaries and relative levels of several hormones during the estrous cycle in cows. By modifying levels of various hormones, scientists are learning how to control when estrus (heat) and ovulation occur and the number of eggs released.

The ovaries of a mature cow contain thousands of "potential eggs." Normally, during each estrous cycle, one egg develops and matures within a fluid-filled cavity, called a Graafian follicle. Ovulation occurs when a Graafian follicle ruptures, releasing the mature egg.

Immediately after ovulation, the follicular cavity and surrounding cells are transformed into a corpus luteum, which increases in weight for several days and secretes a steroid hormone called progesterone. If the egg is fertilized, the corpus luteum persists and continues to produce progesterone, which is necessary for implantation of the fertilized egg in the uterus and the maintenance of pregnancy. If fertilization does not occur, the corpus luteum regresses and the production of progesterone declines. Other follicles then begin to develop, and the cycle repeats itself.

The growth and maturation of follicles within the ovary are stimulated and controlled by follicle-stimulating hormone (FSH) and luteinizing hormone (LH). These hormones are produced in the pituitary gland and released into the circulatory system. The rapid rise in the blood level of LH at the onset of estrus is thought to trigger rupture of the Graafian follicle (ovulation).

Estrogens, released from developing follicles within the ovary, stimulate the female reproductive tract and induce the typical sexual behavior exhibited by cows in heat. The high levels of estrogens in the blood just before estrus also seem to stimulate the release of LH by the pituitary gland.
techniques to synchronize estrous and control breeding in commercial beef enterprises, however, will require sophisticated management of the cow herd.

**Many Eggs Instead of One**

Normally a cow ovulates only one egg at each estrous period and, potentially, bears only one calf. But administration of certain hormones can stimulate multiple ovulation in beef cows.

Research at the Iowa Experiment Station has shown that injection or infusion of follicle-stimulating hormone (FSH) induces development of a limited number of large pre-ovulatory follicles in the ovaries and leads to increased ovulation rates. The number of follicles that develop and the number of eggs released are roughly proportional to the amount of FSH administered. Station scientists currently are studying the effect of another hormone, LH-releasing hormone, on the development and maturation of ovarian follicles and its use as a stimulant of multiple ovulation.

**More Twin Calves in the Future**

An important potential benefit of research on multiple ovulation is boosting the average calf-crop percentage by increasing the incidence of twinning. Natural twinning in beef cattle is rare, occurring in only about 0.5 percent of births. In dairy cattle the incidence of natural twinning is about 3 percent. Because the heritability of multiple births is low, genetic selection and breeding are not likely to increase the incidence of twinning in cattle.

Scientists can induce multiple pregnancies by various hormone treatments, and the feasibility of increasing multiple births has been demonstrated in field trials. In one project conducted at the Oklahoma Experiment Station, beef cows were treated with appropriate hormones and mated. Of the treated cows that conceived during the first post-treatment estrus, 56 percent bore single calves, 23 percent bore twins, and 21 percent bore three or more calves. The calf crop from these cows, taking death losses into account, was 131 percent. Cows that conceived during later estrous periods produced only single calves. The total calf crop weaned from all treated cows was 109 percent, about 30 percentage points above average.
In spite of these promising results, many problems must be solved before twinning becomes commonplace in commercial cow herds. Researchers at the Iowa Experiment Station are trying to fine-tune hormone treatments so that cows consistently produce only two fertile eggs. When three or more eggs are released and fertilized, a cow often aborts all the embryos, or the multiple calves die at birth.

Iowa Station scientists also are studying embryo development and survival rates during early pregnancy in animals carrying multiple embryos. Estrus and conception rates, percentage calf crop, calf survival rate, and calving difficulties will be determined for cows treated to induce multiple births.

**Embryo Transfer**

Experiment Station scientists are combining techniques to synchronize estrus and stimulate multiple ovulation in research on embryo transfer. Embryo transfer can be used to increase production of twins in cattle and also permits greater utilization of maternal breeds with high genetic merit.

The estrous cycle of donor and recipient cows must be synchronized within one day of each other for successful embryo transfer. The donor cow is superovulated by hormone treatment and then mated or artificially inseminated. Scientists surgically remove the embryos 4-7 days later and introduce them into the recipient cow, usually one embryo in each uterine horn.

From their studies on embryo transfer, Station scientists are collecting extensive data on the growth and development of twin calves soon after birth and later on pasture at the Iowa Experiment Station. Scientists are trying to improve the productivity of beef cows by increasing the incidence of twinning.
embryos, the performance of twin calves, and the mothering ability and postpartum reproductive performance of cows with twins. Scientists also are studying the effects of different levels of nutrition and various hormones on embryo development and survival during early pregnancy. This research will provide information on the conditions and management practices necessary for successful twinning in beef cows.

Today, embryo transfer involving surgical procedures is expensive and used primarily as a tool in research on embryo development and multiple pregnancies. Scientists are hopeful, however, that less expensive, nonsurgical techniques can be developed so that commercial producers could use embryo transfer to increase the rate of twinning as well as to obtain superior maternal genotypes in their herds.

Donor cow is prepared for removal of embryos during an embryo transplant experiment. The cow was treated with hormones to stimulate multiple ovulation and then mated. The embryos are surgically removed a few days later and transferred to recipient cows.
Demonstration of stack carrier and spreader at McNay Farm.
The performance of a beef cow is judged by her consistent production of quality calves. If a cow weans an outstanding 600-pound calf one year, but fails to settle and produce a calf the following year, her average annual production is only 300 pounds, substantially below acceptable production levels. Thus, a primary objective in any cow-calf operation is a high calf-crop percentage. One nonproducing cow literally eats up the profit earned from several calves.

Many factors, of course, influence the productivity of a beef cow herd—the genetic potential of the cows, their health and nutrition during pregnancy and lactation, the calving environment, age of the cows, and management.

Maintaining a 12-month calving interval is important to the profitability of a beef cow enterprise. A cow with a calving interval of 14 months in effect loses one-sixth of a production year every time she calves. Keeping the breeding season to no more than 2 months long also produces a calf crop of relatively uniform age and weight. Such calves are easier to manage and have a greater sale value than a group with widely varying weights and ages.

In 1972, Experiment Station scientists began a long-term research project to learn more about how to maximize the reproductive performance and lifetime production of beef cows. The researchers are comparing the performance of fall-born and spring-born calves, evaluating the influence that age of first calving has on lifetime production, and determining the effect of weaning age on a cow's ability to rebreed.

Age of First Calving

Permitting beef cows to produce their first calf at about 2 years of age, instead of the more traditional 3 years, has become an accepted practice in many areas. Further reducing the age of first calving to less than 2 years might increase the lifetime production of beef cows.
Producers attending a field day at McNay Farm learn about research on various aspects of cow-calf management.

In one study at the McNay Memorial Farm, Iowa scientists found that 15 of 22 heifers came into heat and mated at an average age of 9.3 months. The ten heifers that conceived gave birth at an average age of 18.9 months, with only one needing even minor assistance. Birth weights averaged 57 pounds, and the calves gained about 1 pound daily during the first 2 months—values lower than those typical of calves from older cows. Station scientists are evaluating early calving of heifers further before drawing conclusions about the value of this practice.

Pregnancy generally does not hamper future growth and development of well-managed heifers, even if they are quite young. Lactation, however, places several-fold greater demands on the dam than does pregnancy and may adversely affect the subsequent performance of young heifers. Early weaning of calves born to young heifers would alleviate the extra demands of lactation and might make first calving at 11/2 years more practical.

Early Weaning

Although calves ordinarily are weaned at 6-8 months of age, Experiment Station scientists are evaluating early weaning at about 45 days. Early weaning removes the nursing activity, which seems to inhibit the return to estrus. Several years of data from the McNay Farm indicate that cows whose calves are weaned at 45 days return to estrus sooner than cows with calves nursing for longer periods.

So far, the performance of early-weaned calves has compared favorably with that of calves weaned at 90 or 200 days. Daily gains and feed conversion efficiency of calves weaned at 45 days have equaled or exceeded those of calves weaned later.
At first glance, it might seem uneconomical to replace cow's milk with other feeds for calves. But cow's milk does not come free. The total nutrient requirements of a cow-calf herd actually are reduced when calves are weaned early because of the losses involved in converting cow feeds into milk.

