PRESERVATION AND MANAGEMENT OF GENETIC RESOURCES: MAINTAINING ADAPTATION AND DIVERSITY

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SUMMARY

The diverse and changing nature of agricultural development favors a dynamic rather than a static approach to animal genetic resources management. Ecosystems differ widely and are constantly evolving in production and marketing environments in response to climatic, economic, technological, social and political factors. Animal genetic resources to provide for long-term requirements may be most effectively assured by more efficient use of these resources to meet near-term requirements. Much of the concern about providing genetic diversity to meet long-term requirements may arise from failure to establish short-term breeding goals appropriate for each of the many diverse ecosystems that exist on a global basis. To meet both near-term and long-term requirements for genetic variation, effectively and simultaneously, breeding goals should focus on achieving and maintaining optimum adaptation to each of the continuously changing production and marketing environments of diverse ecosystems. This approach should assure great diversity of global animal genetic resources that may be needed for long-term adaptation to unforeseen changes in production and marketing requirements. Carefully monitored and continuously adjusted breeding goals that focus on bioeconomic efficiency for each ecological zone are suggested in lieu of primary emphasis on long-term storage of sperm, ova or embryos, for meeting a major part of the long-term requirement for genetic variation.

INTRODUCTION

Intensification of animal production as part of the evolving food production system tends to reduce genetic diversity in animal germplasm resources. High input or intensive production systems favor populations of animals that have the genetic potential for uniformly high response capability to improved or managed production environments. Thus, the normal evolution of animal agriculture through application of new production technologies tends to result in a gradual reduction in genetic variation in the important food and fiber animal species. This trend in loss of genetic variation can be expected to continue within each ecological zone or production and marketing environment. Even so, genetic variation in a species can be maintained if different populations of food and fiber animals are used that have superior adaptation to different specific ecological zones or production and marketing environments, and if barriers do not prevent exchange of animal genetic resources among ecological zones. On a global basis, there is great variation in production and marketing environments and in animal genetic resources for most food and fiber animal species that are of current or potential economic importance. The purpose of this paper is to examine an approach to animal genetic resources management for meeting both near- and long-term requirements for maintaining adaptation and genetic variation in food and fiber animal species.

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CURRENT STATUS AND TRENDS

New technologies in cereal grain, oilseed legume, pasture, and forage crop production have been primary factors contributing to increased availability of animal products, particularly in developed countries. Improvement in bioeconomic efficiency of food and fiber animals has been an essential component of a series of integrated new technologies in the food production and processing system. Food and fiber animal species differ in their requirements for maintaining genetic diversity and in approaches needed to maintain genetic variation. This is primarily because of differences in feed resources for which different food and fiber animal species are competitive and, thus, in type of production system favored by economic and technological factors. The increasingly intensive systems of production that have characterized the poultry industry for about 40 years, and more recently the swine industry, have generally favored greater uniformity of breeding stocks for commercial production with concurrent loss of genetic variation (CAST, 1984). In dairy cattle, the economic factors of production and marketing that tend to favor maximum output of fluid milk per cow have resulted in a dairy industry in the United States in which more than 90% of current fluid milk production is accounted for by the Holstein breed (U.S. Department of Agriculture, 1982).

Rate of reproduction has a major impact upon the life cycle costs of production of different animal species and, thus, upon the competitiveness of a species for different types of production resources. For example, the average beef cow is capable of producing about 0.7 of her body weight per year in progeny market weight; the comparable value is about 8 in pigs, more than 70 in meat chickens and more than 1,000 in some aquatic species (Dickerson, 1978; National Cattlemen's Association, 1982; CAST, 1984). More than 50% of the total nutrients used by the beef cattle industry of the United States are needed to meet maintenance requirements of the reproducing female population; whereas, in meat chickens, the percentage of total nutrients required to maintain the reproducing female population is less than 3% (Gregory, 1982). The dairy cow produces a unit of milk protein for about one-fifth of the feed energy required for producing a unit of beef protein (Reid et al., 1980). In contrast to other ruminants, the dairy cow is a relatively strong competitor for use of high energy or high value plant resources because of the relatively high production efficiency of milk protein. The relatively low biological efficiency of beef cattle, sheep, and goats in converting high energy and high protein plant resources into meat and fiber relegates them largely to the consumption of high fiber plant products not directly usable by humans or by the more efficient ruminant and nonruminant species (CAST, 1984).

