Livestock Environment Prospects for the 90's

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خلاصة : عندما نتحدث عن احتمالات بيئة الحيوان في التسعينات فإنه من الضروري الانتباه إلى الجوانب المتعددة في طبيعة إدارة أنواع الحيوانات المختلفة في المناطق الحارة. يعرف هذا البحث بمنافذ فسيولوجية ذات إمكانيات مستقبلية هامة خلال دورة حياة الحيوان لها حساسية للاجهاد الحراري وتجاوب مع التحويرات البيئية. يبدو تطور الحويصلات المبيضية حساساللاجهاد الحراري مما يؤدي إلى تقلص في حدة دورة الشبق وبالتالي في الخصوبة. لم يتم حتى الآن تحديد تلك الفترات في تطور الحويصلة الحساسة للإجهاد الحراري. مع وجود الأنظمة المتطورة حاليا التي تغير البيئة الدقيقة للحيوان إختلفت مرحلة حساسية الجنين للاجهاد الحراري حتى تقلصت معدلات فقدان الأجنة المبكر. إن إمكانية استخدام البروتينات المركبة يمكن أن ترفع من معدلات بقاء الأجنة وتعوض النقص في وظائف المشيمة التي يسببها الاجهاد الحراري جديرة بالبحث والتقصي. وتعتبر فترة ما بعد الولادة ذات أهمية خاصة التي تتفاعل فيها مجموعة من العوامل لتؤثر على انتاجية الحيوان وحساسيته للاجهاد الحراري. وقد نوقشت إستراتيجيات التغذية المختلفة لتحسين أداء الحيوان بإضافة الشحوم. ويجب ألا تكتفي عملية تحوير البيئة ونظم الإيواء برفع كفاءة الإنتاج الحيواني إلى أعلى معدل لها فقط. بل يجب أن تأخذ في الاعتبار التأثير المحتمل على البيئة وعلاقته باستخدام المياه وتلوث التربة والمياه. ويجب أن تأخذ أنظمة إدارة الحيوان في الاعتبار كلاً من موضوعات صحة الحيوان والصالح العام. ولتحقيق أعلى عائد تحت ظروف ذات أهمية معوقات اجتماعية وبدائل إدارة متاحة ستكون نظم الإدارة بمساعدة الحاسوب ذات أهمية بالغة.

ABSTRACT: When projecting livestock environmental prospects for the 1990's, it is critical to recognize the multidimensional nature of managing livestock species under hot environments. This paper identifies potential critical physiological windows during the life cycle of the animal that are sensitive to heat stress and responsive to environmental modification. Ovarian follicular development appears to be sensitive to heat stress leading to reductions in intensity of oestrus and subsequent fertility. Periods of follicular development that are sensitive to heat stress have not been defined. With current improved systems to alter the microenvironment of animals, the period of embryonic sensitivity to heat stress has shifted so that early embryonic losses are less. Potential recombinant proteins that may enhance embryo survival and correct deficiencies in placental function that are induced by heat stress warrant additional investigation. The postpartum period is a critical period in which a multitude of factors interact to influence animal productivity and its sensitivity to heat stress. Nutritional strategies to improve animal performance with the use of fat-supplementation are discussed. Environmental modification and housing systems need to not only maximize the efficiency of animal production but need to consider the potential impact on the environment relative to water use, soil and water pollution. Animal production and management systems need to consider both animal health and well-being issues. To optimize profit under conditions of greater societal constraints and available management alternatives, computer assisted management systems will become a critical tool.

Areas of investigation to improve livestock performance and efficiency in the 1990's that relate to the environment are multifactorial in nature. Environmental stress on livestock performance is not limited to climatic factors but involves nutrition, housing systems, disease, and animal well-being as well. Furthermore, modifications of the environment and associated management systems to improve efficiency of production must consider the environmental impact of such systems on contamination of soil and water supplies and on adverse alterations of the food chain. Environmental management systems need to collate optimal animal production and well being with societal needs to maintain or improve our land and water supplies. Also essential to enhancing animal health, productivity, and efficiency of production, is the implementation of computer modelling in the decision making processes of animal and farm management. This presentation will outline specific areas of investigation to improve animal production and efficiency under hot environments with attention to physiological windows within the animal's life cycle that are amenable to enhancing production efficiency and animal well being. Additional areas of integration will deal with concepts of management and environmental control to increase efficiency of production and reduce unit cost of production. Such animal production systems should minimize degradation of our earth ecosystem. The intent of this paper is not to document extensively these interrelationships, but to focus attention to potential priority areas for either continued or future investigation.