Theoretically, the reduction in total nutrient requirements resulting from early weaning should permit a greater number of cows to be carried on a given acreage and increase the number of calves that can be produced on a farm. The feasibility and profitability of early weaning in a particular cow-calf operation, however, depends on several factors, including the price and type of feed available, the quality of management, and the breeding season.

**Fall Calving**

Fall calving, like early weaning, is another departure from standard management practice that Experiment Station scientists are studying. On some farms, fall calving would make it possible to level out the labor demand between cropping and livestock operations. Fall-born calves also are less subject than spring-born calves to heat, insects, and other stresses of the summer environment.

The potential advantages of fall calving are increased when early weaning also is practiced. Early weaning of fall-born calves permits the breeding herd to go through the winter, spring, and summer as dry but gestating cows. Dry cows have less demanding

*Fall-born, early-weaned calves have performed well in tests conducted in southern Iowa.*
nutrient requirements than lactating cows and can utilize low-quality crop residues and other feed sources unsuitable for nursing cows.

Because the kind and source of nutrients required by calves differs markedly from those required by cows, there is little competition between cows and early weaned calves for the available nutrients. Also, the birth-to-market period may be reduced in early weaned calves that are more likely than nursing calves to get all the nutrients that they need and can use to produce maximal liveweight gains.

Station scientists have found that, in general, fall-born, early weaned calves perform as well as calves born in the spring and nursed for 45, 90, or 200 days. The reproductive performance of fall-calving cows whose calves are weaned early also is similar to spring-calving cows with early weaned calves—and significantly better than cows nursing calves for 200 days.

**Feeding the Cow-Calf Herd**

Much of the profit potential for Iowa cow-calf producers comes from using beef to market crops that have limited economic uses—forages grown on land not suited for row crops, crop residues from grain production, and crops grown as part of an erosion-control program.

Although the popular image of Iowa is of endless fields of tall corn, about 25-30 percent of the state’s farmland is in pasture or forage crops. These acres, largely unsuited for row-cropping, could support at least 3 times the present number of beef cows.

Expansion of Iowa’s beef cow herd may seem unlikely given the dismal economics in the cattle industry during the past few years. But in recent years, less than half of the fed-cattle marketings in Iowa have come from Iowa-born calves. About 2 million feeder cattle are shipped into the state each year, at a cost of some $390 million.

A larger cow herd in Iowa, not only would increase the return from pasture and forage lands, but also would help to insure a sufficient supply of feeder cattle to transform the state’s corn crop into marketable beef. In the future, Iowa’s pasture lands also may become increasingly important as a feed source for growing beef
cattle as animals derive a greater share of their feed from roughages and less from grain and protein concentrates.

**Many Forages Available**

Iowa beef producers may grow various forage crops that differ in productivity, management needs, adaptability, seasonal production, and feeding value. The forages useful in Iowa can be divided into four main groups: cool-season perennial grasses, warm-season perennial grasses, legumes, and annual forages, including corn silage and row-crop residue feeds. Legumes and grasses generally are grown together in mixtures. Most forages grown in Iowa can be harvested for hay or silage, and many also are adapted for grazing.

Forage research at the Iowa Experiment Station includes developing improved cultivars, upgrading the nutritional value of different forages, increasing forage output, and reducing harvesting and handling costs. Scientists also conduct grazing studies to determine the management and environmental extremes that different forages can tolerate and to measure the beef output possible with different forage systems.

Station scientists have developed and released several forage cultivars including "Emerald" crownvetch, "Carroll" birdsfoot trefoil, and "Vantage" reed canarygrass. These and other improved cultivars are higher yielding, more winter-hardy, and easier to establish than earlier cultivars. Efforts currently are under way to develop a rust-resistant and winter-hardy orchardgrass.

**Pasture Improvement**

The predominant forage species in Iowa's unimproved pastures is Kentucky bluegrass. These stands, occupying about 2½ million acres, generally are thin and weedy, and yields are low. Iowa scientists have found that nearly all unimproved bluegrass pastures respond to added nitrogen and phosphorus, which thicken stands and increase yields. In one study, Station scientists almost doubled beef output on bluegrass pastures in southern Iowa by annual applications of 60 pounds of nitrogen and small amounts of phosphorus per acre.

Even when fertilized, Kentucky bluegrass is less productive than many other forage species adapted to Iowa. The tall grasses—
Seasonal Productivity of Forages in Iowa

- **Forage Growth Pattern**
- **Suggested Grazing Period**

### Cool-season perennial grasses
- Kentucky bluegrass
- Smooth bromegrass
- Orchardgrass
- Reed canarygrass
- Tall fescue

### Warm-season perennial grasses
- Big bluestem
- Switchgrass
- Indiangrass

### Legumes
- Birdsfoot trefoil
- Crownvetch
- Alfalfa

### Annual forages
- Hybrid sudangrass
- Sorghum x sudan crosses
- Corn, soybean, and grain sorghum crop residues in the fall.
Pastures can be improved by interseeding a legume crop into the existing sod. This technique reduces the erosion hazards associated with plowing and reseeding pastures on sloping lands.

Smooth bromegrass, orchardgrass, reed canarygrass, and tall fescue—all outyield bluegrass and can be grown alone in long-term pastures. Although the tall grasses require fertilization for high yields, they outproduce fertilized bluegrass pastures by at least 2 to 1.

**Interseeding Saves Money and Soil**

Complete renovation of bluegrass pastures, including plowing and reseeding with more productive species, is expensive and is not practical in some areas because the land is so sloping that plowing would cause serious soil erosion. To get around this problem and reduce the costs of pasture improvement, Station scientists developed a machine that interseeds a legume crop into pastures in a one-pass operation, which destroys only a small portion of the old sod.

Station scientists have obtained satisfactory stands of birdsfoot trefoil, alfalfa, and crownvetch interseeded into bluegrass pastures. The interseeded pastures yielded 2.5-3 times more than unimproved bluegrass pastures and about 1.5 times more than fertilized bluegrass pastures. Because legume crops fix nitrogen from the air, legume-based pastures do not require annual nitrogen applications for high yields.

**Turning Crop Residues Into Beef**

Often treated as wastes, residues left after harvest of corn and other crops can supply a major portion of the beef cow's energy...
needs during the winter when the supply of other feeds is low. Since almost 50 percent of the dry matter in a corn crop is left in the field after grain harvest, a sizable feed resource exists in these “waste” materials.

Experiment Station scientists are studying ways to harvest, store, and feed residues from corn, soybean, and grain sorghum crops. They are determining the nutrient quality of residue feeds harvested in different ways and are working out low-cost, nutritionally adequate rations containing residues and necessary supplements.

The most direct method of harvesting crop residues is by grazing. Experiment Station tests conducted for several years in central Iowa show that in relatively open winters, mature beef cows can efficiently graze cornstalks for 3-4 months with no evident ill effects on subsequent calving and reproductive performance. Under favorable conditions, cows need only a salt-mineral-vitamin A supplement when 2 acres of cornstalks per cow are available.

When cows graze stalks, however, they are very selective and use only a relatively small portion of the available dry matter. Also, if the snow cover is heavy, cows may not be able to get adequate nutrients by grazing. To exploit the maximum feeding value of crop residues and to hedge against adverse weather, reserve feeds must be stockpiled in many areas.

Station scientists are evaluating various harvested residues as winter feeds for beef cows. The harvested residues can be field-

*Crop residues, either grazed or harvested and stockpiled, are important feed resources for Iowa’s beef cow herds.*
stored as stacks or dumps or ensiled in various storage structures. The feeding value of harvested residues varies considerably, depending on the time of harvest, moisture content, nutrient losses, harvesting method, method of storage, and degree of processing.

Supplemental feeding of cows wintered on field or harvested crop residues seems necessary on a nutritional basis. However, responses to supplemental protein and energy, as reflected by differences in weight changes and calf performance, have been inconsistent in numerous trials. Some of the observed variation may stem from environmental differences and from variation in the nutritional quality of residue feeds harvested in different years.

Experiment Station scientists are continuing studies on the effect of protein and energy supplements used in various residue-feeding programs. Their objective is to pinpoint the most economical rations that will assure satisfactory performance of beef cows while utilizing large amounts of Iowa's crop residues.

