# Generic Environmental Impact Statement on Animal Agriculture:

## A Summary of the Literature Related to Animal Agriculture Health (L)

Prepared for the Environmental Quality Board

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**MN** ENVIRONMENTAL QUALITY BOARD

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To Interested Minnesotans:

The GEIS on Animal Agriculture is a statewide study authorized and funded by the 1998 Minnesota Legislature and ordered by the EQB. The Legislature directs the EQB to "...examine the long-term effects of the livestock industry as it exists and as it is changing on the economy, environment and way of life of Minnesota and its citizens."

The intent of the GEIS is twofold: 1) to provide balanced, objective information on the effects of animal agriculture to future policymakers; and 2) to provide recommendations on future options for animal agriculture in the state. The success of the GEIS on Animal Agriculture will be measured by how well it educates and informs government officials, project proposers, and the public on animal agriculture, and the extent to which the information is reflected in future decisions and policy initiatives, made or enacted by Minnesota state and local governments.

The GEIS consists of three phases during the period summer 1998 through summer 2001: scoping the study; studying and analyzing the 12 scoped topics; and drafting and finalizing the GEIS. The EQB has established a 24-member Advisory Committee to provide advise to EQB during all phases of the GEIS. The scoping phase of the GEIS was completed in December of 1998.

This literature summary is the first step in the second phase aimed at study and analysis of the 12 key topics. This summary is intended to inform the Environmental Quality Board (EQB) members, EQB staff, and the Advisory Committee on the "Feedlot GEIS" scoping questions and research needed for adequate completion of the GEIS. The EQB would like to acknowledge the time and effort of the Advisory Committee members who provided invaluable input in the development of this "tool" for use throughout the GEIS process.

The literature summary is formatted to address the 12 topics of concern and 56 study questions outlined in the Feedlot GEIS Scoping Document (www.mnplan.state.mn.us). Any conclusions or inferences contained in this report are those of the authors and do not necessarily reflect the positions of the EQB or the Feedlot GEIS Advisory Committee.

The EQB would like to make this literature summary available to others interested in the effects of animal agriculture. Copies of this literature summary will be available for use in the Minnesota Planning/EQB Library: 300 Centennial Building, 658 Cedar Street, St. Paul. The Library will also house copies of the key literature review articles and the searchable database compiled as part of this literature review. A limited number of copies of this literature summary will be printed for distribution at cost.

For further information on the GEIS or this literature summary please contact the EQB at 651-296-9535.

Sincerely,

Gene Hugoson, Commissioner, Minnesota Department of Agriculture and
Chair, Minnesota Environmental Quality Board

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## EXECUTIVE SUMMARY

Animal health and well being are the foundation of any humane, sustainable livestock production system.  Producers must therefore insure the management practices they use are appropriate for the species, the type of production system, and the environment.  To do otherwise would be detrimental to their animals and their livelihood.  Much of what is known has been determined through years of hard work and refinement.  Thus, producers are frequently reluctant to impose new management methods on their animals until it has been demonstrated that the new  methods work in a setting similar to the one they use.  This emphasizes the need for research with appropriate controls so that effects of management practices can be thoroughly evaluated.

Livestock production systems convert feed into valuable products such as meat, milk, eggs, and wool.  Sustainable livestock production systems perform this conversion through effective management practices and the use of animals that efficiently convert the feed they consume into useable products.  Animal research has increased our understanding of the interactions of production animals with their environment and management practices and has greatly enhanced the efficiency of producing animal products.  This increased efficiency means more product can be produced per unit of feed consumed and less waste (manure, methane, etc.) generated per unit of product produced.

In the short-term, disease and stress reduce the ability of animals to efficiently convert feed to product.  This has a profound negative impact on farm profitability.  Prolonged or uncorrected periods of disease and stress are inhumane, compromise animal health and well being, greatly decrease efficiency and result in an unsustainable system.  These factors are clearly undesirable for the animal, the producer, and society.  Thus, sustainable systems strive to prevent disease and stress, quickly treat detected cases, and correct the conditions that contributed to the occurrence.

Traditional, contemporary, and alternative livestock production systems of various sizes operate in Minnesota.  Within each system, management practices exist that can allow the producer to meet a variety of income and quality of life goals.  Large units provide perceived advantages (including labor efficiency, volume of production, and the ability to provide uniform management for groups of similar animals) but the concentration of animals imposes challenges associated with disease control and manure management.  Small units and certain alternative systems are frequently perceived as being more environmentally friendly, more family oriented, and more supportive of animal well being.  However, these systems also impose challenges associated with animal health and well being and may not have sufficient resources to institute protection practices needed to properly manage animals and the waste they generate.

All sustainable livestock production systems strive to minimize any potential negative impacts of the system on the animal, the producer, the environment, and society.  However, there is no one  perfect set of methods that is applicable to all livestock production systems.  Management practices that are effective in small units may or may not be effective in larger units.  Regardless of the size or type of system used, public

awareness and expression of concerns (perceived and/or real) for animal health and well being have increased.

This emphasizes the need to clearly understand the varied and multiple interactions of livestock species with their environment, the production system used, and societal concerns.  Improving this understanding will explain how changes in animal management can have significant effects on animal health and well being, productive efficiency of the system, the environment, and society.  To be beneficial to the animals, environment, producer and society, regulations on livestock production systems should reflect a comprehensive understanding of these interactions.

## CRITIQUE OF QUESTIONS

**QUESTION 1.**

The question was straightforward and clear.  Federal, State, and Local regulations comprise vast volumes – even when restricted to the health and well-being of agricultural animals.  Sections that were considered to be most pertinent were reviewed and described.  Routine practices in animal agriculture also comprise a vast volume of information.  Several textbooks have been written that describes these practices.  Topics that were identified as being of interest to EQB/CAC were discussed.  It was more difficult to obtain compliance data.  Records appear to be limited.  The question could have been improved by the identification of specific areas of interest.  This would have provided more focus.  However, EQB/CAC provided helpful feedback as the process evolved.

**QUESTIONS 2, 3, AND 4 WERE HIGHLY INTER-RELATED.**

Question 2 asked for information of how animal agricultural systems affected animal health and well-being and how these effects were measured and address.  Five specific factors were identified and information requested as to how they were affected by the system.  Although the basic question is straightforward, a response based on a systematic analyses was not possible because such data generally do not exist. The first four of the specifically identified factors do play important roles in animal health and well-being.  The fifth factor (use of processed manure as feed) can play an important role, especially if processing is inadequate.  However, little processed manure is fed to animals in Minnesota or in the U.S.  Although not specifically requested, the team chose to include information on other factors that are known to have important affects on animal health and well-being.  For these questions and the report in general, more information was available for effects of these factors on animal health than animal well-being.