The rapid growth in egg, broiler, and turkey production has been feasible because of relatively low prices of cereal grains and legume oilseed meals as a result of new production technologies that decreased costs of production and, thus, resulted in relatively lower prices for eggs and poultry meat. Similarly, for North America, abundant supplies and resulting lower prices for cereal grains have resulted in finishing a high percentage of beef cattle on high energy diets containing high percentages of cereal grains (CAST, 1984). Cereal grains and oilseed meals provide between 15 and 20% of the nutrient base for beef cattle production in the United States (Byerly, 1975). In the dairy industry, economic efficiency has favored feeding large quantities of cereal grains and oilseed meals to achieve near maximum output of fluid milk per cow because of the favorable price relationship of cereal grains versus forages and dairy products. In all species, feeding more cereal grains in developed countries has increased output per animal production unit by reducing the percentage of the total nutrients required for animal maintenance (CAST, 1984).

Increased demand for cereal grains and oilseed meals for direct use in diets of humans is a reasonable long-term expectation. The ruminant meat animal is not a strong competitor for use of scarce and relatively expensive cereal grain and oilseed meal feed resources, except to the degree that appropriate supplementary feeding of concentrates enhances the utilization of forage feed resources and reduces cost per unit of output on a life cycle basis. Because of relatively high efficiency in converting feed energy and feed protein into milk protein, the specialized dairy cow may continue to be a relatively strong competitor for use of limited concentrate feed resources (CAST, 1984).

No major changes in sources of feed resources, i.e., composition of nutrient base, are expected for swine and poultry diets. Expected long-term increases in demand for cereal grains to meet direct human dietary needs, however, would reduce the economic feasibility of using large quantities of cereal grains and oilseed meals for swine, poultry, and dairy production unless there are either compensating increases of cereal grain and oilseed meal production resulting from new production technologies or increased production of these commodities in areas where they are not now grown in appreciable quantities (CAST, 1984). Thus, commercial poultry and swine industries may be expected to continue in an intensive production mode with reduced production and relatively higher prices resulting if(when) the relationship of price of inputs to value of outputs becomes less favorable.

Approximately 40% of all nonfederal rural land in the U.S. is used mainly for production of pasture and forage feed resources because of either terrain or moisture limitations (Fox and Clayton, 1981). The percentage of nonarable land on a global basis is even greater. Thus, long-term continuation of ruminant animal production for meat, milk, and fiber is assured (CAST, 1984).

Genetic diversity is likely more important and easier to maintain for beef cattle, sheep, and goats than for poultry, swine, or dairy cattle because ruminant meat animals, as a result of their relatively low biological efficiency, are much more dependent upon adaptation to a wide range of climatic conditions and to varying levels of nutrition than are specialized dairy cattle and nonruminant food animal species that have relatively high fecundity. Continuation of current trends toward greater intensification of production systems in poultry and swine tends to reduce the importance of maintaining high levels of genetic diversity in these species.

MANAGING ANIMAL GERMPLASM RESOURCES TO MEET CHANGING REQUIREMENTS

A high level of genetic variation in animal genetic resources is required to achieve and maintain balance among: (1) biological characteristics of commercial breeding stocks, (2) dynamic production environment most favored by technological and economic factors in each ecological zone, and (3) changing market requirement for animal products. Modification of major components of a physical environment to the degree required to achieve maximum production is generally not economically nor technologically feasible. A practical objective is to optimize the conversion of the production resources available into animal products by synchronizing the biological characteristics of animal genetic resources with the production and marketing environment most favored by technological and economic factors (Gregory et al., 1982). This approach should result in optimum adaptation of animal genetic resources. Continued adjustments in the availability and, thus, in the relative costs of different production resources and continued changes in market requirements for animal products requires genetic variation in animal genetic resources in order to continuously adjust the biological characteristics of commercial breeding stocks.