**Tailoring Feed Supplies to Cow-Calf Needs**

Simply growing more and better grass or harvesting additional crop residues won't benefit producers or consumers. Pasture and forage supplies must be tailored to match livestock needs, both on a yearly basis and from season to season. Overproduction of forages often represents wasted inputs from which producers gain no profit in the form of marketable beef. But inadequate forage supplies lead to poor animal performance and less-than-maximal beef output per acre.
Seasonal Productivity and Grazing: Because the production of different forages varies from month to month, a forage program generally must include several species to assure an adequate feed supply throughout the grazing season. The cool-season tall grasses, for example, are rather unproductive during August and September; thus, other types of pasture must be available during this period. In studies at the Shelby-Grundy farm in southern Iowa, Station scientists found that hybrid sudangrass pastures and birdsfoot trefoil-grass pastures are promising alternatives that can support good animal growth from mid-July to mid-September.

The seasonal production of the tall grasses is influenced considerably by the timing of nitrogen fertilization. Normally, these grasses produce about 70 percent of their total annual yield during May, June, and July. But, if nitrogen is applied around Aug. 1, more than 50 percent of the total growth occurs in September-November, according to Experiment Station tests. This spurt of fall growth, which can provide needed fall grazing, is greatest for reed canary-grass and tall fescue.

Because grazing often is the cheapest way to feed beef cows, it usually pays to provide as long a grazing season as possible. Station scientists have found that proper grazing management, timing of fertilization, and use of several forage crops can lengthen the grazing season in Iowa. Producers can estimate the amount and type of forages and reserve feeds needed throughout the year from research data on the month-by-month productivity of different forages and the seasonal energy and protein requirements of cows and calves.

New Project Testing Forage Systems: Integrating production and utilization of forages to provide an adequate, but not overly excessive, feed supply is one of the keys to profit in beef-cow enterprises. In a long-term project currently in progress at the McNay Farm in southern Iowa, Station scientists are using data from earlier studies to develop and evaluate several pasture and forage reserve systems. They hope to improve the efficiency of forage utilization in beef production so that a larger portion of the feed can be derived from available forages and crop residues.

Researchers are using computer-assisted analyses to help identify forage systems that seem to optimize either net income or beef production per unit of time or land area. The selected systems will
be field-tested by grazing growing beef cattle during a 6-month grazing season.

The yield, botanical composition, chemical composition, and persistence of the pastures, as well as animal performance and grazing efficiency, will be measured. Later, Iowa scientists also will study several combinations of pasture and forage reserve systems designed to provide year-around feed supplies for either growing stock or mature beef cows.

Year-around feed supplies can be developed for Iowa cow herds from several combinations of grazed and harvested forages.
FEEDING CATTLE FOR MARKET

Beef cattle and other ruminants have a remarkable two-stage digestive process that enables them to use many coarse, fibrous materials as energy sources and to transform low-quality proteins or nonprotein nitrogen (NPN) into proteins with high biological value.

Within the rumen, the first compartment of the ruminant digestive system, billions of microorganisms ferment or break down cellulose and other complex carbohydrates into volatile fatty acids. These are absorbed by the animal and provide energy for animal growth and maintenance.

Rumen microorganisms also break down proteins releasing ammonia and other simple compounds. Some of the ammonia, volatile fatty acids, and chemical fragments are used to form microbial cell matter, including protein. This material passes into the abomasum (true stomach) and intestine where the microbial protein is digested and absorbed by the animal in the form of amino acids.

Many of the peculiarities of cattle nutrition stem from the interaction between the animal and its rumen microorganisms. Differences in the feeding value of rations, although assessed in terms of animal performance, may be caused by differences in the extent to which rumen microorganisms attack and degrade various feedstuffs. Changes in the rumen environment caused by ingestion of various compounds may enhance or reduce microbial activity and indirectly influence animal performance. Some responses of cattle to changes in their diet result from shifts in the numbers, kinds, and activity of rumen microorganisms.

Improving Grain Utilization

Corn is the most common energy source in Iowa cattle-feeding rations. Corn grain usually is processed to increase its palatability and digestibility or to improve its storage properties and physical mixing qualities. Because improvements in the efficiency of utiliz-
tion resulting from processing can produce significant economic savings. Experiment Station scientists have conducted numerous studies comparing the average daily gain and feed efficiency of cattle fed corn processed in different ways. Roasting, cracking, artificial drying, refrigeration, and ensiling under various conditions are among the processing methods evaluated.

Recently, Station scientists measured the effects of three ensiling methods and three types of heat treatments on the fermentation of corn within the rumen. In these studies, rumen fluid was removed from a cow and incubated with corn samples processed by the different methods.

The total dry matter, carbohydrates, nitrogen compounds, and volatile fatty acids were determined before and after incubation. In general, ensiling increased ruminal utilization of both carbohydrates and nitrogen compounds compared with heat treatments. These studies help to explain the relative performance of animals fed grain processed by different methods and also provide guidelines for designing more extensive feeding experiments.

**High-Moisture Corn**

Corn stored in conventional grain bins without aeration rapidly deteriorates if the moisture content is much above about 15 percent. But corn often is harvested at higher moisture levels

Samples of rumen fluid are removed through a permanent opening and incubated with corn processed in different ways. This is a relatively simple method of testing the effect of processing treatments on the digestibility of feedstuffs.
because of the weather or other considerations. For many years, drying with artificially heated air has been the most common method of preparing corn grain for storage.

Systems for storing high-moisture corn directly, without prior drying, would eliminate the need for costly drying equipment and fuel and usually would permit more rapid harvesting. Tests conducted at the Allee Experimental Farm from 1968 to 1972 showed that high-moisture corn, when properly ensiled, has a feeding value equal or superior to grain handled by the conventional method of drying before storage. In these trials, animals fed high-moisture corn required about 9 percent less feed per pound of gain than those fed regular, dried corn.

High-moisture corn also can be preserved by treatment with proprionic acid or ammonium isobutyrate. Chemically preserved high-moisture corn can be stored in conventional grain bins and does not require ensiling. Station scientists have found that yearling steers gain as rapidly and as efficiently on chemically preserved high-moisture corn as on dried corn.

Dry-matter losses during handling, processing, and storage are considerably less with chemically preserved corn than with dried corn. Thus, the overall system efficiency (pounds grain dry matter going into storage/liveweight gains produced) favored the chemically preserved corn by 10 percent compared with dried corn.

**Sorghum Grain—Alternative Energy Source for Iowa Cattle?**

Inadequate moisture during the cropping season often limits corn yields in the western third of Iowa. Sorghum is more tolerant of drouth than corn and, in some areas, might be an acceptable alternative that could reduce the risks imposed by unpredictable drouths. In the dry southwestern United States, sorghum has been grown and used as the main grain in livestock rations for many years.

Steers generally gain as rapidly on sorghum as on corn, but require somewhat more feed per pound of gain when fed sorghum. In the past, difficulties in drying and storing sorghum grain have been a serious drawback to its increased use in Iowa. Techniques for safely storing high-moisture corn, if successfully applied to
Applying chemical preservative to high-moisture corn.

sorghum, would eliminate many of the problems encountered in using sorghum grain in Iowa.

Experiment Station scientists recently compared the performance of yearling steers fed high-moisture sorghum grain stored in two types of ensiling structures with the performance of animals fed dried sorghum. They found that average daily gains and feed efficiency were about the same for animals fed high-moisture sorghum.

**Protein Nutrition in Cattle**

Many of the energy-supplying carbohydrates in cattle feeds are broken down and absorbed as volatile fatty acids within the rumen. The fate of ingested protein is somewhat more complicated and depends partly on the ratio of available energy to available nitrogen in the ration.

From 50 to 100 percent of natural protein in a feedstuff may be degraded by rumen microorganisms. The **undegraded** protein passes into the lower digestive tract where it is digested and absorbed by the animal. Ammonia released from **degraded** protein is re-formed by rumen microorganisms into microbial protein, which then passes into the lower digestive tract where it is utilized by the animal.

Because synthesis of proteins requires energy, however, the amount of degraded protein re-formed microbially depends upon the energy available in the ration. Extensive breakdown of feed protein without resynthesis leads to loss of nitrogen as ammonia gas, which the animal cannot use.

