Emerging technologies and concerns in the beef industry[1]

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Abstract

Advances in the disciplines of reproduction, nutrition, genetics, plant science, product quality, and equipment have been applied by the beef industry and have resulted in improved production efficiency and greater quantity and quality of products available to the consumer. The fact that U.S. consumers spend only 11% of their total income to purchase food is testimony to the success of this technology adoption. Consumers are the ultimate benefactors of the application of technology in production, processing, and marketing of beef and all agricultural products. This fact must be considered as a strong argument for public funding for agricultural research. However, the extent of technology adoption across the beef industry, particularly in cow-calf production, is relatively low and must increase if U.S. producers are to remain competitive nationally and internationally. Future production will involve major input from animal, people, and environmental representatives and result in reduced independence of decision making by producers at all links of the production chain. Animal scientists must seize the opportunity to shoulder increased responsibility to ensure that the voice of animal agriculture is heard and remains a strong economic force.

Key Words: Beef Cattle, Animals, People, Environment, Technology

Introduction

Accepting the assignment to discuss technologies that are available and that will be applied by the beef industry has been interesting and thought-provoking. But one is reminded that hindsight is 20-20, and, in the words of Warren Buffett, "The view in the rear-view mirror is always better than through the windshield!" It is not my purpose to cover all aspects of the topic but to attempt to give general examples of certain key areas. For those interested in reviewing more complete documentation of industry progress and date-lines, readers are referred to other papers (Ritchie et al., 1997; Benyshek, 1997). I will also expand this discussion somewhat beyond the assigned topic.

Animals: Review and Prediction

Looking over our shoulder, we see some tremendous advances in the last 30 yr. Trying to rank these advances by importance is difficult, but we must place advances in electronics and engineering at or very near the top. Developmental advances and exploitation in areas such as computer technology and computerized equipment have changed both our professional and personal worlds. Professionally, walk around your laboratory and observe the equipment in use now compared to what was used 25 yr ago. The capabilities and time-saving factors are amazing. Personally, computers have literally touched every part of our lives, not only the home and business computer, but automobiles, home appliances, banking and finances, all manner of business and record keeping; the list is endless.

Reproduction. Thirty years ago scientists in reproduction research were using bioassays to determine tissue hormone concentrations and assays for blood hormone concentrations was only a goal. Now we have assays for tissue and blood concentrations of hormones and metabolites, and receptor technology and assays are part of our capabilities, our basic scientific thinking, and research project design. Additionally, hormone action at the cell and molecular level is being identified. How does this relate to the beef industry? Basic research in areas of hormones, metabolites, digestion, rumen function, muscle growth and physiology, product quality, and plant growth and production will continue to generate new information that will affect animal production and product quality. We must ensure that the basic research "pipeline" remains full so technology development and application continues.

Advances in male and female germ cell preservation and transfer have developed rapidly. Discovery that cryoprotectants such as glycerol could result in successful freezing of semen greatly influenced and facilitated the availability and application of AI in the beef and dairy industry (see review by Foote, 1981). Successful embryo collection and transfer and the advances in embryo technology and manipulation of today are astounding: successful freezing, splitting, culture, production of transgenics, chimeras, and now cloning. Prediction of successes of this magnitude even 20 yr ago would have been questioned. The use of many of these techniques is common in the beef industry, and even cloning is leaving the laboratory and moving into the industry (J. Lipsey, personal communication).

Recent accomplishments summarized by Johnson et al. (1999) indicate separating sperm into those producing male or female offspring has been accomplished. The results have been tested experimentally and commercial development is underway, with the prediction that sex-specified sperm will be available for industry use within 2 yr (Schenk and Seidel, 1999). Production of sex-specified offspring could fit into management systems in which male or female offspring either for replacement females or market males are desired. Breeding of replacement heifers with X-bearing sperm to produce only female calves could reduce the incidence and severity of dystocia, but this alone will probably be a minor market depending on semen price and sire availability. As advances in genetic selection and embryo and semen manipulation continue to develop, adoption in the beef industry will expand. This expansion may, in fact, be a matter of producer survival if plans for expanded industry alliances and possible vertical integration progress. It is only a matter of time until value-based marketing is the standard for the beef industry and superior genetics will be important for obtaining price premiums.

Approximately 90% of beef females are bred by natural service (NAHMS, 1997, 1998a,b) emphasizing the fact that bull, as well as female, fertility is of major importance for successful conception. At the present time, fertility evaluation of the bull is based on the breeding soundness evaluation. This exam evaluates physical soundness of the bull, scrotal circumference, and examination of a semen sample. Coulter (1997) agreed that these three factors are important but maintained that a fourth factor should be added: a measure of the bull's reproductive behavior. Unfortunately, determination of mating behavior is a laborious procedure, but research is needed to determine whether there are measurable blood variables that are correlated with mating behavior and whether they can be used to predict this important factor.

Ax and his coworkers reported discovery of a fertility-associated antigen (**FAA**) that binds to sperm during ejaculation. Tests conducted over a 6-yr period in Texas reported a 19% higher pregnancy rate from FAA-positive bulls than from bulls lacking FAA (Ax et al., 1999). Sprott et al. (2000) reported first-service pregnancy rate in 764 females inseminated with FAA-positive sperm was 65.6% compared to 49.7% ($P < 0.005$) for 386 females inseminated with FAA-negative sperm. Among estrus-synchronized replacement heifers, pregnancy rates for heifers (n = 550) inseminated with FAA-positive sperm were 62% compared to 45.7% ($P < 0.005$) for 315 heifers inseminated with FAA-negative sperm. This finding has important implications for evaluation of bulls for both natural and artificial service. Accurate tests to predict bulls of high or low fertility have the potential of increasing pregnancy rates, and this technology could be applied throughout the cow-calf segment of the industry.

Synchronization of estrus has been studied for many years. Results have been variable and many protocols have been successful in synchronizing estrus, but the resultant conception rates, whether breeding was by AI or natural service, were low. Success rates of early synchronization treatments were low unless the females were expressing estrous cycles (Patterson et al., 2000). This was a major restrictive limitation, and efforts have been directed toward developing protocols that will induce ovulation in estrous, prepuberal, and anestrous females for timed AI and mass mating without detection of estrus. New protocols are available that seem promising in this regard and have been summarized by Geary (1997) and Patterson et al. (2000). Recent studies involving combinations of melengestrol acetate (**MGA**), $PGF_{2\alpha}$, GnRH, and controlled intravaginal releasing device (CIDR) have given positive results in terms of acceptable pregnancy rates, and it seems that timed breeding without detection of estrus is on the horizon. Successful synchronized breeding meeting the requirements of induced ovulation, timed mating, and high fertility would facilitate AI or natural service use of bulls proven to sire offspring with superior carcass, growth, and reproductive traits. Expansion and acceptance of this phase of animal management will depend not only on synchronization and conception results, but also on costs and labor involved.