Question 3 asked how the effects of animal agricultural system varied by species, operation, system type, and management practice.  EQB/CAC provided the needed (and requested) clarification of their working definitions of these terms.  The resulting coalescence of operation, system type and system into the single term system (consistent with Question 2) was beneficial.  On a gross comparative level, relative effects of extensive and intensive systems could be made across species.  However, specific systems generally differ sufficiently among species to make such comparison invalid, or at least difficult to interpret.

Question 4 asked what techniques and standards were available to determine and address the effects of the system on animals in Minnesota and other places.  This question was straightforward but difficult to answer in a direct, specific manner because such data are generally not available.  Relatively recent efforts through the National Animal Health Monitoring System provide a growing database.  As the name implies, the focus of this system is animal health.

**QUESTION 5.**

This question was also straightforward.  It was relatively easy to summarize available preventive and mitigative measures for addressing negative effects on animal health and general aspects of animal well-being (animal comfort, physical stress, etc.).  This occurred in part because the industry responds quickly to address aspects that are detrimental to animal health performance.  Considerable less is known relative to the cognitive aspects of animal well-being.

# INTRODUCTION

### ANIMAL HEALTH AND WELL-BEING

Caretakers of animals used to produce food and non-food products for human consumption have long recognized the need and value of ensuring the health of their animals. Most animal caretakers are sensitive to the health and safety of their animals and they have many reasons to do so (Ewing; Lay, and von Borell 1999). There are many obvious negative impacts of unhealthy animals on an animal unit including less efficient production, greater inputs of time, money and treatments required to return animals to a healthy condition, and reduced economic returns to the producer. The multiple detrimental consequences of unhealthy animals quickly become apparent to the producer and this encourages producers to manage their animals to prevent many health problems from occurring. Other factors that affect aspects of overall animal well-being are more difficult to assess and receive varying degrees of attention. Society (both producers and consumers) is paying more attention to these aspects of animal care and is exerting pressure to influence current production practices.

Various animal health measures can be used to assess the overall or specific health of animals. These include measures of animal productivity (e.g., lbs. of milk produced per day, average daily gain), frequency of detecting clinical signs of sickness (e.g., diarrhea and weight loss, coughing and respiratory discharge), and results from specific tests (e.g., parasite burden, specific antibody to disease-causing agents). Although these measures are frequently used to assess overall health quality and usually provide adequate information, the incidence of animal health problems on any animal unit can be difficult to estimate due to inconsistent reporting, use of imperfect tests, variation in the diagnostic abilities of individuals, and presence of subclinical disorders. An ability to accurately assess animal health is required before effects of a production system or management style on animal health can be determined. Herd level animal productivity and health databases (PigCHAMP, DairyCHAMP, DairyCOMP 305, Dairy Herd Improvement Association (DHIA), Standardized Performance Analysis (SPA))are management tools that provide useful information to assist the assessment of individual herd health. National and regional assessment of disease incidence are available through the National Animal Health Monitoring System (NAHMS).

Healthy animals will not prosper if they are managed in an improper manner. Thus, management skills must do more than simply promote animal health. These additional management skills generally fall under the realm of animal well-being and are part of what has been called the "ancient contract between humans and animals". However, although there is good scientific and social consensus on the definition of physical health, the definition of well-being is more nebulous for both humans and other animals. Thus, as summarized by the Council for Agricultural Science and Technology (CAST 1997) several definitions have been proposed but no consensus has yet emerged for the definition of well-being of agricultural animals. This lack of a consensus definition

reflects the fact that there is inadequate information available to assess animal well-being (CAST 1997).

Despite this lack of a specific consensus definition of animal well-being, most agricultural animal scientists believe an acceptable level of well-being is achieved in most of the production systems on American farms (CAST 1997). The overall care provided to agricultural animals occurs in no small part because animal caretakers have a strong working knowledge of animal husbandry and recognize factors that affect animal comfort and normal behavioral patterns (Albright 1993a). However, as in any population, variation certainly exists among animal caretakers in their knowledge, understanding, and ability to practice proper animal care techniques and principles. New employees require proper training before they can effectively master the techniques of proper animal management. New knowledge results in modifications of old techniques and/or generates new techniques. Continued adoption of new, improved methodologies require continued upgrades in training of animal caretakers. Variation in facilities, operating methods, and animal species can make techniques more applicable to some livestock production units and less applicable to others. Throughout the livestock production sectors, there are training programs (see below) designed to improve the understanding and effectiveness of animal caretakers so they may provide proper animal care and enhance overall health and well-being of agricultural animals.

Although results of opinion polls are greatly influenced by the tone, structure and implied message of the questions asked, surveys indicate most Americans support the agricultural use of animals (Becker 1992), believe most producers generally provide humane treatment of their animals (Becker 1992). A more recent survey indicates consumers are concerned about and would like to prevent inhumane treatment of agricultural animals (HSUS, 1999). Many individuals also support governmental regulations to ensure the humane treatment of agricultural animals (Becker 1992). This new social ethic for animals, one that recognizes concern about all animals that suffer and not just those treated with blatant cruelty, has been discussed (Rollin 1995;Rollin 1996;Rollin 1996). Most in the livestock production industries recognize the need for continued improvments in the care of agricultural animals.

Many public and private organizations involved in livestock production have developed training manuals and programs designed to increase the proficiency of animal caretakers. Recently, swine extension specialists at major land-grant universities developed a training curriculum entitled "Farrowing House Management". This curriculum is designed to train animal caretakers in the proper management of sows and piglets housed in farrowing facilities. The curriculum is available in hardcopy and on the worldwide web through the National Pork Producers Council (www.nppc.org). Curricula for other phases of production are under development. Several private companies involved in large scale livestock production use training manuals that include Standard Operating Procedures (SOP's) for proper care of livestock in their operations.

**ASSESSMENT OF ANIMAL WELL-BEING**

Animal well-being has been described as a situation in which an animal exists within a range of acceptable environmental specifications and has been identified as the ultimate goal of farm animal use strategies (Ewing and others 1999).  In a relatively simplistic manner, farm animal well-being has been described as implying a reasonable quality of life and a gentle death (Webster 1989).  Additional criteria are clearly required to achieve a comprehensive definition of well-being.  A special committee report to the British Parliament (Brambell 1965) provided the framework for subsequent efforts to assess farm animal well-being.

A considerable lack of consensus remains among individuals attempting to assess the well-being of agricultural animals.  This may not be too surprising when one considers that the well-being of agricultural animals only began to have a significant public impact after Harrison (1964) wrote "Animal Machines"  and Singer (Singer 1975a;Singer 1990;Singer 1990) wrote "Animal Liberation: A New Ethics for Our Treatment of Animals".  Other summaries of the associated issues are found in Singer (1975), Mason and Singer (1980), Midgley (Midgley 1984), Regan (Regan 1983b), and Rowan (Rowan 1993).  The fact that much of the concerted effort to specifically assess animal well-being has only been initiated since 1990 contributes to the lack of consensus in this area (CAST 1997).