The ability of rumen microorganisms to form protein by using ammonia as the source of nitrogen also means that cattle can
Ruminant Digestion

Ration Constituent

Urea

Natural protein

Carbohydrates

CO₂

NH₃

*VFA

Absorbed into bloodstream

Rumen

Synthesis by rumen microbes

Undegraded dietary protein

Microbial protein

Abomasum & Intestine

Metabolizable protein

Animal digestion

Amino acids

Absorbed into bloodstream

*VFA = volatile fatty acids
benefit from nonprotein nitrogen (NPN) in their rations. The most common source of NPN is urea, although several other materials also have been used. In the rumen, urea and other NPN sources are rapidly broken down, releasing ammonia that is then used to form microbial protein.

As with ammonia arising from degradation of natural proteins, utilization of ammonia from urea depends upon the relative amounts of energy and ammonia supplied by the ration. In the absence of sufficient energy, urea may simply overload the rumen with ammonia and be of no benefit to the animal.

Rumen microorganisms can synthesize all the essential amino acids, which animals themselves cannot make. Because of this, ruminant animals often can obtain enough essential amino acids even when the original ration is low in one or more of them. In contrast, diets of nonruminant animals (including humans) must contain adequate amounts of all the essential amino acids because they have no mechanism for making these nutrients from other dietary constituents. The synthetic abilities of rumen microorganisms explain how cattle can transform nonprotein nitrogen and low-quality proteins deficient in the essential amino acids into proteins of high biological value that contain all the essential amino acids needed by people.

**New Protein Evaluation System Developed**

For many years, the value of a feedstuff as a source of protein was evaluated simply on the basis of its total protein content. This system ignored possible differences in the extent of ruminal degradation, reformation of microbial protein, and loss of ammonia. The influence of ration energy level on utilization of dietary protein also was not considered. And the value of NPN sources could not be accurately estimated with the total protein system of evaluation.

Several years ago, scientists at the Iowa Experiment Station began to develop a new system for evaluating feeds that overcomes the deficiencies of the earlier, total protein system. In the new system, a feed is characterized by two important quantities—its metabolizable protein and its urea fermentation potential.

**Metabolizable Protein (MP):** The quantity of protein actually available to the animal in the postruminal digestive tract is called
metabolizable protein. MP consists of feed protein that is not degraded in the rumen and microbial protein that is re-formed from degraded dietary protein. The MP system avoids the assumption that animals benefit from ration protein that undergoes ruminal degradation without resynthesis.

Station scientists have estimated the extent of ruminal degradation of protein for a large number of feedstuffs. They also have determined the maximum amount of degraded protein that can be re-formed into microbial protein and related this to the energy level, as reflected in the total digestible nutrients (TDN), of various feeds. A comparison of total protein and metabolizable protein for several feeds (Table 1) illustrates how great ammonia losses can be when a feed contains only enough energy for limited synthesis of microbial protein.

**Urea Fermentation Potential (UFP):** The second important quantity in the new evaluation system, the urea fermentation potential, is related to the amount of fermentable energy in the feed and the amount of ammonia formed from feed protein degraded in the rumen. A feed with a positive UFP has more fermentable energy than needed to transform the ammonia arising from degraded dietary protein into microbial protein. A feed with a negative UFP has less fermentable energy than needed to transform all the ammonia arising from degraded protein into microbial protein.

The excess fermentable energy in feeds with positive UFP values can be used to transform excess ammonia from urea or negative-UFP feeds into microbial protein. An animal can use dietary urea only when it’s fed a ration having excess fermentable energy; that is, a positive UFP value.

### Table 1 Protein Values and Urea Fermentation Potential for Several Feeds.

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Total Protein (% of DM)</th>
<th>% of Protein Degraded</th>
<th>Metabolizable Protein (% DM)</th>
<th>UFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn grain</td>
<td>10.0</td>
<td>62</td>
<td>7.2</td>
<td>+11.8</td>
</tr>
<tr>
<td>Sorghum grain</td>
<td>12.4</td>
<td>52</td>
<td>9.3</td>
<td>+6.8</td>
</tr>
<tr>
<td>Birdsfoot trefoil</td>
<td>28.0</td>
<td>95</td>
<td>6.3</td>
<td>-67.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>51.5</td>
<td>75</td>
<td>17.1</td>
<td>-107.7</td>
</tr>
</tbody>
</table>
Experiment Station scientists have found in a large number of feeding trials that the MP/UFP system predicts the relative feeding value of different rations quite accurately. They have determined when urea supplementation will improve animal performance, when preformed protein such as soybean meal is preferable, and when supplemental protein really isn't necessary at all in typical feeding programs.

By using the MP/UFP values developed by Station scientists, farmers can formulate economical cattle rations that provide the protein required for satisfactory animal performance with the least possible waste of ingested protein or urea.

**DES Improves Gain and Efficiency**

Iowa Experiment Station scientists first demonstrated the major benefits possible from feeding certain additives to cattle in the mid-1950s. At that time, they discovered that diethylstilbestrol (DES) stimulated liveweight gains and improved feed efficiency of feedlot cattle significantly. Since then, many experiments have been conducted on the use of DES and several other hormone-like compounds in cattle rations.

Scientists believe that DES acts by stimulating the pituitary gland to secrete more growth hormone, which causes the animal to grow faster. Since faster-growing animals generally show better feed utilization, DES also indirectly improves feed efficiency.

In their research, Experiment Station scientists have investigated the relative effectiveness of feeding and implanting DES, the response to various dosages of DES given to cattle of different ages and on different rations, and the effect of DES on carcass quality. These and other studies have shown that DES fed at 10 milligrams per head daily increases average daily gain of feedlot steers by 12-15 percent and reduces the feed required per pound of gain by 10-15 percent.

**New Feed Additive Affects Rumen Microbes**

Recently, Station scientists began testing a new feed additive called Rumensin that is totally different from DES chemically and seems to produce different physiological effects. As its name implies, Rumensin is thought to influence microbial activity within
the rumen so that more usable volatile fatty acids are released from dietary nutrients and made available for absorption by the animal.

So far, research indicates that Rumensin remains within the digestive tract and is not absorbed into the animal's body. Thus, use of Rumensin would involve none of the problems and concerns about tissue residues that have been encountered with some other feed additives, including DES.

In the first feeding trials at the Iowa Station, feed conversion of steer calves and yearling steers was improved 12-13 percent by addition of small amounts of Rumensin to the ration. Daily gains of Rumensin-fed animals were as high or slightly higher than those of control animals. Station scientists also are testing the effect of Rumensin in combination with DES. The combined use of both compounds in initial experiments gave greater benefits than either compound fed alone.

Rumensin is still quite new and only recently was approved for use in general feeding practice. Station scientists are continuing their evaluations of Rumensin and will obtain data on responses of older cattle and on the carcass quality of Rumensin-fed cattle.

Feeding Crop and Livestock Wastes

Greater use of crop residues and livestock excreta in cattle rations could lessen the demand for high-priced concentrate feeds and alleviate potential pollution problems associated with livestock feeding operations. During the past few years, Experiment

In tests at the Iowa Experiment Station, cattle have performed well on various rations containing excreta and crop residues.
Station scientists have determined the nutritional properties of various crop and livestock waste materials and evaluated several systems for incorporating these feed resources into cattle feeding systems.

Excreta contain considerable nitrogen, phosphorus, potassium, and other essential nutrients, but are not very good energy sources. Crop residues generally are quite low in protein and phosphorus, but contain considerable carbohydrates as potential energy sources. The carbohydrates in crop residues, however, are relatively indigestible unless processed by some method to increase their utilization by animals.

**Excreta Silage:** Station scientists have found that excreta can substitute for urea or soybean meal as a protein supplement in whole-plant corn silage rations for growing-finishing cattle. The excreta were collected from concrete floors in cattle confinement buildings, mixed with corn silage and other ration ingredients, and stored in a silo for a fermentation period. Cattle have consumed the excreta-processed silage well and shown no health problems after consuming it. The odor and appearance of the excreta silage, after a 5-6 week ensiling period, is similar to regular corn silage.

In other feeding experiments, Iowa scientists are comparing excreta-corn stover silage with whole-plant corn silage adequately supplemented. Preliminary results show that, with 3-4 times less soybean meal in the ration, the excreta-stover silage supports nearly the same liveweight gains as whole-plant corn silage.