Production of multiple births in cattle has been a goal of numerous scientists throughout the world; most approaches have involved the use of estrus synchronization, hormonal superovulation, and breeding by natural service or AI. Calves produced have been allowed to suckle their dam, grafted to foster dams, or reared artificially (Bellows and Short, 1972; Bellows et al., 1974). Success rates have been variable, but the most positive treatment protocols have resulted in increased calf production of 30 to 50%, and weaning rates of 120 to 150% have been attained. Recent studies at the U. S. Meat Animal Research Center, Clay Center, NE have demonstrated that selection of females on prior records and for ovulation rate resulted in obtaining a line of cattle that has high twinning rates (Echternkamp et al., 1990; Gregory et al., 1990a,b). Breeding males and females from these lines have been offered for sale to the industry. Acceptance of this technology has been slow, but this research has developed a technology that may prove extremely valuable to animal production when producers are called upon to supply beef to a world population of more than eight billion people by the year 2020.

Watson and Crick's determining the structure of DNA opened a major flurry of research and advances. We are now mapping the human, animal, and plant genomes, and progress is occurring at an ever-increasing rate, leading to breakthroughs unheard of just 10 yr ago. As we look at the area of biotechnology, including genetically modified organisms (**GMO**), we see opportunities for humans to safely predict our ability to produce adequate food supplies for the growing world population even beyond 2050. This is important because demographic predictions generally agree that the world populations will tend to stabilize at about that date. Looking at animal research as a whole, authors of the report on Animal Agriculture and Global Food Supply stated, "Given the remarkable contribution of past scientific achievements to increasing animal productivity, it would be unwise to rule out any possibility" (CAST, 1999). Successful identification of markers associated with specific QTL has been accomplished. Recent advances suggest that markers associated with growth and gain, carcass quality, calf birth weight, and meat tenderness have been identified and marker-assisted animal selections will be used in the near future. Research of this type can have major influence on selection protocols and on traits selected. Expanding of these possibilities, the ability to sort animals into gain and carcass quality groups at birth or into the feedlot may be feasible. If success is forthcoming in this arena, application will be rapid and the impact on the future beef industry will be major.

Product Quality. Major interest has developed in improving the palatability, consistency, and acceptability of beef available to the consumer. Genetic evaluation of animals to gain predictability of tenderness has progressed rapidly and will be on line in the near future. But attempting to reach this desired goal entirely through changing genetics of the basic cow-calf production unit will take time. Unless there is a major change in industry acceptance of AI, progress over a large segment of the beef industry will be based on natural service breeding. Acceptance will depend on availability of bulls, at reasonable prices, that can sire calves with desirable carcass traits. This suggests that it is not wise to consider the genetic approach as the only route to tenderness. Methodology is needed for producing consumer-acceptable beef from animals that are presently available from a wide variety of sources. Numerous techniques have been applied individually or in combination, including tenderizing enzymes or ingredients to enhance enzyme activity, long-time aging of chilled carcasses, short-time aging by elevating the temperature of the carcasses, various muscle separation techniques, and electrical stimulation of the hot carcass, to name only a few.

Electrical stimulation of prerigor carcasses has been studied as a method of processing to improve meat quality. A review by Cross (1979) suggested that electrical stimulation improved tenderness and enhanced lean color and marbling of beef. Solomon et al. (1986) suggested that electrical stimulation of carcasses of young bulls might eliminate toughness and dark-colored lean. Stiffler et al. (1999) reported that electrical stimulation of 656 beef carcasses reduced shear force values by 23% and improved sensory panel ratings by 26%. It is theorized that electrical stimulation 1) reduces muscle pH below 6.0 and prevents cold shortening from occurring, 2) may release lysosomal enzymes that degrade muscle proteins and allow more rapid tenderization, and 3) may favorably change the structure of the muscle bands through physical disturbance so that the muscle filaments are less resistant to chewing. Because use of this technology requires use of high-voltage electrical current (300 to 700 V), operator safety must be ensured. The accompanying dangers have caused reluctance to adopt this procedure in slaughter plants. Studies with low voltage (35 to 150 V) stimulation have been conducted, but results are somewhat inconclusive.

Of the proteolytic systems within skeletal muscle, the major enzyme system involved in meat tenderization is the calpain system. Calpains require calcium for activity, and calcium can be added to meat to activate the system and induce more rapid and extensive tenderization. Koohmaraie et al. (1994) have developed a process whereby calcium chloride (2.2% solution) is injected into meat cuts either pre- or post-rigor, resulting in enhanced tenderness within 24 h postmortem. This process is called calcium-activated tenderization and has been shown to enhance tenderness in tough beef muscle without affecting flavor, color, or microbial count. Consumer response to meat treated with this technology has been positive.

The Hydrodyne process and equipment (review by Solomon, 1998) is designed to tenderize meat by exposing meat cuts to an explosive charge that generates and applies a shock wave. This supersonic, hydrodynamic wave with a targeted pressure front of 68,948 kPa occurs in fractions of a millisecond and is applied to packaged meat suspended in water. The wave passes through objects that are an acoustical match with the water; meat, which is approximately 75% water, is a close acoustical match. Solomon (1998) reported this process performed at 3 d postslaughter improved shear-force values of longissimus, semimembranosus, biceps femoris, and semitendinosus muscles by 5.5, 6.2, 4.1, and 7.2 kg, respectively, and enhanced taste panel tenderness evaluation. Electron microscopy revealed the enhancement of tenderness was due to myofibril fragmentation (Zuckerman and Solomon, 1998).

A recent research study funded by the National Cattleman's Beef Association made an in-depth profile of the individual muscles of the chuck and round of the beef carcass. Tenderness classifications ranged from tender to very tough, indicating that some muscles need some type of processing if consumer acceptability beyond hamburger is to be ensured. Processing such as electrical stimulation, calcium-activated tenderization, or even Hydrodyne treatment may be alternatives that will be adopted by the industry in the future. Because a high percentage of beef animals available for placing in feedlots have no known genetic background for enhanced eating qualities, these technologies may offer an opportunity for enhancement of eating qualities of less tender beef.