The difficulty in defining animal well-being is due in part to the different approaches taken to assess it and to the use, and implied meaning, of the various terms used to describe it.  For example, animal biologists tend to use the term well-being and frequently speak about it in context with the biological, physiological, biochemical and physical interactions of an animal with its environment.  Socio-behavioral scientists appear to favor use of the term welfare and include psychological considerations.  Scientists from similar disciplines also use a variety of definitions.  Some choose to describe this component of animal husbandry as the animal ability to cope with it's environment (Broom 1986) while others indicate well-being goes beyond the mere absence of disease and include the absence of discomfort and stress (Albright 1997).  Cultural differences also contribute to the confusion as Europe tends to favor welfare while the term of choice in North America is well-being (Ewing and others 1999).

Scientists attempting to assess animal well-being tend to be applied ecologists or applied ethologists (Gonyou 1994;CAST 1997).  Ethologists (Lorenz 1981) have developed ethograms for a number of livestock species in different conditions to use as standards for animal behavior.  Ethograms are catalogs of behavioral patterns that occur during the life cycle of an animal species.  Thus, an ethogram should (ideally) provide a benchmark against which one can measure deviations from normal behavior (Banks 1982).  Interpretation of these deviations are based on the assumption that an animal's behavior in a specific situation somehow reflects what the animal feels about that situation.  Thus, ethograms depend on a sound knowledge of an animal's behavior in a variety of conditions (Duncan, 1993; Fraser, 1993; (Gonyou 1986;Moberg 1985).

It was recognized early in the development of ethology that, to be really competent, the ethologist required a strong understanding of a variety of scientific fields (Klopfer 1974). This becomes increasing difficult and future advances will likely occur through extensive collaboration.  In addition, the extensive and detailed nature of ethograms make them difficult to develop for all species in all possible situations.  Consequently, they are of limited value in current production settings and will remain limited until a larger catalog of ethograms is available (Ladewig and Von Borell 1988).  The difficulty of assessing animal behavioral characteristics was recently highlighted when the behavior of well-characterized mice housed under defined laboratory conditions failed to match expectations and failed to agree among laboratory sites despite extensive efforts to ensure laboratory environments and stimuli were similar (Crabbe and others 1999). Nonetheless, these efforts have increased our understanding of interactions between animal behavior and the animals environment and continued efforts are warranted.

CAST (CAST 1997) provides a summary of scientific approaches used to assess animal well-being.  These approaches differ in emphasis with some being purely hedonic [relating to an animal's pleasure] (Bennett 1995), others purely cognitive [based on thinking, feeling, remembering, abstract presentation] and others based on only physical or physiological assessments (CAST 1997).  However, most attempts to assess animal well-being reflect a more moderate and inclusive approach.  Approaches that are based on multiple indicators (Smidt 1983) appear to be gaining popularity and are frequently based on some combination of agricultural, ethological, pathological, and physiological criteria.  Interpretations from these approaches also must be tempered because comprehensive multifactorial indexes have not yet been developed and because animal responses can vary considerably across genotype, age, gender, experiences and motivational impetus (CAST 1997).

A summary of this issue (CAST 1997) indicates that animal scientists and other agricultural stakeholders generally agree on six priority areas for research required to develop an improved assessment of animal well-being:

■ Bioethics and conflict resolution
■ Individual animal response to production environments
■ Stress
■ Social behavior and space requirements
■ Cognition
■ Alternative production practices and systems

Producers of livestock and their advisors often use easily measured traits as indicators of overall animal health and well-being.  For instance, the quantity of feed and water consumed by animals is often used as an indicator of the animals' condition.  These traits are routinely measured on farms and compared against some expected intake for that size and class of livestock.  If intake of feed and/or water are below the expectation, the animals' condition probably is compromised to some degree.  Many factors such as clinical disease, subclinical disease, high environmental temperatures, poor quality feed, and many others can reduce feed intake below the expected amount.  The factor

responsible for the low feed intake may represent a serious threat to the animal's health or merely a temporary uncomfortable, less-than-ideal environment. It could also be the result of a normal physiological process such as when a lactating cow experiences estrus and temporarily decreases the amount of feed she consumes. Clearly a sound animal husbandry background is beneficial, if not required, to accurately assess the factors responsible in any particular situation. A more complete understanding of animal health and well-being requires a coupling of this husbandry background with advances in ethological knowledge.

Social interactions among penmates and herdmates are used by some producers as indicators of animal well-being. Certainly, these observations provide important information about animal well-being in extreme cases (see behavioral vices below). However, in less extreme situations it is difficult for humans to interpret the significance of social interactions to the animal's well-being due to an incomplete knowledge of animal behavior. Active research programs are underway in some universities (including Purdue University and Texas Tech University) and the USDA Agricultural Research Service to fill this void of knowledge. Nonetheless, certain minimal aspects of animal health and well-being are generally accepted by society. Ewing and colleagues (Ewing and others 1999) summarize work in the UK that describe these minimal aspects as basic needs required for health and well-being. These include the need to be free from hunger and malnutrition, free from thermal or physical distress, free from disease and injury, free from fear, and the need to be able to express most normal behaviors (Webster 1989). Although society has chosen to restrict certain animal behaviors in the interest of management, population control, and liability, these needs can provide the conceptual basis for the design and management of animal units (Ewing and others 1999) and, if necessary, the modification of current management practices.

## ANIMAL WELL-BEING - BEYOND HEALTH

There are definite limits to what a literature review about animal well-being can tell us. The philosophy of science tells us that something that is, even in theory, impossible to measure is outside the realm of science. However, something that is difficult to measure is no less scientific than that which is easy to measure. Two possible implications of this are that animal well-being is a scientific issue (beyond simple measures of health) and that *standards* of animal welfare are not a matter of science. For example, Broom states: "The scientist and the non-scientist can have an opinion of where to draw the line between the morally tolerable and the morally intolerable." (Broom 1993). Determining the sufficient level of animal well-being is a socio-political (or moral-philosophy) question. Science, by its nature, can tell us "how much," but not "how much is enough."

The public opinion of the treatment of animals has evolved with time and is fundamentally a social construction (McInerney 1996). That is, it cannot be grounded in any fixed measure of acceptable treatment because the acceptability of any treatment changes with the existence of alternatives and changing human sensibilities. The External Benefits and Costs Report (section F of the overall GEIS) provides further

discussion about these results and the potential economic significance of people being unhappy about animals' situations.

An extensive discussion of animal well-being philosophy, let alone an examination of current socio-political motivations, was not requested in the GEIS Scoping Document. However, just as a basic overview of the underlying principles of economics or water quality is needed for other reports in the GEIS, it is valuable to set the stage in this area too. It is especially worthwhile to examine the origins of animal well-being (or welfare) because the area frequently generates controversy. This controversy is largely attributable to the fact that animal well-being involves both science and social preferences.