It is logical to consider animal genetic resources management in the context of an accelerated rate of evolution. Agricultural development in support of increased production of animal products is the result of adjustments in natural ecosystems or in habitat changes to increase output of products desired by man. Loss of, and additions to, plant and animal species as well as great genetic variation within species has resulted from natural changes of habitat associated with changes in climatic, nutritive, and disease (parasite) environments since the dawn of time. While some of these changes have been the result of chance, primarily these changes have been the result of natural selection for adaptation (fitness) in a continuously changing habitat.

Evolutionary processes have been highly dynamic when time is considered in geological units. Agricultural development makes it necessary to consider ecosystems in time frames considerably shorter than geological units in order to maintain the balance required for optimum adaptation of animal genetic resources. Because agricultural development results in changes in ecosystems at rates much greater than normal evolutionary processes, there is greater risk or hazard of losing balance, or equilibrium, in complex and generally well balanced ecological systems that exist in the natural state. This greater risk occurs, in part, because of inadequate understanding of highly interactive components of these complex biological systems. Thus, it is desirable to develop national, regional, and international programs of animal genetic resources management to help insure against the hazards of loss of genetic variation needed to provide continuously for optimum adaptation to each production and marketing environment. In this context, optimum adaptation is achieved when all production resources or inputs are converted at the maximum rate into animal products that have greatest economic value; i.e., when maximum economic return from resources is achieved. Both economic and biological factors are involved; thus, optimum adaptation is synonymous with maximum bioeconomic efficiency. Because of the major effect of fitness (fecundity and survival) on the ratio of costs of inputs to value of outputs in most food and fiber animal species (Notter et al., 1979; Tess et al., 1983), a high relationship exists between biological efficiency and optimum adaptation.

Because agricultural development accelerates components of evolutionary processes, it is also necessary to accelerate programs of animal genetic resources management to achieve optimum adaptation to each ecosystem. The primary objective should be to organize programs of animal genetic resources management on a global basis that will result in animal genetic resources that possess biological characteristics that are continuously adapted to the dynamic production and marketing environment most favored by technological and economic factors in each major ecological zone. Thus, the breeding goal favored is optimum adaptation to continuously changing production and marketing environments in each ecological zone.

The replacement of adapted indigenous genetic stocks with exotic genetic stocks can be a hazard to the preservation of genetic diversity and to achieving and maintaining maximum bioeconomic efficiency (CAST, 1984). Even though exotic genetic stocks may have greater production response capability than indigenous genetic stocks in a greatly modified production environment, economic and technological factors often prevent modification of major components of local environments to the degree required to achieve optimum adaptation or maximum bioeconomic efficiency. Thus, breeding goals that focus on achieving maximum bioeconomic efficiency in each ecosystem through use of optimum combinations of indigenous and exotic germplasm should result in the maintenance of high levels of genetic variation among ecosystems.

Changes in production and marketing environments of "ice age" magnitude are unlikely when viewed in time frames relevant to agricultural development. Thus, a "Noah's Ark" approach to animal genetic resources management does not seem adequate for meeting long-term requirements or contingencies. Because we are unlikely to recycle the same or even similar production and marketing environment scenarios in any major ecological zone, there are major hazards to a policy that will result in static management of animal genetic resources. Static management of animal genetic resources involves putting primary emphasis on long-term storage of preserved sperm, ova, embryos, and postnatal animal populations in a bank or repository to provide for future requirements (Hickman, 1982).

Our inability to predict the production and marketing environment that will likely be most favored by technological and economic factors over extended time frames makes it essential to maintain sufficient genetic variation in food and fiber animal species to enable adjustments of genetic resources to achieve optimum adaptation on a continuing basis. Thus, primary programs for animal genetic resources can be managed most effectively in concert with the trends that characterize the most efficient production systems for each food and fiber animal species; i.e., with breeding goals adjusted continuously toward achieving optimum bioeconomic efficiency in each production and marketing environment. On the basis of these assumptions, the primary emphasis of an enlightened genetic resources management program to provide for future requirements can be a nurtured and monitored element of current production systems with breeding goals oriented toward achieving and maintaining optimum adaptation on a continuing basis. A basic assumption involved in this approach is that changes in production and marketing environments for each food and fiber animal species of interest will likely be continuous and micro rather than macro in nature in each major ecological zone. This implies trends in the same general direction for extended periods of time.