Feeding supplemental vitamin E to the animal prior to slaughter prolonged shelf life of meat cuts. Findings suggest feeding 500 IU of vitamin E for 100 d prior to slaughter prolonged color life of fresh meat from 2 to 5 d (Smith et al., 1994). This effect is apparently associated with the antioxidant properties of the alpha-tocopherol molecule.

Electronic evaluation (instrument grading) of carcasses to determine quality and yield grade and also tenderness is a technology goal of numerous research projects. One of these instruments is the BeefCam equipment. Smith (2000) described a study in which this system was used to evaluate 296 steer and heifer carcasses. Of those certified to produce tender beef, 98.6% produced tender steaks as based on the Warner-Bratzler shear force data and consumer sensory panel ratings. This result is encouraging, and equipment of this type has been installed in the new Cargill slaughter plant in High River, Alberta, Canada.

Nutrition. Feeding of cattle, ranging from cow-calf production to feedlots, has made major advances in the last 30 yr by more completely and accurately defining nutrient requirements. More work is being done to reduce the feeding of harvested feeds and for shortening the feeding-to-market time periods. Defining critical nutritional periods for the pregnant cow has led to acceptance of body condition scoring as a useful management tool and defining the last trimester of pregnancy as an important period for building reserves in the pregnant animal and gestating calf that can be utilized postpartum by dam and calf. For units managing on seasonal forage, the period from calving to availability of adequate forage to maintain body weight or result in gains in the lactating dam is another critical nutritional period. Research studies on energy, protein, vitamins, and minerals have progressed rapidly in not only defining nutrient requirements, but also in determining when the various nutrients are needed, leading to *strategic supplementation*. Recent studies have indicated that dietary fat may be an important nutrient for calf thermogenesis and also may increase ovarian activity and rebreeding conception rates in lactating dams, especially first-calf heifers (DeFries et al., 1998; Bellows et al., 1999; Lammoglia et al., 1999).

Feed costs represent from 50 to 75% of the total overhead costs associated with beef production, and improvement in rumen efficiency could result in increased financial return to the beef industry. Genetic manipulation of ruminal microorganisms seems to be a technology that awaits exploitation. Increasing digestion of dietary fiber, altering the rumen fermentation products, or increasing rumen production of such products as conjugated lineolic acid are exciting areas of research that could result in technology applied rapidly by the industry.

A major amount of feedlot nutrition research has been directed toward improving utilization of feedstuffs. Development and feeding of ionophores and antibiotics and the widespread use of these compounds is commonplace in present-day feeding operations. Hormonal implanting of calves on the ranch and in the feedlot is another common practice. These practices have clearly resulted in improved gains and reduced feed costs and reduced animal morbidity and mortality, but use of these compounds is not without controversy. The demands by the European Union for "hormone-free beef" is an example of this concern, but recent developments suggest this may be resolved. Continuing the practice of feeding antibiotics is less than certain. The medical community has concluded that feeding antibiotics to animals is partially responsible for an increase in organism resistance to many of the common antibiotics. This controversy will continue, and unless definitive data are available and accepted by proponents on both sides of the argument, routine antibiotic feeding may be terminated. Use of repartitioning agents that alter the priority for deposition of fat or lean is an area the industry will consider in future feedlot and possibly cow-calf production units. Advances in the additive arena will be highly dependent on governmental policies, FDA attitudes toward clearance, and consumer acceptance.

Feeding of so-called waste material has advanced rapidly. Use of material such as feather meal and poultry by-products as protein sources and soy and peanut hulls as roughage are common throughout the industry. As other metabolizable "wastes" are identified they may be incorporated into the diets of cattle, but effects on gain efficiency, carcass quality, and tissue residues must be evaluated carefully.

Development of new grain varieties with higher nutrient content of protein, starch, and oils (fat) and with higher feeding value is an important and exciting area of research. Many new varieties are now available for commercial use and not only have improved nutrient content, but also have higher yields. Within this class, development of new forage varieties must be considered. Examples of these are the NewHy forage grass, which is a cross between bluebunch wheatgrass and quackgrass. This grass was selected on agronomic traits and yield and on cattle selection preference and has been evaluated (Haferkamp et al., 1995) at Miles City, Montana and Mandan, North Dakota. It was found to be highly productive under a number of management systems. Development of rhizoma perennial peanut as a legumenous forage for use in semitropical regions seems promising (Hammond et al., 1989). New varieties of oil seeds from sunflower and safflower can produce essentially any fatty acid composition desired. Production of high-oil corn raises the possibility that this grain could be altered in similar manners to meet nutrient needs of both humans and livestock. One of the most important goals of the plant breeder would be to develop plants with reduced requirements for mineral fertilizers. Plants have been developed to resist diseases and various pesticides, and reaching the goal of having plants (other than legumes) supply their own supplemental nitrogen would be a major breakthrough in production.

Another potentially important area in the arena of improved plant varieties is that of selecting or developing grains with increased digestibility. The rapid progress in molecular biology, plant cell culture techniques, and gene transfer have resulted in transformation of all major cereals, including corn, rice, wheat, and barley. Barley cultivar has been shown to affect rate of digestion and feedlot performance in cattle (Boss and Bowman, 1996; Surber and Bowman, 1998), and some important feed characteristics seem to be under genetic control. Selection of cultivars that result in positive effects on livestock response traits could potentially result in improved animal gains, meat quality, and greater production efficiency. As new varieties are made available they will be added to the forage or production arsenal of the beef producer.

Within this portion of the discussion one cannot ignore the impact that invasive weeds have and will potentially continue to have on agricultural production. Two invasive, weedy plants receiving major attention are leafy spurge (*Euphorbia esula*) and spotted knapweed (*Centaurea maculosa*). These weeds occupy millions of hectares of range and forest land and the infestation is spreading. Control of leafy spurge has been attempted in many ways, but pesticides, grazing by sheep, and biological control seem reasonably promising. Control of knapweed has been very difficult, but recent advances in use of various beetles for biological control seem more promising. Developing methods of controlling weeds in pastures and on ranges is becoming a critical necessity. Adoption of new, effective treatments and management schemes will be rapid as they become available.