Several books are particularly important for establishing the case for animals as interested parties, rather than simple objects, in the production process. Singer's (Singer 1975b) *Animal Liberation* presents the utilitarian case for consideration of animal well-being. Regan's (Regan 1983a) *The Case for Animal Rights* presents the case from a rightists perspective. Midgley's (Midgley 1983) *Animals and Why They Matter* and Mason and Singer's *Animal Factories* [1980] are less well-known but provide critical arguments in the field.  Other works present extensive discussions of animal consciousness and pain underpinning those characteristics of well-being (Langley 1989;Rollin 1998). Others chronicle the development of modern concern about animals (Finsen and Finsen 1994;Regan 1987;Walters and Portness 1999). Rollin's (Rollin 1995) *Farm Animal Welfare: Social, Bioethical, and Research Issues* is particularly comprehensive, offering a definitive summary of the issues surrounding the welfare of farm animals in terms of breadth and depth. It addresses the importance of the well-being of animals, especially farm animals, in the minds of the public. It covers each of the major farm species, including cows (beef, dairy, and veal), chickens (layers and broilers), and pigs. It explores the various perspectives of animal well-being issues that get particular press and popular attention, such as "downer" cows, veal production, and transportation practices, as well as less visible issues such as forced molting in layer hens and farrowing crates in pigs. When possible, alternatives to these practices are identified, as are areas where further investigation for alternative protocols is needed

The bulk of the Animal Health report is based on the premise that high levels of productivity from farm animals (and the closely related absence of diagnosable morbidity) are sufficient evidence that animals are well cared for and have an acceptable level of well-being. In many – but not all – ways, animal productivity and well-being go hand-in-hand. Most productivity measures are very likely to be positively related to animal welfare (Ekstrand, 1997). There is a lot to be said for basic non-morbidity and protection from gross adversity (as well as for measurability). Furthermore, one possible interpretation of the animal health questions in the GEIS is that health as it is measured by productivity is exactly what this report is about. Nothing in the Scoping Document clearly contradicts this interpretation.

However, many observers point out that productivity is not a sufficient measure of animal well-being. Measures of productivity may only indicators of lowered welfare, rather than

indicators of good welfare, and thus should be combined with other measures (Baxter, 1989).  Duncan (1993) points out that welfare has to do with what sentient animals feel, and offers what he calls the "pine tree" test of supposed measures of animal welfare – if the measure can be applied sensibly to pine trees (as can health, absence of stress, and biological fitness) then it is not actually measuring welfare.   Attempting to measure well-being through proxies that are easily measured has clear advantages, but it does not mean that what is being measured is actually welfare.  Much of the literature in the field that measures things that are legitimate *proxies* for or *contributors* to welfare implicitly makes the ungrounded claim that the factors being measured *are* welfare.  But there is no reason to accept the validity of this equation when it is not based on socially defined notions of what we really want to measure when we consider well-being [Rutter, 1995].

The literature frequently suggests that the proxy measures are more scientific than (and thus superior to) intuitive notions of well-being.  Indeed, uncritical appeals to intuition can go astray and are no substitute for the best possible research of things measurable.  But this does not mean that intuition should be dismissed out of hand, nor that empirical science does not often lead us astray or contain embedded socio-political agendas.  It is most people's intuition that other animals are bothered by many of the same things humans would be bothered by.  Studying something by drawing analogies to the most similar system that we do understand is a typical and well-respected method in the natural sciences, including life sciences. Indeed, it is the bedrock of a huge portion of scientific research.  In the animal well-being literature this approach is even given a label, "the analogy postulate" (Alban and Agger, 1997).  As a jargon-free description, we can simply say that good science is generally aided, not degraded, by common sense.  In the social sciences, the issue is even clearer.  If people are concerned about something, then it is real -- emotion *is* reality when it comes to valuing something economically (Frank, 1991).

It is obvious that sometimes productivity and well-being are inversely related.   An example is the stress associated with persistent, prolonged overcrowding that prevents the animal from engaging in virtually all of its natural behavior, as is the case in some confinement facilities.   Other activities that cause acute temporary pain, such as administering vaccines, have obvious positive effects on long-term well-being (and are similar to what we do for human children).  Other situations fall in the middle of these extremes.  This is where the interpretation of potential effects on animal well-being become more controversial.  Examples include the immediate separation of a newborn dairy calf and its mother (the dam) or the removal of body parts (chickens' beaks, pigs' tails) without anesthesia in order to reduce the negative effects of subsequent behavior.  Appealing to the closest model that we do understand – human well-being – suggests that a valid starting assumption is that many such activities lower animal well-being (until and unless proven otherwise, of course).

As described in a subsequent section of this report (Routine Practices), the literature reports that practice of separating the dairy calf and dam soon after birth facilitates the transition of the cow and the calf to the production environment, and contends that both appear to adjust rapidly, and neither suffers any apparent long-term effects.  However,

this practice raises the question of the relative magnitude of distress and whether this represents a significant compromise of animal well-being. The philosophy of current management practices is that restriction of this aspect of animal behavior represents a temporary, justifiable, minimal distress that is imposed to facilitate long-term management goals.  Can we quantify the magnitude and consequences of this practice to animal well-being?  Will society consider this practice too detrimental and choose to pay a potentially increased price for dairy products to eliminate this practice?  Answers to these questions for this practice and for other currently routine management practices are generally lacking.

A wide variety of indicators of animal well-being and suffering have been proposed and examined.  Some, but not all of these are discussed in specific applications elsewhere in this report.  These include vocalization [Braithwaite et al., 1995; Leppelt and Marx, 1995; Marx, 1995; Weary et al., 1998; Weary and Fraser, 1995], habitual biting and chewing [McGreevy and Nicol, 1995], various forms of violence toward their fellows [Kjaer, 1995], heart rate [Uetake, et al., 1995], multiple manifestations of stress and diversion of resources [Dantzer, 1993; Moberg, 1993], coping behavior [Broom, 1998], pain perception mechanisms [Rose and Adams, 1989], cognition and related manipulation of their surroundings [Dawkins, 1988; Nicol, 1995; Kiley-Worthington, 1993; Duncan and Petherick, 1991], play behavior [Jensen et al., 1998], true feelings/emotional expressions/friendships [Duncan, 1996; Wiepkema et al. 1993], integrative examination of emotional, motivational, and cognitive factors [Mench, 1993], preference as indicated by choice or expenditure of resources to acquire a good or situation [Dawkins, 1980; Faure, 1986; Lagadic and Faure, 1987; Fraser, et al., 1993], and, of course, various measures of production (growth, food consumption, lactation, etc.).