The economic advantage of feeding excreta-stover silage rather than properly supplemented whole-plant corn silage depends on the relative prices of corn grain and protein supplements. But both types of silage-based rations produce economical gains and require much less corn grain than more conventional feedlot rations.

**Future Developments:** Many problems still must be solved before extensive use of crop and livestock wastes becomes common in cattle-feeding operations. Handling and storage of excreta and bulky crop residues present some difficulties. Problems may occur because of variation in the quality and composition of excreta and crop residues collected by different methods or under different conditions.

Scientists also are seeking new ways to “biologically enhance” stovers, cobs, and excreta to increase their palatability, digestibili-
Animal wastes and crop residues are treated with additives or ensiled in small-scale laboratory silos in an effort to increase their feeding value. Treated materials are incubated with rumen fluid to test the ability of rumen microorganisms to degrade them.

The fermentation that occurs during ensiling is one type of biological enhancement. This might be improved by stimulating the activity of the microorganisms that break down cellulose and other complex materials within a silage mixture. Chemical treatment of normally undigestible materials also might release more nutrients that cattle can use.

For the future, Station scientists envision continuous systems that automatically remove excreta from cattle confinement units and mix it with crop residues and other feed ingredients. The fresh silage would be added to the top of a silo, and the fermented silage (after a 2-3 week transit time from top to bottom) would be unloaded and fed to cattle. In such a system, the silo would serve both as a short-term storage chamber and as a fermentation vat with a rapid turnover of contents.

**Digester Generates Fuel and Feed Supplement**

Some scientists at the Iowa Experiment Station are testing a slightly different approach to reusing crop and livestock wastes. In this approach, animal excreta and corn stover are digested within an enclosed anaerobic digestion unit. The products of this microbial digestion include gases, which can be collected and used
as fuel, and a slurry residue similar to municipal sewage sludge. This residue is rich in nitrogen, potassium, and phosphorus and could be used as a feed supplement or fertilizer.

One advantage of the anaerobic digestion process is that about 95 percent of the nitrogen in the excreta is recovered in the slurry residue. In contrast, 30-40 percent of excreta nitrogen is lost as ammonia during preparation of excreta silage.

Research on anaerobic digestion of excreta began quite recently at the Experiment Station. Scientists have built a pilot-scale digester to study the mechanical, power, and temperature requirements for full-scale units of different capacities. They also will measure nutrient retention more thoroughly, evaluate the solid residue as a feed supplement, determine the fuel-generating capacity of the system, and evaluate the system for pollution control in confinement feeding operations.

Station scientists are using a 100-gallon digester to answer questions about the design, operation, and feasibility of anaerobic digestion of beef manures in Iowa cattle-feeding operations.
Hedging Strategies for Beef Producers

A cattle feeder's job isn't done until he has marketed his animals. But the extreme fluctuations in cattle prices make marketing an uncertain business. When he starts feeding a group of cattle, a producer does not know what prices will be when the animals are sold 6-8 months later and, therefore, whether he will make a profit, incur a loss, or just break even.

One way for producers to reduce this uncertainty is through hedging in the futures market. To take advantage of this opportunity, however, producers need guidelines to follow in making decisions about hedging. Researchers at the Iowa Experiment Station recently developed and evaluated several hedging strategies applicable to typical midwestern feeding systems.

Two criteria were used to assess the various strategies: (1) the expected net return and (2) the risk involved or variability in expected returns over time. By using historical data on cash prices for cattle, future prices, delivery costs, and estimated costs of hedging, the researchers calculated the net returns that producers would have received by following the different strategies to decide whether and when to hedge.

A "routine" strategy of always placing a hedge resulted in average returns considerably lower than those received without any hedging. But the routine hedging strategy markedly reduced the risk or variability in returns from year to year, compared with routinely not hedging. Station researchers also tested three "selective" strategies involving additional information to decide whether and when to hedge. These selective strategies resulted in nearly the same or higher average returns and less variable returns than were obtained when hedging was not used at all.

No single hedging strategy is best in all situations. The guidelines and information developed by Station scientists can help individual feeders choose a strategy or combination of strategies that produce average returns at a level of risk acceptable to them.
Research at the Allee Experimental Farm generally has not supported earlier expectations that cattle would perform markedly better in confinement units than in open feedlots. In one project started in 1970, Station scientists have compared the performance of yearling steers fed (a) in confinement, (b) in outside lots with access to overhead shelter, and (c) in outside lots without any shelter. The "cold" confinement facility used in these studies is an uninsulated building, closed on three sides, with the south side open.

The rate of gain for steers in the confinement unit has about equaled that for similar steers in open lots without shelter on an annual basis. Confinement steers were somewhat more efficient, requiring about 6 percent less feed per pound of gain than animals in open lots. But steers fed in open lots with shelter available have performed better than either confinement steers or open-lot steers without shelter.

The performance of cattle fed in confinement and in open lots is compared in research at the Allee Experimental Farm near Newell.
Problems resulting from wet weather and knee-deep mud are eliminated when cattle are fed in confinement facilities.

Advantages of Confinement

Although feeding in confinement may not pay off in terms of the rate and cost of liveweight gains, there are other advantages to confinement systems. Cattle in confinement generally perform uniformly throughout the year, while the performance of animals in open lots varies considerably, depending on the weather. Cattle in open lots, for example, are likely to make very poor gains during periods of wet, muddy weather, which have little effect on confined animals.

Confinement systems also permit better waste control and offer more possibilities for reusing animal wastes. To meet new pollution-control standards, some producers may have to feed their cattle in confinement units. As mentioned earlier, recycling of manures for use as livestock feed or fertilizer may become an important advantage of confinement systems if the prices of feed and fertilizer continue at high levels.

Confinement systems also eliminate the need for bedding, require less land, and permit greater mechanization of the feeding operation. However, a higher level of management is required for successful operation of confinement facilities than for open-lot systems.

Optimal Design Criteria Lacking: More research is needed on the various factors influencing the performance of confined cattle. The optimal amount of space per animal in confinement units is not known accurately, nor is it known whether this varies with the season. Ventilation within confinement buildings affects both the
life of the building and animal performance, but the information needed to develop optimal ventilation systems is lacking.

The influence of environmental factors on performance of animals in different types of confinement units also is not well documented. As these and other questions are answered, scientists will be able to develop improved designs and operating procedures for confinement facilities and to predict expected cattle performance more accurately than is possible today.

**Waste Management**

A 1000-pound feeder steer produces about 60 pounds or 7.5 gallons of raw manure daily. In a year, this animal would excrete about 11 tons of manure containing 125 pounds of nitrogen, 40 pounds of phosphorous, and 90 pounds of potassium. Little wonder that waste management is a major concern of cattle feeders and a primary consideration in the design and operation of any feedlot, whether an open lot or some type of confinement unit.

For several years, Iowa State researchers have monitored various commercial feedlot systems and their associated waste-handling facilities. Measurements are made of nutrient concentrations in the wastes, runoff water from open lots, total volume of wastes generated, odors, and the operating characteristics of the various systems. This type of information provides guidelines for designing systems with different capacities, estimating the area needed for land disposal, and evaluating possible uses of treated waste materials.

*Livestock wastes from this feedlot run directly into nearby river.*
Oxidation Ditch: Because of the need for more knowledge about techniques to handle, treat, and eventually dispose of cattle wastes, Station scientists are testing three confinement units at the Allee Experimental Farm near Newell. In the first unit, built in 1970, animal wastes drop through a slatted floor into an oval-shaped oxidation ditch. Aerobic bacteria within the oxidation ditch consume and break down a large portion of the organic matter in the manure, forming harmless gases and bacterial cells.

Because aerobic bacteria require plenty of oxygen to survive, a paddle-wheel type of device is used to force air into the liquid manure and to circulate the manure within the ditch. Objectionable odors are reduced to a minimum by aerobic treatment of wastes, one of the major advantages of this system.

Flushing Systems: A second confinement facility was built in 1974 to test and demonstrate two variations of the "flushing floor" principle. In half the building, the solid concrete floor slopes toward two U-shaped flumes or open pipes set 12 feet apart below floor level. Movement of the cattle's feet pushes manure down the sloping floor through slots located over each flume.