Disease Control and Medicinals. Advances in disease control with new and improved vaccines have resulted in improved production efficiency at all phases of the production cycle. These have reduced animal morbidity and mortality and have resulted in increasing the number of cattle marketed. Improved identification of diseases and parasites and diagnosis for appropriate methods for control are areas that have advanced rapidly. New antibiotics or reformulation of existing ones have been important in control and treating disease, but one must wonder how long these compounds will be available for use in the industry. The veterinary profession is faced, in some instances, with a reduced arsenal of useful drugs. Some products are being removed from the market, and some that are used off-label can potentially lead to unacceptable residues. One of the goals of livestock pharmaceutical production must be the elimination of intramuscular and subcutaneous injections. These have been shown to result in tissue damage and infection at the injection site and have a very negative effect on product quality. A goal of all vaccines being administered orally, nasally, or topically must be given serious consideration. These techniques would be adopted rapidly by all phases of the livestock industry.

Several laboratories have studied the feasibility of electronic monitoring of body temperatures in cattle (Hahn et al., 1990; Lammoglia et al., 1997) and the use of other electronic devices for detection of estrus. These monitors have proven reasonably successful, and as costs for equipment are reduced the possibility of this technology's being adopted for routine monitoring of animals increases.

Advances in human medicine, surgery procedures, and disease diagnosis and control over the last 30 yr have been unprecedented. Heart bypass surgery, angioplasty, joint reconstruction, tumor diagnosis and control, and organ transplant and manipulation are commonplace, as are various techniques for microsurgery. These are only a few of the many examples that could be mentioned. A very encouraging statistic released recently is that the overall death rate from cancer has declined 0.8% yearly since 1990. This decline is attributed to early detection and treatment and to development of new treatments (American Cancer Society, 2000). Diagnosis and slowing of the progression of Alzheimer's Disease have improved, and hope for breakthroughs is more encouraging now than at any time in our history. These are encouraging statistics, but these advances will mean more people to be fed. That can be good as long as we as scientists and the agricultural industry continue to meet the challenge of producing more food of a quality demanded and purchased by the consumer.

Recent studies and reports suggest that animals can be genetically altered and used to produce various medicinal compounds. Some have even suggested we refer to these altered animals as "pharm animals." One of the most interesting and potentially exciting areas of investigation is in the area of conjugated linoleic acid (**CLA**). This compound is an intermediary product of ruminal biohydrogenation and highest concentrations are found in milk and fat products from ruminants consuming forage diets. Growing evidence in animals suggests that CLA has numerous health benefits ranging from reduced incidence of cancer, suppression of growth of existing cancers, normalizing impaired glucose tolerance in diabetic rats, and reduced body fat and increased lean mass in mice. Results of controlled studies in humans are somewhat lacking, but studies in Finland and France suggest an inverse relationship between CLA concentrations and risk of breast cancer in women. Numerous studies have been conducted to determine effects of alteration of the ruminant diet on production of CLA and preliminary results seem promising (for review see Dhiman, 2000). Expansion of this area of research with subsequent positive findings relating to human health could have a marked effect on both production practices and demand for food products from ruminants. We will undoubtedly be hearing much about CLA in the future.

The expanding field of organic food production and herbal remedies must not be ignored as an important area for future production impacts. If consumers develop a negative attitude toward so-called "unnatural" food products, their demand could have an impact on production practices and efficiency. Perception is reality in the minds of many consumers, and we must not forget they are the ones buying our product. This may well be an instance of supplying what they want (at a higher price).

Genetics. This field of research has made major contributions. Crossbred females are now considered the common production base in the cow herd. These females are bred in systematic rotational crossing, terminal sire, or backcrossing breeding programs. Composite breeds are available that take advantage of breed complementarity for a number of economically important traits. The resultant animals may be adapted to a specific environment or meet certain breeding or production objectives. Breeding programs have improved reproductive performance, calf weaning weights, and weight gains and efficiency in feedlot cattle. Introduction of breeds from around the world has had a major effect on expansion of the genetic base of the cow herd. But one must be aware of the potential of reduction of the advantage of the crossbred dam and hybrid vigor in the crossbred calf if one breed becomes dominant. As breeders promote a specific breed for having superior traits of any kind and a breed and certain individuals within a breed become widely used throughout the industry, this possibility becomes uncomfortably close to reality.

Muscular hypertrophy (double muscling) has marked effects on muscle mass in the carcass. Short et al. (1999) evaluated Piedmontese-cross cattle for the G-A transition mutation at the myostatin locus and classified genotypes as having zero, one, or two copies of the mutant allele. They found incremental increases in all carcass traits with the addition of each copy of the allele, indicating that a portion of the genetic control is additive. When basic findings of this kind are applied by the industry, it will allow breeders to more critically plan breeding programs for optimum beef production.

New methodology based on the mixed-model equations of Henderson (1963) has resulted in major advances in estimation of variance and covariance components and prediction of breeding values and EPD. These methods are key to systems for National Cattle Evaluation and have affected genetic improvement and selection programs worldwide (Benyshek, 1997). Use of systems analyses to evaluate tactical and strategic alternatives for use in production has advanced rapidly. We now have relatively complex models such as the Decision Evaluator for the Cattle Industry to evaluate financial and productivity measures for production systems across years, geographical regions, and populations of livestock. Modeling is a dynamic field that integrates fundamental research into livestock production, yielding gains in knowledge and in developing selection and management strategies for low-cost, sustainable systems that produce high-quality animal products. This arena will expand and result in important impacts on production practices in the industry and research project direction.

One of the ancillary areas for genetics is that of developing GMO. Production of GMO, chimera formation, formation of transgenics, and cloning have the potential to markedly affect production of food products from animals and plants. We are presently involved in a major controversy regarding consumer acceptance of food from GMO. Scientists must ensure the safety of GMO and develop and be involved in factual public education schemes because this battle is too important for future food production to be lost to unfounded claims and emotionalism.

Equipment Changes. One only needs to attend a local fair and marvel at the changes in farm machinery. New units are now designed to incorporate latest computer technology, to be more fuel-efficient and safe, and to provide exceptional operator comfort. Costs have escalated such that operators must consider whether they run the machines or the reverse is true. But as new developments occur in machine engineering, improvements will continue to be made. Within this arena, the improvement of highways and transportation, refrigeration, and transportation vehicles can have impacts on national production and distribution and also on supplying international markets. If we are to be serious players in the business of meeting increased demand for animal products on both the national and international scenes, transportation and distribution equipment and schemes must keep pace.