It is indeed telling that this list is similar to how we judge the well-being of human children and even adults under some circumstances.  This similarity is frequently described as attributing human characteristics (desires and feelings) to that which is non-human (anthropomorphism).  Though often used as an accusation of non-scientific behavior in the literature, "anthropomorphism" is more-or-less a synonym for "using the best available model for animal well-being, namely human well-being."  There is not a morphological or physiological determinant of suffering in humans, but most people believe that human suffering is possible [Rose and Adams, 1989].

Most of the articles cited in the previous paragraph are quite conservative in withholding assignment of unproven abilities to animals, and many present standards of well-being that might be considered "weaker" than production-oriented definitions.  The only thing remotely unifying all these different approaches is that they imply dissatisfaction with indirect measures of well-being, such as productivity .  As with production-oriented measures, most of the literature on well-being focuses on management skill and practice rather than size and type of operation.  It is not obvious from the literature whether this is because management is so much more important than other factors in all types of operations or just because the findings are only likely to change management practices and not fundamental decisions about operation size.  The research that actually measures indicators of well-being is largely reductionist in that it has looked at experimental

settings rather than considering animal "lifestyles" as a whole.  Reductionist experiments can be much easier to conduct and may produce cleaner results, but they can result in major gaps in our understanding.  Studies that have a broader, more comprehensive design and include a mixture of scientific fields (including ethology, which has inherent similarities to human ethnology) may offer deeper insights.

**THE IMPORTANCE OF MANAGEMENT**

The overall care provided to agricultural animals occurs in no small part because animal caretakers have a strong working knowledge of animal husbandry and recognize factors that affect animal comfort and normal behavioral patterns (Albright 1993a).  This working knowledge provides an understanding of animals and results in husbandry practices that achieve and maintain health, general well-being and productivity (CAST 1997).  This may or may not provide an overall acceptable level of well-being as (or if) society's perspective changes.  A variety of guidelines based on this accumulated knowledge for the proper care of agricultural animals have been published (Canadian Agri-Food Research Council 1998;American Veal Association 1994;National Pork Producers Council 1996;National Cattlemen's Beef Association 1997;National Turkey Federation 1997).  The Guide for the Care and Use of Animals in Agricultural Research and Teaching (Federation of Animal Science Societies 1999) outlines standard management practices that are followed by agricultural universities and research institutes throughout the U.S.

Agricultural animals of today are considerably different than their predecessors.  Contemporary agricultural animals evolved from those that had traits favorable for domestication.  These traits include agreeable temperaments, readily adaptable to new environments, ability to live in groups, weak mate bonds, and delivery of precocious [exhibit mature qualities (locomotion, feeding, etc.) soon after birth] offspring (Craig and Swanson 1994).  Domestication and selection for particular traits of economic importance have modified some of these characteristics and have resulted in animals that have specific environmental needs.  Management of these animals must be based on their specific needs, not the needs of their predecessors or of humans (Craig and Swanson 1994;Siegel 1995;Siegel 1995).  Thus, the continued selection for desirable traits through selective matings and through genetic modification and the use of metabolic modifiers (such as steroid implants and somatotropin) require that the assessment of management techniques relative to animal care be an ongoing process (Gonyou 1994).  Producers that fail to improve their management skills to meet the increased needs of contemporary animals may be reducing the well-being of their animals.

Some animal scientists have argued that livestock breeding practices that select primarily for traits of economic importance have compromised the "fitness" of modern, commercial agricultural animals. (Rauw and others 1998).  They cite the Resource Allocation Theory of Beilharz et al. (Beilharz and others 1993) as evidence for this lack of fitness. The Resource Allocation Theory suggests that animals continuously selected for traits that increase production of products (meat, milk, eggs, wool, offspring) will be less able to cope with stressors such as disease or adverse environmental conditions when

they are encountered.  The theory predicts these animals will have difficulty coping with additional stressors because most of their resources (feed nutrients, body stores of nutrients, metabolic processes) are programmed to produce products.  The final result according to is presumed to be an increased incidence of disease or pathological conditions that presumably compromise animal well-being (Rauw and others 1998).

However, it is becoming increasingly apparent that the biological processes within the body, the metabolic function of the various body organs, do not compete with one another for available resources but instead function in a coordinated manner to benefit the animal.  The concept of homeorhesis (Bauman and Currie 1980) has been described as the ability of the animal to adjust its biological processes in a manner that supports a dominant physiological function and preserves animal health and  well-being.  Several good examples exist (Bauman 1999) but perhaps the best example is the high producing dairy cow.

The contemporary cow produces considerably more milk than her distant ancestors and nearly twice as much milk as cows did 40 years ago.  For example, Minnesota cows produced an average of 10,022 pounds/lactation in 1956 and 18,920 pounds/lactation in 1998 (MN-DHIA 1999).  Despite this tremendous increase in productivity and the increased metabolic activity associated with milk production, the contemporary cow compensates (just as her ancestors did) by reducing the quantity of milk she produces when she is confronted with adverse environmental conditions, poor health, or poor management.  She also decreases her milk production when she becomes pregnant.  The physiological adaptations of pregnancy result in the diversion of nutrients away from milk production and toward those processes that support fetal growth and development.

These alterations clearly indicate the biological mechanisms within the contemporary high-producing cow continue to function in a coordinated manner to support the dominant physiological function.  The fact that the cow decreases the quantity of milk she produces when confronted with less than ideal conditions clearly indicates that selection for milk yield has not made the cow an appendage to her mammary gland and does not force the cow to produce milk at the expense of her health, well-being and survival.  Instead, the homeorhetic mechanisms continue to coordinate her overall metabolic processes and physiological functions.

Thus, as described by Bauman (Bauman 1999), the suggestions by some (Rauw and others 1998;Broom 1999) that genetic selection results in stressed animals that have "their normal biological functioning controls are overtaxed" (Broom 1999) fail to recognize that genetic selection is successful because it results in improvements in the biological control and coordination of mechanisms in the entire animal.  To do otherwise would result in a non-sustainable biological system and would indeed be detrimental to animal health and well-being.  These observations magnify the importance of developing management systems that match the genetic potential of livestock to the environment within which they are housed.  This is discussed in more detail in subsequent sections of this literature review.

As in any effort, a range of abilities exist among individuals involved in animal agriculture. This contributes to easily recognizable instances where animals have not received adequate care. This variation in care is not limited to any particular type of production system. Poor to excellent care can occur in small to large units, in extensive to intensive units, and in grazing to confinement units for any animal species. As in other endeavors, continued acquisition of knowledge and experience plays an important role in improving performance. For animal agriculture, this continued acquisition of knowledge includes a wide variety of topics including health, physiology, nutrition, behavior, environment, and facility design.