A new type of floor, the ISU Multi-Flume Flush Floor, has been installed in the other half of the building. Hollow cores or flumes are embedded within concrete floor sections and extend continuously from end to end. Slots open from the hollow cores up to the floor surface. As manure is deposited, the cattle push it through the slots into the cores below. Three slot spacings (24, 16 and 8 inches) are being tested in the experimental multi-flume unit.

A paddle-wheel unit circulates waste material in oxidation ditch located below slotted floor of confinement building.
The two types of “flushing floor” in the new confinement building at the Allee Farm are shown in this photograph. The solid floor on the left slopes toward two U-shaped flumes. The multi-flume floor on the right has a series of slots opening over hollow cores embedded within the floor sections. Manure pushed into the flumes or cores is flushed into the central ditch, which drains into an anaerobic lagoon.

With both types of flush floor, water flowing through the flumes, under the floor surface, moves the wastes to an anaerobic lagoon located apart from the confinement building. Water for flushing is recycled from the lagoon. Organic matter in the manure is partly decomposed by anaerobic bacteria in the lagoon. Because these bacteria don’t use oxygen, agitation and mixing of the lagoon liquid is not required.

Feeding trials with yearling steers began in the flush-floor building during 1974. The performance of the cattle on the different floors will be of major interest. Scientists also will evaluate periodic versus continuous flushing, effect of cattle density on the movement of manure into the slots, general performance of the flushing system, and the effectiveness of waste treatment in the anaerobic lagoon.

Land Application of Treated Wastes

All systems of manure handling and treatment produce end products that must be used or “disposed of” in some fashion. The excess liquid effluents from a lagoon or oxidation ditch are not safe for discharge into streams or other surface waters. Furthermore, the nutrients within the effluents and solid sludges that accumulate are potentially valuable.

Direct application of manure or lagoon effluents on farmland is
a desirable practice because the nutrients help to build and maintain soil fertility. Manure also improves soil tilth, increases waterholding capacity, lessens wind and water erosion, improves aeration, and promotes the growth of beneficial soil organisms. Excess application of wastes, however, may harm crops, pollute surface and underground waters, and waste nutrients.

From information on the nutrient levels in the end products of various waste-management systems, scientists can develop guidelines for safe application rates. Studies on the influence of waste applications on soil characteristics and plant growth suggest where and when applications are most beneficial. Improved application methods also might reduce the time and labor required for land disposal and increase the benefits derived from waste nutrients.

In tests begun recently at the Allee Farm, Station scientists will determine the value of anaerobic lagoon effluents applied by irrigation equipment to cornfields. Crop responses and soil characteristics will be measured on irrigated plots with and without conventional fertilizer and on unirrigated plots with and without fertilizer.

**Choosing a Cattle Feeding System.**

Although uncovered, open feedlots still are the most common cattle feeding system in Iowa, confinement systems are gaining in popularity. Differences in management ability and the resources available to individual producers, however, make it difficult to pinpoint the best system in every situation. A recent study by Experiment Station researchers provides cattle feeders with useful guidelines for deciding which system would be most profitable and suitable for them.

Labor requirements, investment capital, feed and nonfeed costs, and land required to produce the necessary grain and roughage were analyzed for six types of feed lot facilities at six different capacities. The systems analyzed included open lot with windbreak fence, open lot with overhead shelter, and four cold confinement units that differed primarily in the waste-handling technology used.

The researchers found substantial economies of scale in the various types of facilities examined. The largest cost reductions per
Station scientists are measuring the effect on yields and soil characteristics of irrigating cropland with effluent from the anaerobic lagoon at the Allee Farm.

head occur between 100- and 1000-head lots, with 75 percent of the savings taking place as capacity is increased from 100 to 600 head. Cost reductions per head as lot capacity increases are greatest for labor costs, capital investment, and fixed costs related to feed storage and handling and waste handling. Lot capacity makes relatively little difference in feed costs per unit or other cash costs when similar management is used.

The annual operation costs are about the same for all the systems analyzed. But confinement systems generally require more capital investment than open lots, although they can be operated with less labor. Thus, the relative availability of capital and labor, rather than just overall annual cost, is important in choosing which system to use.

Station scientists currently are carrying out more complex, multiperiod analyses of cattle feeding options available to Iowa producers. The aim is to determine which types of operation maximize total income or terminal net worth with the fewest risks under different conditions of resource availability. These analyses, which cover a 10-year period, will help farmers plan the long-term growth and development of their enterprises.
GROWTH AND DEVELOPMENT

It often is stated that beef cattle are a very inefficient source of human food, with values of 3-5 percent quoted as the efficiency of converting crude feed protein and energy into edible beef products. What is overlooked in these calculations is that a major portion of the feed consumed by cattle consists of various plant materials— forages, nonfood grains, and by-products—that people can’t or won’t eat.

If one considers only that portion of beef cattle feed that humans could consume directly, it takes about 2 pounds of available feed protein to produce 1 pound of available product protein, a 50-percent conversion efficiency, with current production practices. In addition to high-quality protein that provides all the essential amino acids, meat and dairy products supply considerable calcium, phosphorus, iron, and vitamins.

During the past 10-15 years, however, grain and high-protein concentrates consumed per head of beef cattle increased substantially. This increased rate of concentrate feeding was accompanied by a 10-percent decrease in beef output per feed unit consumed, partly because cattle were placed on concentrate rations at lower weights and fed to heavier weights and higher slaughter grades than was previously common.

The trend toward more concentrate feeding in beef production resulted largely from the availability of quite cheap grains and high demand for beef. But higher prices for grains and protein concentrates in comparison with market prices for beef have led to a reassessment and partial reversal of this trend during the past few years. A return to greater use of forages and other feedstuffs that nonruminants cannot use makes sense in a period of high demand and prices for concentrate feeds.

As described in earlier sections, scientists at the Iowa Experiment Station are developing and testing many practices that would reduce the competition between people and cattle for grains and plant proteins that both can utilize.
Station scientists also are trying to understand the underlying physiological and biochemical processes involved in cattle growth and development. These efforts, focused on the growth of muscle (the major constituent of meat) and on fat metabolism, eventually may pave the way for increasing the efficiency of cattle in converting feedstuffs into nutritious products for human consumption.

**Growth of Muscle Before Birth**

Prenatal muscle growth occurs by an increase in the number of embryonic muscle cells (myoblasts), which eventually fuse together to form multinucleated cells or myotubes. As the myotubes acquire specialized contractile proteins, they develop into mature muscle fibers. Unlike most other body cells, multinucleated muscle cells do not divide after fusion occurs. Although the number of nuclei in a muscle cell may increase through additional fusion, this does not cause an increase in the total number of muscle cells.

Most evidence suggests that myoblast fusion ceases about the time of birth in domestic animals. A young calf contains nearly all the skeletal muscle cells that it will ever have, and growth of skeletal muscle after birth primarily occurs through enlargement of existing cells.

*Preparation of muscle samples in experiments on factors regulating the growth and development of muscle cells.*
Studies with cultures of embryonic muscle cells suggest that the number of muscle cells formed during prenatal development is determined by the time at which myoblast fusion begins and the rate at which fusion proceeds. If this process could be regulated so that more myoblasts were present before fusion began, then the newborn calf might have more muscle cells and the potential for increased muscling during its life.

**Growth of Muscle After Birth**

Some myoblasts seem to escape fusion during prenatal development and exist as mononucleated cells, called satellite cells, after birth. It is believed that satellite cells fuse with existing multinucleated muscle cells during postnatal growth, thereby increasing the number of nuclei and eventually the size of muscle cells.

Experiment Station scientists are investigating the role of satellite cells in muscle growth by comparing the relative numbers and activities of satellite cells in animals of different ages and genetic potential to grow. They also are studying the effect of various hormone and dietary treatments on satellite cells.

In earlier studies, Station scientists found a substantial increase in muscle weight, accompanied by a steady increase in the number of nuclei per cell (presumably from fusion of satellite cells), as cattle grew from 250 to 800 pounds. But muscle growth in animals gaining from 800 to 1100 pounds was greatly reduced and resulted largely from an increase in muscle mass per nucleus. Much of the weight gain during this latter period of cattle growth is not in the form of muscle protein, but rather in the form of fat.

These results and other evidence suggest that the main factor limiting muscle growth as cattle reach maturity is the reduction and gradual cessation of satellite cell activity and fusion with existing muscle cells. If the factors regulating satellite cell activity were known, then the period of most active muscle growth might be prolonged, and the feed conversion efficiency of cattle improved.