Ultrasound imaging technology has advanced rapidly. Image resolution has been greatly improved and uses have been expanded in reproduction, genetics, and nutrition. Use of ultrasound to determine intramuscular fat, tenderness, and product quality seems promising, and this technology could be adopted rapidly by the industry.

Various schemes for animal identification are available, ear tags being the most popular. Permanent electronic identification of animals from the cow-calf producer through the entire production and marketing chain is a technology that is advancing rapidly. Adoption will depend on price, but market demand by meat processors seems to be a major influencing factor.

As we look at advances in electronic technology, global positioning system (**GPS**) is on line. Recent studies suggest this technology may also have application in animal agriculture such as improving grazing distribution of livestock. Grazing regulations on public lands require protection of riparian areas by reducing or preventing grazing in these areas. It has been suggested that equipping grazing cattle with a device that could deliver an electric shock and having this device coordinated with the tracking of GPS could be used as a means to distribute grazing or to keep animals out of critical habitat areas. Preliminary results of studies in Canada by Markus et al. (1998) and in Montana by Bailey and Welling (1999) indicate this technology with supplement distribution has potential for controlling livestock movement without the use of physical barriers. If this is successful it would be a welcome change away from the requirement of building fences and other barriers. Adoption by individuals attempting to control grazing distribution of their livestock would depend on the cost:benefit ratio and public land grazing policies.

People (Social) Concerns

Technology Adoption Record. Agricultural statistics may not be considered the most interesting subject, but there are often numbers that should be considered. Statistics from surveys by NAHMS (1997, 1998a,b) reveal important information. The summaries represent results obtained from 2,713 producers from 23 states representing 85.7% of beef cows and 77.6% of beef operations in the United States on January 1, 1997. From 1993 through 1996 there were just over 900,000 beef operations in the United States. Size and animal inventory of the survey operations by herd size are summarized in Table 1.

The survey reveals some interesting and potentially disturbing figures. The beef herd was a primary source of income for only 14% of all operations; 81% of all operations maintained some type of records, 79% of which were handwritten ones. As to important information sources, 61% considered veterinarians in this category, compared to 24% for extension service/universities/vocational agriculture instructors, 23% for other producers, 16% for salespersons, and 15% for beef magazines or agricultural journals (Table 2). It is unfortunate the survey did not have a category for the Internet as an information source because it would be of interest to know how widely this source is used, even though producers must be aware that not all Internet information is factual. The survey found that 53 and 48% of animal operations used some form of identification for individual cows and calves, respectively, but on the average 49% used no animal identification (Table 3). Of the operations using identification, methods used were equally divided between plastic ear tags (27%) and hot iron brands (27%). Sixty-four percent of operations reported that male calves were castrated before sale. Forty-nine percent weaned calves on the basis of calf age or weight, 14% weaned calves based on the condition of the cow, and 12% weaned based on tradition. Cow culling was based on age or bad teeth (40%), 24% on pregnancy status, and 18% was based on economics including drought, herd reduction, or market conditions (NAHMS, 1997, 1998a,b).

Fifty-four percent of the operations had no set breeding season. The average length of the breeding season was 110.9 d and did not seem to be affected by the number of cows on an operation. Ninety-four percent of the operations completed their calving over a 5-mo calving period. Special calving locations that allowed increased observation during the calving season were available on only 21% of the operations, and 40% of these were on operations with over 300 cattle. Observation of heifers during the calving season averaged every 6.7 h and observation averaged every 9.6 h for cows; 56% of all operations observed heifers twice or less daily. They reported that 97% of all cows and 83% of heifers calved without assistance and that 11% of assisted calvings were classed as easy pull and 5% as hard pull. It was interesting to note that 61% of all operations allowed heifers to remain in labor for 2 h or less before assistance was given. But when observation frequency was as low as reported, this time limit is probably questionable. Twelve percent of assisted calvings were attended by a veterinarian. Calving season was relatively uniform across location, with 64% of all calves born in February, March, and April (Table 3; NAHMS, 1997, 1998a,b).

Ninety-two percent used only natural service for breeding; 7% used any artificial breeding. Those using natural service averaged 18 cows per yearling bull and 25 cows per mature bull. Breeding soundness examinations were used by 17% of all operations; use was 12% of operators with fewer than 50 cattle and 54% of operators with over 300 cattle. Only 10% of operators used any measure of scrotal circumference, and the greatest frequency of use (42%) occurred in herds with more than 300 cattle. Despite availability of the standardized performance analysis for evaluation of production efficiency of cow-calf operations, only 4% reported using this model and its use did not seem to be affected by herd size (selected values shown in Table 3, NAHMS, 1997, 1998a,b).

Figures regarding use of reproductive technologies were also of interest. Twelve percent had used estrus synchronization, 13% had used AI, 34% used pregnancy testing, 6% used pelvic measurements, 23% used body condition scoring, 40% used semen evaluation, with 58% of the operators reporting use of any of these five technologies (Figure 1). Labor requirement was considered the most critical factor as to why these reproductive management techniques were not used (Table 4).

Accuracy of these statistics can be discussed at great length, but it is apparent that with 54% of the operators having no set breeding season, 49% of the units not using any animal identification, and only 34% of the operators adopting technology as basic as pregnancy testing, we have a long road ahead if we expect major adoption of the reproductive technology we anticipate being available in the new century. The importance of this conclusion must not be minimized because successful reproduction in the cow-calf production unit is basic to the entire beef industry. No matter how one evaluates the new technologies, successful usage will be based on intensive management of animals, records, labor, finances, and facilities if they are to have a positive effect on industry profitability and sustainability, and on product quality. Decision making will require managers that have the technical and managerial ability to make correct evaluation of technology and the ability to accurately predict outcome of their decisions.