The production system plays a very important role in determining the health and well-being of the animals. The design of the production system provides a physical layout or structure which dictates what management practices are required to meet the basic needs of the animal. Production systems provide for those needs in different ways. For example, protection from predators is essentially guaranteed in confinement systems by placing animals inside a building that excludes predators. This form of predator protection is very effective. In outdoor systems, predator protection is accomplished with extensive fencing, companion animals that act as guards (dogs, donkeys, llamas), and mechanical devices (pop guns). These predator protection measures may or may not be effective. Other aspects of aniaml care are more difficult to provide in confinement systems (see below).

Similar to predator protection, the production system determines the methods required to influence or control the environmental conditions (temperature, humidity, wind, precipitation) to which livestock are exposed. Windbreaks (natural or manmade), offering more feed, providing bedding material to act as insulation, and group housing are all methods of combating cold weather for animals housed outdoors in extensive production systems. In confinement systems, supplemental heat from furnaces and air flow (ventilation rates) from fans (usually) are used to obtain a temperature previously determined to be ideal for a given size and class of livestock (Jacobson and others 1985).

Regardless of the production system, management is the key to ensuring good animal health and well-being. A properly designed system operated with poor management will likely compromise animal health and well-being. For example, if animals are provided bedding material to combat effects of cold weather in an outdoor system but the bedding becomes wet and is not replaced, the animals will become chilled, uncomfortable, and likely will be more susceptible to disease. Although the system was designed properly, a management error (not replacing the wet bedding) compromised animal well-being. Another example of a properly designed system operated incorrectly can occur in confinement barns when ventilation rates are reduced in winter to conserve heat and keep animals warm. If the reduction is too severe, air quality in the barn can be compromised. Poor air quality could foster respiratory diseases in the confined animals.

Management decisions have a large influence on the ability of the system to provide for animal health and well-being. A production system is only as good as the management used to operate the system. Excellent systems can be managed improperly and be

detrimental to animal health and well-being.  In poor systems, animal health and well-being can be improved through appropriate modifications in how the system is managed. Management strategies need to be directed towards the specific operation, regardless of whether the system is intensively or extensively managed, or the facility is large or small. Given the important interactive roles of facilities and management in determining health and well-being of production animals, considerable research efforts will continue to be focused towards development of new strategies that improve animal health, well-being and productivity.

Most agricultural animals eventually leave the animal unit for slaughter and harvesting of food and non-food products.  Caretakers are becoming increasingly aware of the need to ensure animal well-being after the animal has left the production unit.  Many of the factors that contributed to reduced animal well-being during handling, transporting, and slaughtering can be and have been corrected through appropriate training of individuals involved in these tasks (Grandin 1994a;Grandin 1994b;Grandin 1994c;Grandin 1994c;CAST 1997).  Areas that require additional research include long-distance transport and the handling of excitable animals (Grandin 1993;Grandin 1996). Improvements in equipment design and animal handling facilities (Grandin 1993) will make quiet humane slaughter of farm animals easier to achieve.  Difficulties with situations such as the downer cow have been improved but identify that continued improvements in the handling, transportation, and slaughter of farm animals would improve animal well-being.

The well-being of animals that must be destroyed prior to slaughter due to injury or chronic disease that is unresponsive to treatment must also be maintained.  The National Pork Producers Council (NPPC) has developed a pamphlet that describes humane methods available to euthanize swine on farms (National Pork Producers Council 1997). These guidelines are based on standards for euthanasia developed by the American Veterinary Medical Association (AVMA 1993).  The Canadian Council on Animal Care (CCAC) has developed similar guidelines for humane euthanasia of animals (CCAC 1993).

## CONFINEMENT SYSTEMS

Animal health and well-being are influenced by a broad array of factors.  Some factors are controllable by the caretaker (stockperson, livestock producer) while others are not. Production system and management abilities of the livestock producer are two very important factors that have a large influence on animal health and well-being.  Systems for livestock production in Minnesota range from fairly extensive systems in which the animals spend most if not all of their life outside to intensive, environmentally-controlled, confinement systems that house animals indoors throughout their life.  To more clearly appreciate the potential impacts of confinement systems on health and well-being of animals, an understanding of what indoor confinement is and why it evolved is beneficial.

Prior to the 1960's, practically all livestock were raised in some type of outdoor system. Typically, some type of shelter was provided to protect animals from the harshest

environmental conditions.  Livestock producers planned production schedules based on seasonal changes in weather and feed availability.  This in turn created seasonality in the quantity of retail animal products that were available to the end consumer.  The daily work of caring for livestock was physically demanding due to a lack of mechanization in feed processing and handling, removal and distribution of animal manure, animal handling and restraint, and fencing.  The hard work and high labor requirements limited the number of animals one person could properly maintain.  Cold and snow during winter and rain with associated mud during spring made caring for livestock outside difficult.  Environmental conditions during parts of the year were very uncomfortable for the animals and their caretakers.

Livestock producers started to exert greater control over environmental conditions for housing livestock in the late 1950's and early 1960's by moving livestock indoors.  Indoor confinement systems were developed to provide producers greater control of the environment that housed their livestock.  Indoor confinement systems usually

■ house animals at a greater density than is typical of outdoor systems;

■ maintain a targeted room temperature by capturing heat radiating from the animals, and/or providing supplemental heat with furnaces in winter and providing mechanical cooling systems in summer; and

■ control quality of air in the building with a ventilation system that relies on exhaust fans and/or strategic control of openings to allow outdoor air to enter the barn.

Targeted conditions inside the barn vary depending on the species and age/size of the animal.  By-products, such as manure, urine, wasted water, and wasted feed, can be handled as a liquid slurry collected under perforated floors or as a solid that includes bedding material collected from solid floors.  Confinement systems concentrate these by-products in one location and generally provide more control in collecting and managing these waste products than is possible with less intensive operations.  This concentration of waste products requires a greater management effort but also provides the economies of scale to properly address the issue of waste management, something that is more difficult to achieve with smaller units.

Producers of the nonruminant species of livestock (swine and poultry) rapidly adopted intensive, indoor confinement systems such that the vast majority of current production of these two species is in confinement facilities.  Producers of the ruminant species (dairy cattle, beef cattle, and sheep) with the exception of dairy cattle have been slower to adopt the confinement model of production.  Presumably, swine and poultry were moved into confinement production barns because their rapid and efficient growth does not require that grass, hay or other forages be provided in the diet.  Hence, there is no strict nutritional requirement for pigs or poultry to graze forages and no need for the large land base required for forage production.  Effects of housing and intensive and extensive production conditions on animal well-being and economics have been evaluated (Barnett and others 1984;Curtis 1993;Lyons and others 1995;Waterhouse 1996).

Indoor confinement systems address many of the challenges associated with outdoor production systems.  Increased animal density allows one person to care for more animals than was previously possible.  More uniform production of livestock can occur year round with a reduced seasonal influence.  Production flow can be scheduled and tightly controlled to increase biological efficiency.  The increased biological and labor efficiency compared with outdoor systems allow indoor confinement systems to be profitable despite the high capital costs of constructing environmentally controlled barns.  In addition, stockpersons are indoors and not exposed to challenging environmental conditions in winter and spring.  They are also indoors during the nice weather of summer and fall and are exposed to the same environment as their animals (see the Air Quality section of this report and the Air Quality Report - Topic H).