**Synthesis of Muscle Proteins**

Growth also is influenced by the rate at which proteins accumulate within muscle cells. Station scientists are trying to determine what factors regulate protein synthesis in muscle and are
A counter for measuring radioactivity. Compounds containing low levels of radioactivity are used as "tracers" in studies on the synthesis of muscle proteins and other cell constituents.

comparing the rate of synthesis in heavily muscled, rapidly growing cattle with that in poorly muscled, slowly growing cattle. They also are studying the effects of nutrition, hormones, and animal age on the synthesis of muscle proteins and the relationship between satellite cell activity and protein synthesis in muscle.

Muscle cells that divide, fuse, contract, and behave very much like intact, living muscle can be grown in the laboratory. Station scientists are using these cell cultures to identify control mechanisms that could be manipulated to produce either more cells or more muscle protein. The findings from these cell culture experiments eventually will be applied and tested on whole animals.

Fat Metabolism

Excessive fat deposition in cattle is both undesirable and uneconomic. Most consumers dislike large amounts of fat because of the waste involved, the excess caloric contribution to their diets, and concern about possible health hazards. Synthesis of fat also requires more energy than does synthesis of protein. This is one reason for the decline in feed efficiency in older animals when they begin to accumulate more fat.

Under the present beef-grading system, intramuscular fat or marbling generally increases the economic value of a carcass
because marbling is an important factor in determining federal meat quality grades. But excessive accumulation of back fat, intermuscular fat, and other internal fat deposits reduces meat quality and leads to large fat trim and economic losses. An estimated one-third to one-half billion bushels of corn are wasted every year putting on fat that is later trimmed off beef carcasses.

Experiment Station scientists are trying to determine the physiological factors that regulate the amount and site of fat deposition. In one type of experiment, they use samples of adipose tissue to measure fatty acid synthesis and the influence of specific enzymes, hormones, and dietary treatments on the rate of synthesis. Studies on animals with different genetic ability to accumulate fat also may provide clues about the basic controls of fat synthesis in cattle.

Although the extent of fat accumulation is related to many factors—age, sex, exercise, nutrition, and genetics—the underlying processes are still unclear. Station scientists believe that a greater understanding of lipid metabolism is necessary to devise effective means for reducing wasteful fat accumulation in cattle.

**Animal Fats and Heart Disease**

Another reason for studying lipid metabolism in beef cattle is the possible relationship between animal fats in the diet and heart disease, especially atherosclerosis. More than half of all deaths in the United States each year are due to atherosclerosis, the accumulation of lipids and connective tissue within arteries. If these lesions get large enough, blood flow is reduced, blood clots may form, and a heart attack may occur.

Many factors have been suggested as possible contributors to atherosclerosis—heredity, stress, obesity, smoking, lack of exercise, diet, and increased blood cholesterol. Despite a great deal of research, the relative importance of these factors and their possible interactions are not clearly defined.

Since the late 1960s, scientists at the Iowa Experiment Station have been studying the relationship between fats, cholesterol, and atherosclerosis in ruminants. Calves and goats are good experimental animals for assessing the influence of various factors on the development of atherosclerosis. Information gained in these experi-
ments may help to resolve some of the controversy and uncertainties concerning atherosclerosis in humans.

It is generally thought that saturated fats in the diet lead to higher levels of cholesterol in the blood, which in turn is associated with development of atherosclerosis. These relationships suggest that people should substitute polyunsaturated fats (vegetable oils) for saturated fats (animal fats) in their diets and also reduce their consumption of all fats. Recent studies by Experiment Station scientists and others, however, throw some doubt on the value of drastically changing the ratio of saturated to unsaturated fats in the diet.

The Iowa scientists fed calves reconstituted milk containing either soybean oil (polyunsaturated fat) or beef tallow (saturated fat). In some instances, the calves receiving polyunsaturated fat had greater levels of cholesterol in their blood and tissues than did calves receiving saturated fat.

Because these results were unexpected, Station scientists are conducting similar experiments on other animal species. They hope to clarify the relationships between total fat intake, the ratio of saturated to unsaturated fat in the diet, and cholesterol levels in the blood and tissues.
(Courtesy of National Livestock and Meat Board).
BEEF - THE FINAL PRODUCT

Marbling and Meat Tenderness

For many years, people have considered marbling, the small flecks of fat within lean meat, an indicator of desirable eating quality. Marbling and age (maturity) are important factors in determining USDA quality grades of beef carcasses.

The assumption underlying the use of marbling in grading beef is that marbling somehow relates to those qualities of cooked meat that consumers desire, such as tenderness, juiciness, and flavor. Generally speaking, however, this assumption has not been supported by scientific research.

Numerous studies at the Iowa Experiment Station and elsewhere have shown that carcass marbling scores, based on official USDA standards, are not significantly related to the tenderness of cooked meat. When the method of cooking and final cooking temperature are held constant, the animal's age at slaughter generally causes the biggest differences in meat tenderness, with younger animals typically yielding more tender meat.

Experiment Station scientists recently restudied the question of marbling and meat quality. They used only carcasses from the youngest maturity class (animals 18-24 months old). The carcasses showed slight, modest, and moderately abundant marbling characteristic of good, choice, and prime grades, respectively. Steaks cut from aged wholesale rib portions were broiled to three different internal temperatures and were evaluated by a taste panel. The tenderness of each steak also was determined by mechanical shearforce measurements.

As in earlier studies, the degree of marbling had essentially no influence on the flavor, tenderness, or juiciness of steaks. The internal temperature at doneness, however, significantly affected palatability. All the characteristics—tenderness, juiciness, and flavor—were rated lower as the final internal temperature was increased.
Warner-Bretzler shearing machine measures the amount of mechanical force necessary to cut through a piece of meat. Shearforce and other measurements indicate that marbling is not a reliable indicator of meat tenderness.

Muscle and Meat Tenderness

Because meat is composed largely of muscle, it seems reasonable that variations in meat tenderness would stem largely from differences in the muscle fibers and the changes these undergo during postmortem aging. Scientists at the Iowa Experiment Station are using various techniques to study the detailed architecture of muscle and the process of meat tenderization, which occurs during postmortem aging. These studies could contribute to improved meat processing methods that result in faster, more complete, and more uniform tenderization.

In their early work, Station scientists observed that muscle fibers removed from an animal right after slaughter were relaxed. But after storage for a few hours, excised muscles develop rigor mortis and contract or shorten. If muscle is held rigid or restrained by muscle-bone attachments in the carcass during postmortem storage, its length remains constant, but tension develops and the muscle becomes stiff. Meat eaten during this period, when muscle is shortened or stiff, would seem tough and unpalatable.

As postmortem aging continues, rigor mortis gradually declines, and meat becomes more tender. The storage temperature, manner in which the carcass is suspended, and condition of the animal before slaughter all influence the rate of tenderization.

The increasing tenderness of meat after prolonged storage results partly from relaxation of contracted or tensed muscle fibers. In addition to this, Station scientists discovered that degradation of Z-lines plays an important role in decline of rigor mortis toughness and subsequent tenderization.
Z-lines are normal parts of muscle that appear, under a microscope, as narrow dark bands oriented crosswise to muscle fibers. Serving much like crossbeams, Z-lines probably help to maintain the structural integrity of skeletal muscles.

As muscle is stored for longer and longer periods after death, Z-lines gradually broaden and become amorphous, culminating in fragmentation of myofibrils, the basic contractile elements of muscle fibers. This Z-line degradation and myofibril fragmentation, which are visible under the microscope, parallel the loss of muscle stiffness and increased tenderness.

**Z-line-Degrading Enzyme Discovered**

Because Z-lines are composed of proteins, Station scientists reasoned that Z-line degradation probably was carried out by a proteolytic enzyme, which splits proteins into small units. Despite earlier unsuccessful attempts by others, the Iowa researchers eventually discovered a proteolytic enzyme (CAF) in muscle cells that specifically degrades Z-lines. They have isolated and purified this enzyme and determined many of its properties.

When small amounts of CAF are added to muscle fibers previously treated to remove the enzyme, Z-lines are rapidly degraded. Z-lines are broken down, however, only when calcium is added along with CAF. If no calcium or no CAF is present in muscle fibers, Z-lines remain intact.