Are animal scientists going to recognize or ignore that veterinarians are considered important sources of producer information for both disease- and non-disease-related conditions? We may find we are looking at continued future competitiveness and even survival of the United States beef industry. Ensuring that correct information is being disseminated and that the appropriate technology is adopted by producers is an assignment that must not be considered discipline-dependent. Patterson et al. (2000) point out that products of beef production research and technology are being "exported" and adopted much more rapidly by our international beef production competitors than by beef producers in the United States. This exporting includes semen sales; these authors reported a 19% decline in semen sales in the United States compared to a 74% increase in Brazil. *We must clearly recognize that we are in a highly competitive business nationally and internationally and we must not allow our competitors to become more serious about survival and growth of their beef industry than we are.*

The survey allows two important conclusions. First, technology development does not mean automatic adoption by producers. Technology must be user-friendly and have a low labor requirement if use and application is to be high. Second, successful adoption of technology will probably start with larger operations, and they will benefit at the expense of the smaller, less-intensive and less-organized producers.

The population involved in agricultural production is a minority. In the recent United States census, farming was not listed as an occupation. The reason given was that so few individuals are involved in farming that it did not merit consideration. The number of small farms is decreasing and the number of larger corporate farms is increasing, but not all corporate farms are owned by multinational corporations. Many farms are now family corporations and are incorporated as a method of financial management and good business sense. Corporate mergers, alliances, and vertical integration are all industry components that will, in all probability, continue to grow in the beef industry. This is probably more true as the industry becomes more global in scope. The large production, feeding, slaughter, and marketing companies are going to affect the industry through dictating product quality, production practices, and price. If appropriate technology is not adopted in the beef industry, individuals involved in production agriculture may become an even smaller minority.

We must not overlook the continuing movement of part of the United States population "back to the farm." Families are moving out of the city onto acreages of various sizes formed from subdivided farmland, and it is not uncommon for these families to raise animals such as a horse, a beef animal, a pig, or a sheep. Children from these families are often members of local Future Farmers of America or 4-H clubs, and this movement represents a welcome continuation of our agricultural heritage and base. These families are some of the individuals represented in the NAHMS survey that do not have livestock production as their primary occupation, but have other sources of income from off-farm employment. These individuals must not be overlooked in terms of improved livestock management and production because the meat animals they produce end up in the livestock market system and food chain. What are we doing to help these individuals in terms of breed selection, improved feeding practices, disease prevention and treatment, and environmentally sound and ethical livestock production?

A social concern that must receive high priority is food safety. For example, bovine spongiform encephalopathy and its possible link with Creutzfeldt-Jakob disease in humans resulted in devastation of the cattle industry in Great Britain. Data from the Centers for Disease Control and Prevention (CDC, 2000) reveal some sobering statistics. As of 1997, Great Britain identified over 168,000 cases in 34,000 herds, and in 1993, 1,000 cases were being reported weekly. This outbreak destroyed consumer confidence in the safety of British meat supplies and demand plummeted. It will take years for this damage to be repaired and markets regained. The relationship between Johne's disease and Crohn's disease in humans is an unresolved controversy. Intensive efforts to prevent, control, and eradicate zoonotic diseases from herds in any location must keep high priority.

Outbreaks of food-borne pathogens such as *E. coli* 0157:H7, salmonella, and listeriosis occur repeatedly in this country, and government regulators and the meat industry must be commended for and be vigilant in efforts to keep this under control. Recent approval and use of irradiation technology, steam sterilization of carcasses, the SureBeam electronic pasteurization of hamburger patties, and intensive education and training of workers slaughtering animals or handling meat products have reduced the incidence of these problems. We must continue to add reassurance that the industry is committed to maintaining a safe product. One must recognize that a free press is more than willing to spread information regarding safety and contamination problems encountered by our industry and products.

Animal well-being is an important socio-ethical consideration both nationally and internationally. The beef industry has not received as much adverse publicity as the poultry and swine industry in this regard, but as cow-calf, feeding, and slaughter units become more concentrated and larger this may change. The best way to handle these criticisms is to anticipate problems before they occur. Insisting on adequate cattle handling facilities and equipment that ensure humane treatment and safety for both the animal and operator, adequate disease control, and pain and discomfort prevention must be high priority at all phases and stages of the beef production industry.

Consideration must be given to the changing lifestyle of our consumer. A high percentage of United States homes are single-parent households. Many heads of these households have more than one job and time with their family is limited. The beef industry has responded admirably by efforts to produce products and items that are simple and quick to prepare while maintaining nutrient quality. Television in homes is now considered as necessary as an automobile and is often the main source of entertainment, but it is also the main source of information for many households. Unfortunately, this medium often forgets that it is playing such an important role in the lives of our product consumer. For example, when food safety, animal well-being, or environmental issues are being reported, it seems that it is simpler to shock or frighten the viewer with a 2-min news item than it is to educate them. An industry goal must be to counteract this negative type of message and image by presenting positive, factual information presented in an acceptable manner. This means the industry may well need to hire publicity firms and use their expertise to tell the story and project a positive image.

Looking at the diet habits of the consumer, sales of zero- or low-calorie foods and diet drinks have grown to a multibillion dollar industry. New diets guaranteed to result in weight loss are advertised daily, and sales of books and "fact sheets" expounding the benefits of each regimen sell on every newsstand. This will probably not change and emphasizes the importance of keeping foods from animal products accepted as important and viable food sources in weight-loss programs.

As an industry, we must recognize and address these issues so that consumer perception of our product translates into consumer demand. Because the consumers are the ones with the money to buy our product we must supply them with what they want. That means the product has been produced in an environmentally and ethically acceptable manner and that product safety has been ensured throughout the production system. If we do not do this, we will pay dearly for our decisions in terms of demand and, importantly, governmental regulations.

Agricultural industries and scientists can take pride in the accomplishment that the share of income spent for food in the United States has declined from 24% in 1929 to 11% in 1998 (Putnam, 2000). This is a remarkable accomplishment and leaves 89% of the income available for purchase of other items. Nonagricultural industries, politicians, and consumers need to be constantly reminded of this figure! The consumer is the one benefiting from application of technology and this fact is strong justification for continued public funding of agricultural research.

Environmental (Regulatory) Concerns

We are justifiably concerned about various pressures on our industry because social and environmental concerns and public pressure can lead to regulations that can have important impacts on our industry. Some regulations are good, such as those ensuring public safety, but regulations at both the federal and state level are becoming more stringent and demanding. If public perception and concerns conclude, either correctly or incorrectly, that animal food production is contributing to problems with waste management, degradation of air or surface water quality, contamination of ground water, or degradation of public lands by grazing animals, we can expect those concerns to be reflected in more regulations. These can and will affect profitability at all phases of the production cycle because they often force adoption of technology far removed from profitable livestock production.