The Animal

Increasing animal productivity is associated directly with increasing metabolic heat production, which aggravates the problem of maintaining homeothermy under conditions of elevated environmental temperatures and/or humidity, or dealing with consequences of hyperthermia. Genetic approaches to enhance heat tolerance of animals generally are not compatible with improving animal productivity. Thus, management options are related to improving the thermal balance of the animal (e.g., reduce heat input to the animal and/or increase heat loss from the animal), and identifying treatments to correct the disturbed homeostasis of high producing animals in a hot environment. There are many biological components which when altered compromise animal performance and productivity.

Periovulatory Period: Distinct seasonal periods of infertility are encountered during summer heat stress months. With the use of intensive management systems in lactating dairy cows, this period of reduced fertility is associated with increases in temperature and/or humidity that induce hyperthermia and not due to changes in quality of feedstuffs. Pregnancy rate, which is the product of heat detection and conception rates, are markedly reduced during seasonal periods of heat stress. Lactating dairy cows express a less intense behavioral oestrus than non-lactating cows or heifers. Indeed, the metabolic and hormonal changes of lactating dairy cows reduce the proestrus concentrations of oestradiol (de la Sota et al., 1993), and this is further reduced by heat stress (Gwazdauskas et al., 1981). Collectively, these changes reduce the probability of detecting cows in oestrus. The transitional patterns of reduced fertility in early summer and the restoration of fertility in the fall are strikingly different. Conception rates drop precipitously in the beginning of the stress season and return gradually (e.g., from October to December) with the end of the summer stress season.

A series of recent observations indicate that perhaps heat stress compromises follicle development since follicular dynamics are altered during periods of heat stress (Badinga et al., 1993; Wolfenson et al., 1995), noncooled cows with lower oestradiol concentrations had lower mean concentrations of FSH with reductions in FSH and LH responsiveness after GnRH injection compared to cooled cows with lower oestradiol during summer (Gilad et al., 1993), and that induction of acute heat stress on the day of oestrus for 15 h reduced subsequent embryo survival following insemination. Presently, it is not known at what stage in the follicular hierarchy of the ovary does heat stress damage the ovarian follicle and/or oocyte. This is an important area for future investigation since heat damage of the ovary may be analogous to damage of the testis in which a time lag of approximately 45 days is required before completion of the spermatogenic cycle leading to the production and ejaculation of new sperm that were not damaged by heat stress. A comparable time lag in the female ovary may account or contribute to delays in restoration of fertility in the fall. Systems of ovarian control that optimize and synchronize follicle development, control the time of corpus luteum regression, and precisely induce the time of ovulation could lead to a timed insemination that would eliminate the need for oestrus detection. It is not unusual for the frequency of missed oestruses to be 80% during hot summer months. Implementation of a timed artificial insemination program coupled with the application of efficient cooling systems would improve reproductive performance.