After several years of research, Station scientists are convinced that Z-line degradation and the resulting fragmentation of

*Myofibrils isolated from an animal immediately after slaughter still are intact (left). But after aging of the carcass, when Z-lines are degraded, myofibrils fragment during isolation (right). These changes in muscle structure parallel increases in meat tenderness. Both photomicrographs are magnified about 2700 times.*
myofibrils caused by the activity of CAF is very important in postmortem tenderization of meat. They have found good correlations between the extent of myofibril fragmentation, shearforce measurements of raw meat, and taste panel evaluations of tenderness on cooked samples.

During postmortem aging of meat, Station scientists speculate, calcium gradually is released from membranes that normally bind it in living muscle. This free calcium then stimulates CAF to degrade Z-line proteins. This process weakens the structure of muscle and leads to increased meat tenderness.

**Applications to Meat Processing**

Although many questions remain about how meat becomes tender, Station scientists already are trying to apply their new knowledge to improve meat processing methods. For example, because many enzymes work faster at higher temperatures, aging carcasses at temperatures higher than normal might accelerate CAF activity and reduce the time required to produce palatable, tender meat.

To test this idea, beef carcasses were aged for 7 days at 35 degrees or for 1 day at 70 degrees. A taste panel detected a significant increase in the tenderness, but no difference in the flavor or juiciness of steaks cut from beef carcasses aged at the higher temperature.

Station researchers also are assessing whether high-temperature aging leads to increased problems with disease-producing bacteria or spoilage organisms. So far, no problems have been observed, but additional experiments are in progress to evaluate the microbiological and safety aspects of high-temperature aging.

The shorter time required for high-temperature aging probably would reduce storage, refrigeration, and handling costs associated with meat processing. There also is evidence that high-temperature aging smooths out some of the variation in meat tenderness and produces more uniform products.

Another possibility for speeding-up tenderization is to stimulate CAF by injecting calcium either before or just after slaughter or by triggering the release of calcium stored within muscle fibers. Station scientists also have found that CAF is most ac-
Fragmentation of myofibrils during postmortem tenderization can be observed with a light microscope. Station scientists hope to develop an easily measured Fragmentation Index that accurately reflects the tenderness of meat.

tive at a neutral pH (neither alkaline nor acidic). Because the carcass pH gradually becomes more acidic after slaughter, it's possible that CAF activity might be enhanced by controlling the pH. Experiments now are under way to measure the effect of pH on Z-line degradation and postmortem tenderization.

**Grading and Beef Quality**

Grading of beef or other agricultural commodities offers potential benefits to both producers and consumers. For beef producers, an effective grading system provides a means to identify and reward higher-quality products. Also, by establishing certain criteria and standards of quality, a grading system simplifies communication between buyers and sellers.

For consumers, a beef grading system provides a relatively uniform and predictable measure of product quality and helps to assure that they get what they think they are getting. A grading system also permits consumers to send more precise signals to producers about their preferences. People may not be willing or able to buy the highest-priced prime beef, but they still may want somewhat lower-priced grades.

**Problems with Present System:** To achieve these potential benefits, a grading system should be based on quality characteristics that users consider important, these characteristics should be subject to objective measurement, and the cost of implementing the system should not be excessive.

Unfortunately, the present beef grading system really satisfies only the criterion of reasonable cost and provides only a crude indication of those attributes that determine consumer satisfaction.
The recent changes in the grading system, which stimulated so much controversy during the past year or so, do not improve the system significantly.

**Improving Beef Grading:** No one denies that beef varies tremendously in eating quality. Some of the observed variation is due to cooking—a good cook can make a big difference, and a poor one can ruin the best piece of meat. But much of the variation is due to intrinsic subcellular differences in meat. The still unanswered question is which external or easily measured carcass characteristics are reliably related to the tenderness, juiciness, and flavor of cooked meat.

Scientists at the Iowa Experiment Station are trying to answer that question. In their research on meat tenderness, scientists are developing new techniques for measuring the tenderness of commercial meat cuts. They are comparing various types of tenderness measurements made on raw meat with the tenderness of cooked products and are trying to identify visual measures that relate to tenderness.

In other studies, scientists are trying to pinpoint carcass traits associated with different types of cattle and the proportion of fat to lean meat in the carcass. Results of these various studies could form the basis for a better beef-grading system that reflects the important traits desired by consumers more accurately than does today’s grading system.

**Samples of beefsteak are prepared for evaluation by members of a taste panel. To be useful, physical or chemical methods for measuring the tenderness, flavor, and juiciness of meat must agree fairly well with taste panel evaluations.**
Reducing Off-Flavors in Meat Products

The flavor of meat products deteriorates rather rapidly after cooking because of oxidation of lipids within the meat. Development of off-flavors poses problems particularly when there is a delay between the time of cooking and consumption as in restaurants, institutional food systems, and in the production of frozen, canned, or other processed meat products.

Station scientists are studying the influence of various factors on the rate and extent of lipid oxidation and are testing possible ways of retarding development of off-flavors. The concentration of vitamin E and iron, pH, cooking temperature, and type of meat are among the factors under study.

Techniques have been developed for measuring the end-products of oxidation, including the compounds responsible for off-flavors. These chemical methods of analysis correlate fairly well with taste panel determinations of flavor changes and permit relatively rapid, reliable measurement of off-flavor development.
BEEF PRODUCTION IN THE FUTURE

For thousands of years, livestock have played a beneficial role in human agriculture. At one time a major source of power, livestock today primarily satisfy the human desire and need for high-quality protein in forms that are palatable and desired by many people.

But unlike plants, domestic animals are consumers, not net producers of chemical energy. And in their need for organic nitrogen, animals may compete directly with people for usable sources of nitrogen. In recent years, escalating populations and severe stresses on the world’s food production systems have caused some people to wonder whether we can continue to enjoy the “luxury” of meat and meat products. It is argued that more of the world’s crop production must be used directly for human food rather than for livestock feed if expanding human populations are to be fed.

On an overall basis, beef cattle are about 3-6 times less efficient than other livestock in converting feed energy and protein into edible food. Cattle and other ruminants, however, can utilize many plant materials and nonprotein nitrogen compounds that people, hogs, and poultry cannot digest. Because of this, ruminants can be integrated into agricultural production systems in ways that exploit their unique ability to digest roughages and minimize their consumption of feed resources that people can use directly.

At the same time, although advances in animal production have not kept pace with those for crops during the past several decades, exciting possibilities exist for improving the efficiency of beef production. Scientists at the Iowa Experiment Station don’t expect a “Green Revolution” in the beef industry, but they are looking toward many innovations for the 1980s...

— Increased recycling of animal wastes as livestock feeds and fertilizer or processing wastes to produce fuel.
— Feed additives that enhance ruminal utilization of feed energy and reduce energy losses.
— More productive forages and greater integration of forage production and use.
— Methods for increasing the feeding value of poor-quality roughages, including crop residues and industrial by-products, through chemical or biological treatments.
— Sampling of muscle on live animals and selection to increase meatiness.
— Controlled breeding and other management techniques to improve beef cow fertility.
— More sophisticated use of crossbreeding so that cattle are tailor-made to their specific environments.
— Twinning, made possible by hormonal control of ovulation rates.
— Prolonging the period of most active muscle growth and reducing excessive fat accumulation in mature cattle.
— Processing methods that speed up tenderization and produce beef of more uniform quality.

These and other advances would increase the overall efficiency of converting feedstuffs into edible beef and tend to reduce the competition between cattle and people for feed resources that both can consume directly. Probably the most powerful stimulus to development of more efficient beef production systems is the very squeeze between production costs and beef prices that has plagued producers during the past few years.
THE CHALLENGE AHEAD

The challenges facing U.S. agriculture are many and, to some extent, conflicting. We seek greater farm output and assured food supplies here and abroad...reasonable consumer prices...equitable returns to producers...increased efficiency in the use of nonrenewable resources...nutritious and enjoyable food products...a quality environment.

Internationally, the growing interdependence of world food demand, production, and trade and the urgent need to use limited resources most efficiently have created pressing problems for people throughout the world.

The continuing challenge for the Iowa Agriculture and Home Economics Experiment Station is to provide knowledge that will help the people of Iowa and the nation respond to the changing economic, technological, and political environment of our Third Century.

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