One issue being addressed is global warming and how ruminant production of methane may be a contributor. Polley (1997) reviews the implications of increased atmospheric CO_2 on plant growth and production and global warming is a predicted consequence of this atmospheric change. Response to increased CO_2 could lead to changes in chemical composition of plant tissues and to changes in the ecosystem function and species composition of plant communities. Public perception of these problems, whether real or imagined, must be addressed and solutions to negate the impact must be found. If this concern develops into regulations, it becomes almost ludicrous to predict what form they might take.

Considering factors affecting future production, we must look seriously at competition for and availability of our basic production resources, soil and water. This competition may become the deciding factor regarding continued success of animal agriculture and the entire global agricultural system. Future battles, opinions, and regulations of animal production may become moot if we reach a position of having to decide who gets soil and water and who does not. This is not a problem limited to the semi-arid and arid regions of the planet, but concerns all regions. Will the "haves" be able to supply and share with all the "have nots"? In this regard, attainment of accurate, long-range (at least on an annual basis) weather prediction would be a major contribution to all agricultural production. Adoption of this technology would be almost automatic and would result in profound effects on production practices and efficiency. In addition, this could result in major improvements in management of soil and water resources. But what is the stewardship image of beef production? We must realistically and honestly examine that image and clearly demonstrate sincere commitment to justifying an image that is positive.

Environmental regulations such as the Endangered Species Act are destined to impose severe restrictions on beef production. These restrictions can lead to total overaction on the part of environmentalists who have as one of their agendas to stop all grazing of livestock on public lands. The United States Department of Interior is now considering breaching of dams on the Columbia River in efforts to speed the recovery of the wild salmon population. Wolves have been introduced into a number of wilderness areas and the numbers have increased rapidly. Their predation has resulted in reducing elk and deer numbers in Yellowstone National Park (Kay, 1996), and the packs are moving into surrounding states, increasing predation on livestock. Bison in Yellowstone National Park are a reservoir for brucellosis. The danger of brucellosis transmission to domestic livestock, although not proven in the wild, is a very real possibility, and any reasonable plan for control is immediately opposed by environmentalists vocally, physically, or in the courts. The Endangered Species Act is becoming a vehicle for furthering the agendas of various "anti- and rights" movements that have minor concern for endangered species. The voice of agriculture will continue to be heard in these issues only as long as we have lawmakers and regulatory agencies that have an appreciation for agriculture as a basic industry and that it is the industry feeding our population and that decisions made must be based on sound science.

Trade policies negotiated between various governments have major effects on marketing agricultural products. Banning trade with any country we disagree with philosophically is a common diplomatic tool. This activity is strictly political and has been repeatedly shown to have little effect except to prevent producers in the United States from having access to their market. Negotiations for the North American Free Trade Agreement, World Trade Organization, and granting favorable trade status to China are all under control of negotiators that must have major interest in and understanding and awareness of agriculture. We must continually monitor and influence where agriculture will stand in their decisions and the final agreements.

Philosophical Concerns

I believe the relationships in the arenas discussed can be illustrated as shown in Figure 2. The three main players influencing the beef industry are animals, people (social), and environment (regulations). Overlaps are indicated in three areas: the animal/environment interface, the animal/people interface, and the people/environment interface. The fourth interface is that of animal/people/environment, and activity here becomes complex.

Over the last 100 yr, animal scientists have been concerned with various aspects of the animal, the environment, and the animal/environment interface. How could the animal or the environment be manipulated to obtain maximum, efficient production? This manipulation has involved breeding and selection of animals and plants, altering management, supplemental feeding, establishing stocking rates, and developing new water sources, to name a few. This work must continue if we are to keep the pipeline full for development of new technologies. The animal, the people, and the animal/people interface have received much less emphasis in traditional animal science. This has been addressed in husbandry research and looked at rather superficially in companion animal studies. But this relationship has become very important as we consider not only production profitability, but also odor pollution, waste disposal, water pollution, and global warming. Research interest in these areas has grown rapidly since approximately 1980, and is also an active regulatory arena. Finally, how much research activity has traditional animal science conducted on the people, the environment, and the people/environment interface? Unfortunately, very little, and this is responsible for some of the present problems we are now experiencing. This void is being filled by various environmental and advocacy groups and, unfortunately, extremists that spread information often not based on facts on subjects covering the environment, food contamination, and GMO that directly affect our industry by shaping consumer opinions and formulating regulations.

The last interface is that of animals, people, and the environment. This is where we now find ourselves. In this arena, animal production is losing its independence for decision making and is becoming involved in "committee" decisions. The "committee" members represent animals, people, and the environment and committee decisions and resulting actions will be based on majority votes. Where will agriculture and food production stand in this arena? It is difficult to predict, but unless reasonable, knowledgeable people are members of the "committee" and make decisions based on sound science, production agriculture may become a member of an even smaller minority and the United States could even be destined to rely on imports to meet its food needs. I strongly urge those that have the privilege of teaching students that your goal be not to develop their ability for critical thinking -- we have too many that are experts at criticizing -- but to train them to be *rationally thinking problem solvers!* The American Society of Animal Science must seize the opportunity to shoulder increased responsibility at the national and regional levels in charting the course of animal science and production as we produce animal products within the animal, people, and environmental interface.

Implications

Research supplies findings that have positive influence on technology available to the beef industry, but technology development does not automatically result in application. With 900,000 beef cow operations in the United States and 80% of these having fewer than 50 cows, the production base results in diversity in the cow herd and wide variation in product. Targeting small producers to make use of production technology resulting in a commercially acceptable product must be a goal of those supplying and disseminating information. The American beef industry is under close scrutiny nationally and internationally, and our product must be safe, nutritious, healthful, and produced in an ethical and environmentally sustainable manner. Decision makers from producers to regulators must make decisions based on sound science. The American Society of Animal Science must play a major role in supplying sound scientific direction and charting the course of the future beef industry.

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Notes

1. This research was conducted under a cooperative agreement between USDA-ARS and the Montana Agric. Exp. Sta. Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana Agric. Exp. Sta., or the authors and does not imply its approval to the exclusion of other products that may be also suitable. USDA, Agricultural Research Service, Northern Plains Area, is an equal opportunity/affirmative action employer and all agency services are available without discrimination.
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Table 1. United States beef cow operations and herd[a]

Item	Year	
	1993	1996
No. of operations	903,680	900,680
Percentage of operations by herd size		
1–49	80.8	79.8
50–99	11.2	11.9
100–499	7.3	7.7
500 or more	0.7	0.6
Percentage of inventory by herd size		
1–49	32.6	30.8
50–99	19.5	19.5
100–499	35.0	35.7
500 or more	12.9	14.0

[a]National Agricultural Statistics Service data; summarized by NAHMS, 1998a.