EMBRYONIC LOSSES: Severe periods of heat stress, in which body temperatures reach 40-41C in lactating dairy cattle on the day of oestrus (D0) and days 1-2, causes a high rate of abnormal embryonic development and death by day 7 (Putney et al., 1989b; Ealy et al., 1993). These losses can be alleviated partially by the use of embryo transfer in which high quality frozen embryos are transferred to cattle on day 7 (Putney et al., 1989a ; Drost et al., 1994). With continued advancements in *vitro* maturation, fertilization and culture of oocytes, the costs of embryo transfer likely are reduced and this technology implemented to by-pass early embryonic losses. With the utilization of efficient cooling systems and maintenance of body temperatures at <39.5C, the timing of embryonic losses has been delayed until after day 7 (Ryan et al., 1993; Drost et al., 1994). These latter losses seem to be associated not with death of the embryo but a reduction in embryonic growth leading to insufficient production of the antiluteolytic protein, interferon tau. Interferon tau causes an attenuation in $PGF_{2\alpha}$ secretion and maintenance of the corpus luteum for the duration of pregnancy. A failure of this system leads to a later stage of embryonic death due to insufficient production of progesterone to sustain development of the embryo. With the production and availability of recombinant interferon tau it may be possible to supplement sheep and cattle to enhance embryo survival. Application of this technology is dependent on developing a delivery system that delivers small amounts of interferon tau to the uterus and minimizes potential side effects, such as induced hyperthermia, that reduce embryo survival in cattle (Thatcher et al., 1994). An alternative strategy is the transfer of trophoblastic vesicles which secrete interferon tau and enhances conception rates in lactating postpartum dairy cows (Ryan et al., 1994).

PLACENTAL AND FETAL DEVELOPMENT: Hyperthermia in sheep during pregnancy causes fetal stunting. This phenomenon of fetal growth retardation in chronically heat-stressed ewes occurs in late pregnancy and appears to be a consequence of a primary reduction in placental growth during early gestation (Vatnick et al., 1991). When dairy cattle are heat stressed during the last 2 to 3 months of pregnancy, there are clear reductions in placental function (reduced concentrations of oestrone sulphate), calf birth weight and subsequent milk production during the ensuing lactation (Collier et al., 1982; Wolfenson et al., 1988; Moore et al., 1992). Indeed, cooling of dry cows during the latter stages of pregnancy is an efficient means to improve animal productivity; this is a physiologically sensitive period that often is ignored by producers. It is possible that perhaps the secretion of bovine placental lactogen has been reduced due to reduced placental function. Additional research is needed to determine if administration of recombinant bovine placental lactogen (Byatt et al., 1992a) during late pregnancy in heat stressed cows would enhance both fetal growth and mammary development of the maternal unit. This would potentially compensate for a potential deficiency in placental hormonal secretion induced by heat stress. Maintenance of fetal growth and maternal mammary gland function after parturition likely would enhance neonatal survival and production of milk. Administration of bovine somatotropin (bST) during the dry period had no detectable effect on subsequent milk yield (Bachman et al., 1992). Bovine placental lactogen had distinctly different effects on intermediary metabolism than bST (Byatt et al., 1992b) and should be tested during the dry period for its potential effects on the fetal and maternal responses of the periparturient period.

POSTPARTUM PERIOD: The transition from pregnancy to lactation is a sensitive period in which calving disorders and a complex of related problems (e.g., uterine prolapse, retained fetal membranes and milk fever) result in subsequent losses of both milk production and reproductive efficiency. The cow also is undergoing a transition to increase dry matter intake at a time when energy requirements for maintenance and milk production exceed the energy that can be consumed in the diet. Thus, cows spend an extended period of 4 to 5 weeks in negative energy balance which antagonizes the endocrine changes leading to restoration of normal ovarian cycles. This is exacerbated by periods of heat stress in which cattle reduce their dry matter intake as a means to reduce heat production. The postpartum period is a complex period involving marked changes in nutrition, immune competence, mammary gland function, nutrient partitioning, involution of the uterus and recrudesce of ovarian function. Undoubtedly, heat stress alters these systems and their interrelationships to reduce performance and efficiency of production. First calf heifers in particular have a much longer delay in restoration of ovarian activity due to their lower inherent ability to consume dry matter which extends their period of negative energy balance. Coordinated production management and medicine programs to optimize postpartum performance and minimize effects of heat stress are needed.

A major technological advancement is the administration of bovine somatotropin (bST) to lactating dairy cows which induces a 10 to 25% increase in milk production. Associated with chronic bST treatment is an increase in feed intake. An initial report indicated that the stimulatory effects of bST on milk production were observed in heat-stressed cows without enhancing heat stress responses (Johnson et al., 1991). However, several recent reports indicate that hyperthermia induced by heat stress and associated changes were greater for cows treated with bST (Elvinger et al, 1992; West et al., 1991). It is important that with the use of new pharmaceutical drugs to enhance production, that careful management be implemented to avoid overexposure of treated animals to heat stress.