The typical minimum standards of acceptable health and well-being criteria include adequate nutrition, freedom from environmental stress, and lack of disease, injury, and pain (Smith 1989).  Other identified criteria include general behavior, cognition, and satisfaction of non-nutritional desires (Klopfer 1974;Broom 1999).  One of the main criticisms of confinement systems is that they deny normal animal behavior.  This is true in some cases.  This evaluation must be placed in context with other animal health and well-being criteria when comparing alternative husbandry systems.  The interaction of these criteria was exemplified by research conducted in the UK that evaluated free-range and confinement laying hens.  Although allowed access to go outside, half of the 'liberated' hens choose to remain inside.  This behavior was presumed to be caused by the natural behavioral instinct of the birds to seek somewhere to hide and take cover from potential predators.  Free-range birds also exhibited increased aggression which led to cannibalism and mass hysteria to perceived outside threats such as crows and passing helicopters (Webster 1989).

The confinement system in this study was also viewed as less than ideal.  Concerns of the confinement system focused on poor physical comfort, the prevalence of osteoporosis, bone fractures, and deformed feet caused by the restricted space (70 sq inches/bird) provided by multi-occupancy cages (battery cage).  In addition, the absence of a nesting site and nesting materials caused apparent bird frustration and abnormal anti-social habits such as feather-pecking.  These concerns prompted proposed changes in the late 1980's to increase the space allowance by 45%, and provide a suitable nest and perch (Webster 1989).  Some European countries have increased the minimum space allowance for laying hens and others have banned battery cages altogether.  Several alternative systems for laying hens are being investigated in Europe.  These vary from an intensive system which includes a modified battery cage with perches, dustbaths and nestboxes (the Edinburgh cage) to extensive systems such as aviaries, straw yards, and free range (Mench and Siegel 1997;Appleby and others 1992;Appleby and Hughes 1995).  It is still being debated if the more extensive alternative systems will prove to be economically viable and to result in improvements in animal well-being.  A major difficulty with extensive systems is the enhanced aggressive behavior patterns exhibited under free range conditions.  In Britain, free-range eggs cost 50% more to produce than cage eggs and this is primarily due to increased labor costs per egg produced.  Use of a careful balance of intensive and extensive systems has been suggested (Mench and Siegel 1997).

In some instances, a compromise of indoor and outdoor husbandry is beneficial to meet the seasonal needs of animals. An example would be the provision of winter housing for breeding ewes. This housing provides shelter for newborn lambs and provides improved access to proper nutrition and health programs. The sheep flock is subsequently pastured throughout the summer months. Breeding ewes housed outside during the winter frequently are exposed to muddy paddocks, inconsistent nutrition and potential threat from dogs or other predators (Webster 1989). The use of winter housing reduces lamb mortality and can increase the net economic return to the farm.

Increased animal density associated with confinement requires improved management skills to meet the needs (nutrition, health, well-being, etc.) of the contemporary animal. Because contemporary animals produce more than their ancestors, their specific needs, and the management required to meet these needs, also differ. Genetic potential, housing, production system, and other factors interact and impinge on the health and well-being of the contemporary animal and the profitability of the farm. Thus, it is difficult to compare specific items such as animal health and well-being across a variety of farms. For example, there is a perception that the average veterinary and medicine costs for dairy cows in confinement exceed those of cows that are grazed and that this must reflect a negative impact of confinement on animal health and well-being. However, a specific comparison of the medical expenses for these diverse management systems appears to be lacking. This is especially true when one seeks information on individual health expenses across a variety of production systems. Use of total health costs per animal within a system can provide a certain indication of the relative health and well-being status of animals in a particular unit, especially over time within a unit. Although also useful to compare health and well-being across units, total health costs can frequently provide misleading information. For example, special biosecurity health measures and the practice of preventative medicine to minimize health problems are an increasing priority for livestock systems. Producers using confinement systems may spend more on disease prevention which would increase their total medical expenses but would likely (should) result in an overall greater health status of their animals.

Animal health and well-being considerations are size neutral for both indoor and outdoor systems. Since their inception, the size and scale of indoor confinement systems has continued to increase. Increased size allows these production units to capture economies of scale and spread their large fixed costs of facilities over more production units. Rising input costs with static commodity prices have squeezed profit margins for livestock producers over the last 30 or so years. One response to these shrinking margins is to increase biological efficiency and output. Large-scale production units compensate for slim margins with increased output to generate the desired income. While a large unit may be more likely to capture benefits associated with economies of scale compared with a smaller unit, being large does not guarantee profitability. Large units are less able than smaller, less capitalized units to respond to changes in market conditions. Similarly, size of the production facility does not automatically infer a particular state of animal health and well-being. The perception that extensification of livestock systems is synonymous with animal well-being and that intensification is synonymous with animal abuse is a myth (Webster 1989). The decision by society and/or by individuals to use animals

(labor, recreation, etc.) and to consume the products they produce (meat, milk, eggs, etc. requires steps to ensure that the health and well-being of these animals is adequate and consistent with societal norms and expectations.  In order to achieve and maintain these norms, society needs to have an understanding of where and how their food sources are produced, have an active invovement in the process, and intervene if and when necessary.

## RULES AND REGULATIONS

**INTRODUCTION**

One of the first Federal laws protecting animals against cruelty or abusive treatments was the Twenty-Eight Hour Law of 1873. This law was intended to insure that livestock being transported to market would be rested and watered at least once every 28 hours during their journey. As in Europe, it was not until much later that other specific Federal regulations and standards were put into law. In 1958, the Humane Methods of Livestock Slaughter Act (7 U.S.C. 1901) was enacted. The Act stated that "The Congress finds that the use of humane methods in the slaughter of livestock prevents needless suffering". In 1966, the Laboratory Animal Welfare Act (7 U.S.C. 2131) was passed that set standards for use of animals in biomedical research. The Animal Welfare Act was amended in 1970, 1976, 1985, and 1990. The Act requires that "minimum standards of care and treatment be provided for most warm-blooded animals bred for commercial sale, used in research, transported commercially, or exhibited in public".

Minnesota animal agriculture is regulated by an extensive group of laws developed by the federal and state government. Animal caretakers and farm businesses are subject to laws and regulations that cover many aspects of animal agriculture, including those that deal with animal health and well-being. Our review of the statutes, rules and regulations has included extensive research on both federal and state legislation for all sections that relate to livestock. We have specifically focused on the main agricultural animals of Minnesota: dairy and beef cattle, swine, poultry, sheep and horses.