Table 2. Percentage of operations by importance of information sources for operating the cow-calf operation[a]

Source	Percentage of operations		
	Not important	Somewhat important	Very important
Extension service/universities/ vocational agric. instructors	32.4	43.5	24.1
Veterinarians	8.2	31.0	60.8
Beef magazines or agricultural journals	30.7	53.9	15.4
Producer associations	58.0	32.2	9.8
Other producers	30.4	46.9	22.7
Salespersons	41.7	42.3	16.0
Consultants	77.5	16.1	6.4
Radio, television, or newspapers	55.5	36.5	8.0

[a]Modified from NAHMS, 1997.

Table 3. General herd management on operations surveyed[a]

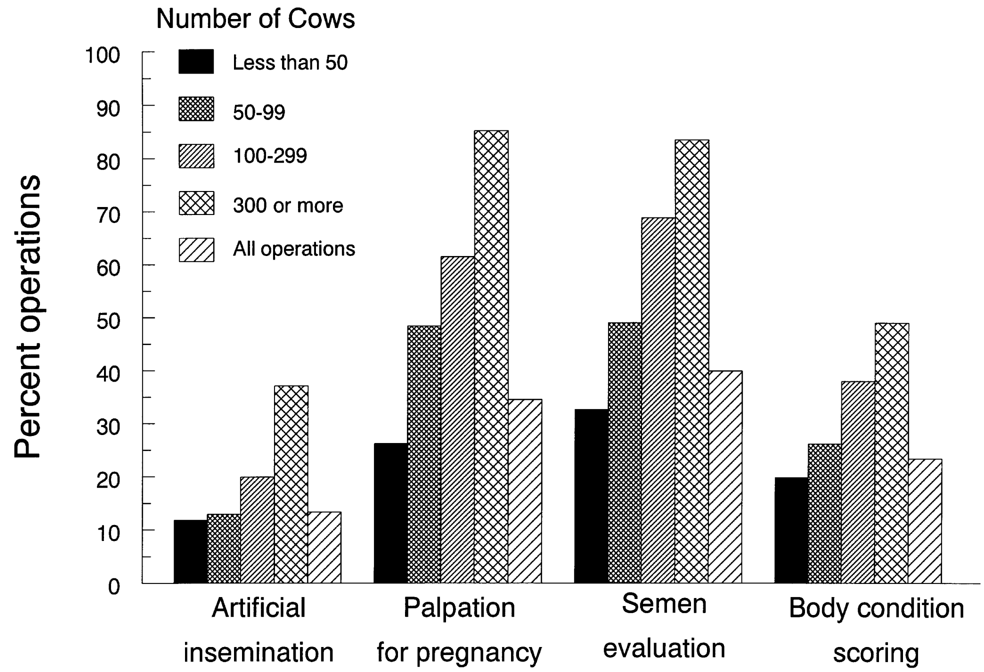
Item	Response % Yes	No
Beef herd - primary income source	14.0	86.0
Maintain some type of records	81.3	18.7
Cow identification	53.2	46.8
Calf identification	48.1	51.9
Male calves castrated prior to sale	64.0	36.0
Cows culled for age	57.8	42.2[e]
Restricted breeding season[b]	46.4	53.6
Calving over 5-mo period[c]	94.1	5.9
Calving area allowing increased observation	21.1	78.9
Heifers calving observed twice or less daily	55.7	44.3
Breeding natural service only	91.9	8.1
Breeding soundness exam of bulls[d]	17.3	82.7

[s]Modified from NAHMS, 1997, 1998a,b.
[b]Represents 35.3% of the beef cows; average breeding season, 110.9 d.
[c]Calving season 90 d or less for 69.8% of operations.
[d]Herds with 300 or more cows reported 53.6% used exam.
[e]Culled for pregnancy status, 25.6%.

Table 4. Reasons (%) for not using reproductive technologies[a]

Reproductive technology	Reasons: Does not work	Labor; time	Lack of facilities	Cost	Too complicated	Other
Estrus synchronization	2.4	36.0	7.8	13.5	19.5	20.8
Artificial insemination	3.0	38.8	7.3	12.5	19.6	18.8
Palpation for pregnancy	0.3	33.9	11.1	18.7	14.4	21.6
Body condition scoring	2.4	32.2	3.9	8.3	22.6	30.6
Semen evaluation	0.5	26.5	6.8	16.8	20.3	29.1

[a]Modified from NAHMS, 1998a,b.



Modified from NAHMS, 1997; technology use tended to be greatest in West and North Central regions.

Figure 1. Adoption of reproductive technology summarized by operation herd size.

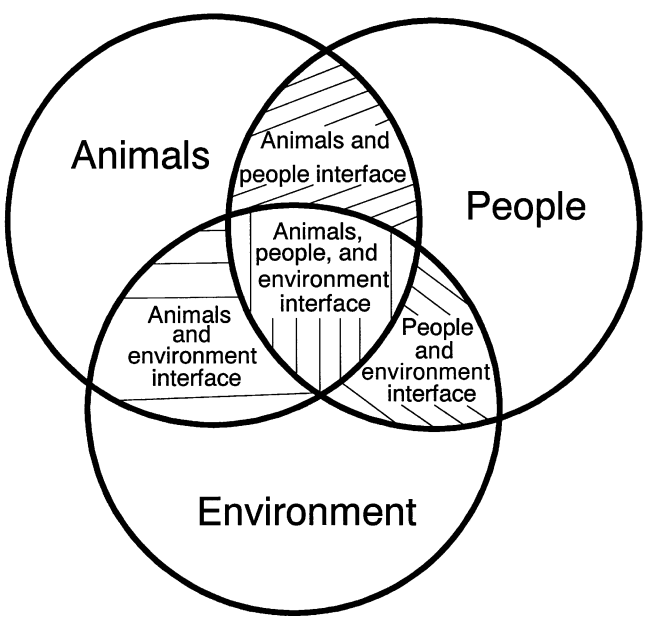


Figure 2. Interrelationships affecting agricultural production and technology adoptions.