Nutrition

If an animal is heat stressed, it will reduce feed intake to decrease heat load associated with digestion and metabolism of feed nutrients. Less heat is generated with digestion and metabolism of fat relative to carbohydrates and proteins. Consequently, feeding fat during periods of heat stress lessens the heat load on the animal and will increase energy density of the diet during periods when feed intake is depressed. Indeed, fat-supplemented diets enhanced lactational performance during warm weather but a beneficial effect was not observed during cool weather (Skaar et al., 1989). Although fat supplementation beginning in the early postpartum period does not usually stimulate milk production until later in the postpartum period, there are distinct effects of feeding fat on enhancing ovarian follicular function in early lactation (Lucy et al., 1991). When lactating dairy cows were fed fat-supplemented diets between 60 and 100 days of lactation, ovarian follicular dynamics were influenced by fat supplementation when diets were either isocaloric with the basal ration or contained additional energy due to fat supplementation. A recent report indicated that the type of dietary fat infused into the abomasum of lactating dairy cows altered the degree of oxytocin induced secretion of $PGF_{2\alpha}$ from the uterus (Thatcher et al., 1994). Infusion of yellow grease that contained 20% linoleic acid reduced the oxytocin-induced secretion of $PGF_{2\alpha}$. Collectively, these results indicate that by feeding fats in the diet and by tailoring fat composition, there is the potential to regulate reproductive function. Thus, nutritional management of the animal may be a means to minimize heat stress effects and alter physiological responses that enhance production efficiency (reproduction and lactation). It is interesting that heat stress appears to enhance uterine secretion of $PGF_{2\alpha}$, which may antagonize maintenance of early pregnancy (Wolfenson et al., 1993). Furthermore, endometrial tissue of early pregnant cows has higher concentrations of free linoleic acid which will act as a competitive inhibitor with arachidonic acid for prostaglandin endoperoxide synthase (Thatcher et al., 1994). Thus, it may be feasible to feed diets during summer periods of heat stress with supplemental by-pass fats that are enriched in linoleic acid that antagonize potential luteolytic secretion of $PGF_{2\alpha}$. Such diets would also enhance caloric density of the diet to help sustain milk production. Furthermore, feeding protected fats that contain polyunsaturated fatty acids may be a means to alter fatty acid composition of the milk in a manner that is more acceptable to the health needs of consumers. The area of nutritional management, under conditions of potential heat stress, to optimize productivity, animal well being, and quality of food products is an exciting area of future research.

Environmental Modifications and Housing Systems

It is known that there will be relatively little future changes in climate which would improve animal productivity in tropical, subtropical and arid areas of the world. However, major advancements in knowledge and its application have altered the environment to reduce impending heat loads on animals in a manner that is combined with systems to enhance heat loss from its body (Armstrong et al., 1995; Berman and Wolfenson et al., 1992). These types of systems need to be optimized for the region of application and integrated with the production potential of the area. For example, in many tropical areas, the period of stress most often extends for an extended period of the year and is coupled with diseases, parasites, and low nutritional inputs. Obviously, a system under this environment needs to incorporate a management plan that not only protects animals from periods of thermal stress but provides more stringent health care, well being and nutritional inputs to reach the production potential of the animal unit in the system. Such systems involve increased investment of monies to allow maximal performance of high-producing animals.

An additional and less intense management program is to upgrade local animals (e.g., bos indicus cattle) by upgrading to bos taurus dairy cattle (e.g., Holstein). As the percent bos taurus breeding increases the need for environmental management will enhance. Nevertheless, lower percentage upgrades often out-produce local native cattle with minimal management inputs. Fluctuations in environmental conditions (climate, feeding, management, etc.) from year to year at the same tropical location can be important in determining the preferred genotype of dairy cows. McGlothlen et al., (1995) showed that on the average in 27 years, and in 14 good years, upgrading of Butana cattle (bos indicus) to over 70% Holstein or Ayrshire in Sudan resulted in greater annual milk yield per cow. In 13 poor years, however, highest yields were obtained from 3-breed crossbreds, 3/8 Holstein, 3/8 Ayrshire, and 2/8 Butana.