Breeding goals that focus on achieving and maintaining optimum adaptation to a dynamic production and marketing environment for major ecological zones will encourage the maintenance of a high level of genetic diversity in most food and fiber animal species, particularly in a global context. This is basically because of the great variation in production and marketing environments that exists on a global basis. Maintenance of genetic variation in populations whose biological characteristics are generally in harmony with the production and marketing environment provides the basis for continuous change of genetic resources on an organized basis for biological traits influenced by a large number of loci in food and fiber animal species.

Managing animal genetic resources to meet near- as well as long-term needs for genetic variation as part of the framework of current global animal production systems requires that the custodians be good students of evolution. I doubt if we have always been good students of evolution! Perhaps one of the major values of having breeding goals oriented in a life cycle production systems context of optimum adaptation, or maximum bioeconomic efficiency, to continuously changing production and marketing environments is to encourage our thinking to include all elements of complex biological systems and, thus, stimulate us to become better students of evolutionary processes and its emphasis on fitness.

The approach to animal genetic resources management to provide simultaneously for both near- and long-term requirements of genetic variation will require a functional organized structure on a global, regional, and national basis. More complete characterization for biological traits of interest of the earth's most promising food and fiber animal genetic resources and of the earth's major ecosystems should be a continuing part of enlightened programs of animal genetic resources management. The maintenance of comprehensive global inventories of important genetic resources for each food and fiber animal species should be an essential component of animal genetic resources management. Programs of technology transfer involving both public and private sector interests would be a logical function of international, regional, and national organizations whose focus is on animal genetic resources management.

CONCLUSIONS

The great diversity of production and marketing environments, or ecosystems, that exist on a global basis can insure maintenance of high levels of genetic variation in most food and fiber species of interest, provided breeding goals focus on achieving and maintaining optimum adaptation of biological characteristics most favored by technological and economic factors in each ecological zone. For the most part, animal genetic resources needed to provide for both near-term and for long-term requirements of genetic variation can be most effectively managed as part of dynamic production systems of food and fiber animals in each major ecological zone, or production and marketing environment, with continuously adjusted breeding goals focused on achieving and maintaining optimum adaptation.

An animal genetic resources management program that is dynamic in nature is essential for meeting both near- and long-term requirements for maintaining genetic variation. Genetic improvement programs oriented toward achieving and maintaining maximum bioeconomic efficiency and, thus, based on balanced evolutionary concepts that optimize fitness are favored for both near- and long-term objectives of animal genetic resources management.

Macro changes in production and marketing environments seem unlikely. Furthermore, if macro changes should occur, they are so unpredictable in their direction that the chances seem low of having stored or preserved (i.e., sperm, ova, or embryo) germplasm needed to make rapid adjustments to a grossly different production and marketing environment. Further, because of the economic importance of fitness, it seems likely that current genetic improvement programs may be more effective for achieving improvement in bioeconomic efficiency if their focus is on achieving and maintaining optimum adaptation between biological characteristics of genetic stocks and the production and marketing environment most favored by economic and technological factors in each ecological zone. Dynamic breeding goals that focus on bioeconomic efficiency require balanced evolutionary concepts rather than alternating single trait selection objectives with less than optimum attention to fitness (fecundity and survival). Hazard of loss of genetic variation should be reduced through use of continuously adjusted breeding goals that focus on achieving and maintaining maximum bioeconomic efficiency in harmony with differing dynamic production and marketing environments. Thus, the goal of maintaining genetic variation to provide for long-term requirements for animal production seems to be synergistic with the goal of achieving maximum bioeconomic efficiency to meet near-term requirements.

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