In subtropical and arid areas, the period of thermal stress is more restricted to a limited seasonal period of the year. The consequence of a shorter duration of environmental stress is to reduce the magnitude of detrimental effects and their carryover into better seasons of the year. Conversely, animal management (e.g., breeding, etc.) in more favourable times of the year may minimize upcoming detrimental effects during the non-favourable season. For example, animals could be bred to avoid inseminations during the less fertile season. Alternatively, young and non-lactating animals could be inseminated during seasonal stressful periods since they are less sensitive to heat stress. These types of management decisions could balance out the flow of animal productivity (e.g., milk production) to minimize seasonal fluctuations.

POLLUTION: As our world population grows in number and the standard of living rises in developing countries, water usage will increase and the availability of water for agricultural uses will decrease. Thus, efficient systems of environmental management will need to be implemented that minimize water use, re-cycle water efficiently, and minimize pollution of the water supply and soil with animal wastes. Animal production units with a high density of animals need to have feeding programs that meet production needs efficiently and which minimize negative effects on the environment such as nitrogen and phosphorus excretion. Production units will need to have on-site capabilities to recycle animal wastes and minimize contamination of water leaving animal production lands.

This problem is evident by the phosphorus dilemma encountered in the ecological systems in South Florida, USA (Fitzpatrick, 1993). Dairy systems are comprised of a high density of animals that receive large volumes of nutrients. The volumes of subsequent animal wastes are enriched highly in nutrients such as phosphorus and nitrogen. Downstream of these production units are ecological systems such as Lake Okeechobee and the upper Everglades. High concentrations of phosphorus in the native waters during the last decade and periodic blooms of algae have caused regulatory agencies to set phosphorus standards for water leaving the animal production lands. Expensive systems involving a flushing system, two stage lagoons (anaerobic or aerobic), and a spray field for dispensing waste water on cropland are implemented to minimize off farm runoff and contamination of downstream areas (Nordstedt, 1992).

Unfortunately, there is a sparsity of research data available to determine the long-term effects of phosphorous and nitrogen on the environment and more research is needed to define minimum dietary requirements, and hence excretions, of phosphorus and nitrogen (Morse et al, 1992). Agronomic, animal science, and engineering disciplines need to complement their interdisciplinary efforts. Optimal nutrient requirements of crops and maximal nutrient loads of soil (e.g., phosphorus, nitrogen and copper) need to be determined. Reducing or modifying manure is a management option for future investigation. Nutritional and genetic research to reduce animal output of phosphorus and nitrogen is considered to be a high priority for research. Proper feeding of environmentally sensitive elements and protein type to eliminate excessive excretions in waste is an important area for research investigation. Alternative uses of manure (e.g., electrical generation from waste), dead animals (e.g., insect degradation, composting, fermentation), contaminated biomass (such as diseased animals, contaminated milk, etc.) and animal by-products (e.g., whey from milk manufacturing as a supplement to animal feed) to economically dispose of these wastes in an environmentally acceptable manner are needed (Oltjen, 1993). These areas dealing with pollution and the need for integrated management of animal production systems with the environment will receive a high priority for research in the future.

ANIMAL WELL-BEING: This is a very controversial area from several perspectives. The public tends to regard animal well-being an issue dealing with animal health and behaviour, whereas producers tend to associate well-being with health and productivity of the animal (Mench, 1993). Research in this area needs to establish criteria for normal and abnormal behaviour, and to characterize these behavioral criteria with production, health, neuroendocrine, immunological and metabolic response of the animals. Animals' responses to the production environment need to consider their genetic backgrounds and previous experience. Management and housing systems for the most part deal with animal groups. Studies are needed to establish effects of group size, composition of the group, space requirements for the group and consider behavioral responses such as aggression. The feelings of the animal are a major issue with the public. However, there is little agreement as to what is an objective and quantitative approach to measure feelings as an experimental response in order to evaluate whether improvements in a production system enhance well-being of the animal. It is clear that advancements in this area require an interdisciplinary approach involving the sciences of animal behaviour, genetics, immunology, pathology, physiology, epidemiology and neurobiology. It will be important to consider individual animal variability, the entire production cycle of the animal, and a range in production management conditions.

Current advancements in technology related to the non-invasive monitoring of animals will assist the scientific discipline in evaluating animal well being. For example, the modern milking parlour is becoming an animal management unit that is highly integrated with computer technology for monitoring health, productivity and behaviour of lactating dairy cows. Each animal is identified by transmitters individually. Milk production at each milking can be recorded automatically and coupled with electrical resistance of the milk as an indication of sub-clinical and clinical mastitis. Furthermore, milk temperature is an index of body temperature that further allows careful monitoring of health status and well-being. The ability to measure milk production on a milking to milking basis allows managers to make decisions regarding feeding management. Monitoring animal activity with the use of pedometers at each milking permits detection of behavioral oestrus that aids with artificial insemination. Future advancements regarding non-invasive monitoring of animals will further optimize animal production and well being.

Impact of Biotechnology on Animal Health

Biotechnology has contributed significantly to the area of animal health via the production and use of antibodies, immune response modifiers and vaccines. Biotechnology techniques have led to new and improved diagnostics, vaccines and treatments for diseases of animals. Bovine diseases under study by biotechnologists include rhinotracheitis, herpes viruses, mastitis, brucellosis, scours, bluetongue, lymphosarcoma and leptospirosis. The newer diagnostic tests are usually more effective, faster and less expensive than conventional ones. The newer vaccines are also more effective, safer, field- and temperature-stable, and less expensive than the original and conventional types. Parasites and ticks have been targeted for control by use of new biotechnology -based vaccines. The biotechnology industry has produced large quantities of bovine proteins, such as interferons and cytokines, in bacteria in order to treat various diseases and mastitis. Biologists are using biotechnology techniques to alter rumen microflora from the standpoints of improving forage digestibility and nutrient utilization within the rumen. In the future, isolated rumen microorganisms will undergo genetic modifications via gene insertion and be reintroduced to the rumen as a way of increasing nutrient utilization and production. With this in mind, efforts are under way to isolate the genes that specify the production of enzymes to degrade plant celluloses and other material. Biotechnology is working to develop new, safer and more environmentally compatible biopesticides. Research should be implemented to understand the cellular basis of immunity. Immune modulators, molecules that enhance natural immunity, have the potential to replace the use of antibiotics for the treatment of diseases. Such a therapeutic approach to disease has the potential to replace the use of antibiotics. This approach would sustain animal health, protect the food supply and also have positive effects on humans.

Computer Assisted Management

Multidisciplinary approaches to scientific problem solving will improve the sustainability and competitiveness of food production from animals. Integration of knowledge is essential to the decision-support systems and management practices that optimize animal productivity, maximize economic returns, as well as interface with societal concerns of environmental and animal well being. Computer technology will be instrumental to the development and implementation of these systems to integrate resource management and provide preventive herd health management programs. Strategies will be developed to optimally utilize land, water and labour resources in an environmentally, economically and socially acceptable manner. Computer modelling will define in a mathematical, quantitative and objective manner the sources of variation that effect the efficiency of production in our food producing animals relative to the interactions of reproduction, nutrition, genetic selection and disease control. With the acquisition of new knowledge and major technological advancements, it is critical to continue this technology with production and financial information to forecast future production and financial performance of the animal unit and cash flows for the farm unit in the future.

DeLorenzo (1992a,b) has used dynamic programming that utilizes sophisticated economic models to combine production and financial information to forecast a dairy's future milk production and financial performance. An optimizing model is developed that determines breeding and culling policies that will maximize profit from each cow ranked in the herd. The model responds to the production and cost data from the specific dairy. Inputs include lactation curves, heat detection rates, conception rates, seasonal breeding performance, seasonal milk production, seasonal milk prices, etc. Many of the inputs are unique to the individual dairy.

The model produces three important pieces of information. First it generates breeding and culling guides that identify which cows in the herd should receive the highest priority for breeding and those that are likely cull candidates. This is done from a profit-maximizing standpoint. In the breeding guide, for each open cow a value is calculated which indicates the expected net discounted return from inseminating at thenext oestrus versus waiting until a later heat. These values can be viewed as a priority list for breeding. Cows with higher values should receive the highest heat detection intensity. The culling guide lists all cows that are candidates for culling. When a cow appears on the culling guide, it means that a higher profit could be gained from this cow's position in the herd by replacing it with an average first calf heifer. The second part of the model takes the current herd through the next 12 months and forecasts the herd structure (e.g., number of total cows, cows in milk, dry cows, cull cows, calvings, etc.,) milk production, and feed costs assuming current non-optimized breeding and culling policies are maintained. This forecast in combination with other financial data collected from the dairy is used to forecast cash flows for the next 12 months. Various alternative scenarios can be tested.

The third part of the model compares the current herd forecast for 12 months to a forecast assuming optimal policies for breeding and culling are followed. Auxiliary information can be tracked such as labour and feed inputs and cost for monitoring by the producer. Such a modelling program provides: descriptive information as to the state of herd performance at a point in time; diagnostic information that helps determine when profitability and herd performance are not where they should be; predictive information that predicts potential future events with the opportunity to pose "what if I changed specific goals" that relate for example to potential implementation of a new technology or production constraint; and prescriptive information that deals with the result of following profit-maximizing breeding and culling strategies considering all alternative strategies.

A vivid example of the application of such an optimizing model is the economic evaluation of whether an environmentally controlled structure should be built on a dairy unit (DeLorenzo and Beede, 1989). One could model four different scenarios Table 1 in which the structure would cause non-seasonal and seasonal changes in milk production of 10% versus 18%, heat detection rates of 40 versus 60%, and pregnancy rates of 30 and 48%. Theeconomic evaluation is depicted in Table 2 and indicates that with scenario 4 the structure potentially would pay for itself in 2.5 years based upon increased forecasted profits compared to the present profit function of the unit. Similar potential impact of technologies related to use of embryo transfer, embryo and semen sexing, use of bST, nutrition of high producing dairy cows (e.g., fat supplementation) and new reproductive management options can be evaluated relative to their potential to optimize profit. Further, optimal responses to societal constraints such as environmental policies can be determined.

TABLE 1

Four scenarios resulting from improvements in milk production and reproduction due to potential construction of an environmental management system.

Scenario	Milk production change* Non-seasonal	Seasona	Annual increas e milk	Heat detection	Pregnancy rate
1	+ 5%	+ 5%	+ 10%	40%	30%
2	+ 9%	+ 9%	+ 18%	40%	30%
3	+ 5%	+ 5%	+ 10%	60%	48%
4	+ 9%	+ 9%	+ 18%	60%	48%

* Increase is a net result of altered level of milk production and lactation curve shape.

TABLE 2

Economic evaluation: changes compared with the base run (per cow per year, including dry cows) associated with use of current management.

Item	Scenario 1	2	3	4
	--- Increase over base run ---			
Milk revenue, $	257	406	334	484
Feed cost, $	56	89	74	107
IMFC*, $	200	317	260	377
Feed cost/cwt, **$	-.31	-.50	-.40	-.57
Heifer RC, ***$	-	-	-138.41	-127.27
Payback, years	5.8	3.7	3.2	2.5

* Income minus feed costs.
** Feed cost per 100 lb milk prouced.
*** Heifer replacement cost.

Summary

Dealing with the hot environment relative to livestock production involves and will continue to require an interdisciplinary approach to maximize animal productivity and efficiency. Biological responses to hot environments need to be identified and considered when designing management programs to improve animal performance. Modern systems of management need to integrate the principles of physiology, nutrition, engineering, animal management and health, and computer expert systems to optimize production and efficiency of production. The animal industries and producers need to be aware of current concerns about the impact of animal production systems on the environment and the public's concern regarding animal well-being. Governmental regulated constraints to maintain the environment and insure the production of safe foods for human consumption will continue to enter into the costs of making a profit by the producer. Such constraints will be considered in optimizing management decisions to maximize farm profits.

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