As with all law in the United States, the highest level of legal authority governing animal agriculture rests with Federal Statutes. There are more than ten (10) Federal Statues that directly relate to animals raised for food or fiber in agricultural settings. At the next lower level of regulation, the Code of Federal Regulations (CFR) takes effect, with many volumes related to animal agriculture. After that, Minnesota State Statutes add to the scheme, followed by the Minnesota Code of Agency Regulations or, as they are commonly referred to, the "Minnesota Rules".

The "Animal Welfare Act" (Animal Welfare Act. ) (7 U.S.C. et. seq. 1970 as ammended) is the federal government's principal law protecting the welfare and well-being of animals. It provides that animals covered under the act be provided with "humane care and treatment", that "animal pain and distress are minimized", and that animals be given the services of doctors of veterinary medicine whenever necessary. The Act was first passed in 1970 and has been amended since its initial passage.

However, animals raised for food or fiber, the animals of animal agriculture, are specifically <u>excluded</u> from the Animal Welfare Act and the regulations promulgated thereunder. The farm animal exclusion states:

> "…but such term excludes horses not used for research purposes and other farm animals, such as, but not limited to livestock or poultry, used or intended for use as

food or fiber, or livestock or poultry used or intended for improving animal nutrition, breeding, management or production efficiency, or for improving the quality of food or fiber (7 U.S.C. 2132)."

Thus, farm animals are excluded from the primary federal law protecting the welfare of animals. This exception plays an important role in legislation applicable to farm animals. Therefore, while the Scoping Document does not specifically define the terms "animal", "animal agriculture", "livestock", "poultry", or their related terms, it is clear that, for purposes of this literature review, the Animal Welfare Act does not apply. However, it should be noted that Minnesota animal welfare laws do not necessarily make the same distinction as the federal act (covered in following sections).

## FEDERAL STATUTES

The United States federal statutes are contained in the United States Code (U.S.C.), a Fifty (50) volume set of titles. Title Seven (7) of the U.S.C. entitled "Agriculture" and Title Twenty-One (21) entitled "Food and Drugs" contain most laws related to animal agriculture. Federal statutory law covering animal agriculture is centered on, but not limited to three specific areas: (1) drugs/controlled substances, (2) transportation/slaughter, and (3) marketing.

For animals raised for food or fiber, federal law has a fairly large number of statutes and regulations relating to the use of drugs on the animals. Principal examples of these federal statutes referenced by popular name are the following:

Animal Drug Availability Act of 1996 ( Pub.L. 104-250, 110 Stat. 3151) (Animal Drug Availability Act. (1996))

Animal Medicinal Drug Use Clarification Act of 1994 (Pub.L. 103-396, 108 Stat. 4153) (Animal Medicinal Drug Use Clarification Act (1994))

Food, Drug, and Cosmetic Act of 1938 (21 U.S.C. 301) (Food 1938)

Generic Animal Drug and Patent Term Restoration Act of 1988 (Pub.L. 100-670, 102 stat. 3971) (Generic Animal Drug and Patent Term Restoration Act )

Virus-Serum-Toxin Act of 1988, ( 7  U.S.C. 851) (Virus-Serum-Toxin Act ) and,

Swine Health Protection Act of 1980, (7 U.S.C. 3801) (Swine Health Protection Act )

These federal statues cover activities on three areas of drug use in animal agriculture: (1) testing and approval for use of new drugs, (2) appropriate use of drugs on the farm, and (3) use of drugs/controlled substances in animal feed.

Federal statutory law covering the means of transport of farm animals are based on the federal preemption granted under the "Commerce Clause" (Article 1, Section 8) of the United States Constitution. The principal statutes are "Livestock Transportation Act of

1995" (49 U.S.C. 13501) (Livestock Transportation Act ) and the "Packers and Stockyards Act of 1921" (7 U.S.C. 182) (Packers & Stockyards Act ).

Related to transport, marketing, and sale of food and fiber animals are the   Humane Methods of Livestock Slaughter Act of 1958" (7 U.S.C. 1901), the "Agricultural Marketing Act of 1929"  (12 U.S.C. 1141) , the "Livestock Bankruptcy Act of 1935" (49 U.S.C. 246) (Livestock Bankruptcy Act ), the "Anti-Hog-Cholera serum and Hog-Cholera virus Act of 1935" (7 U.S.C. 851), and the "Horse Protection Act of 1970" (15 U.S.C. 1821) (Horse Protection Act ).  As to slaughter, Congress stated:  "It is therefore declared to be the policy of the United States that the slaughtering of livestock and the handling of livestock in connection with slaughter shall be carried out only by humane methods".  Congress has not, however, extended the requirement of humane treatment to these same animals while they are being raised on the farm.

Federal tax law also affects animal agriculture.  The federal statutes on taxation, the Internal Revenue Code (I.R.C.), is contained in Title 26 of the U.S. Code.  An important section of the Code for producers is Section  1231 (26 U.S.C. 1231).  Section 1231 of the I.R.C. defines "property used in the trade or business and involuntary conversions."  Under subsection 1231 (b) (3) "Livestock" including "cattle and horses" are "property" used in the trade of business of farming.  The live animals on the farm are considered no differently than crops.  The animals can be depreciated, and capital gains and losses are applied to them.  The animals on the farm are another business commodity, much like cars,  paper, steel or any other business product.

The Federal Acts cited above, under the auspices of the United States Department of Agriculture, have commenced activities designed to promote agriculture, including animal agriculture.  These Statutes, and the regulations promulgated thereunder, are examples of government policies that directly affect animal agriculture.  In fact, some of the sections promote different species of agricultural animals.  An example is the National Poultry Improvement Plan, which is discussed later in this report.

Another example of marketing is pork promotion.  Congress has stated:  "Congress finds that pork and pork products are basic foods that are a valuable and healthy part of the humane diet...pork and pork products must be available readily and marketed efficiently to ensure that the people of the United States receive adequate nourishment" (7 U.S.C. 4801).  Sheep are also included in the regulatory marketing scheme.  About sheep Congress has stated:  "Congress finds that sheep and sheep products are important goods" (7 U.S.C. 7101).

The Federal Statutes cited above comprise hundreds of pages in the United States Code, and are often enabling statutes.  The Rules and Regulations promulgated under the authority of these enabling acts comprise many thousands of pages in the Code of Federal Regulations (CFR).  The United States Department of Agriculture (USDA) and the Food Drug Administration (McChesney and others 1995) have primarily promulgated these Federal Rules and Regulations.

The CFR consists of volumes containing section 1.1 through 4287.200. For purposes of a literature search relating to animal agriculture, CFR volumes Seven (7), Nine (9), and Twenty-one (21) are most applicable (CFR ;CFR ;CFR ). Sections of these volumes are used to make applicable the requirements and purposes of the Federal Statutes to everyday life on the farm. Caretakers of animals are required to comply with the regulations.

The sections of CFR relating to animal agriculture are lengthy. CFR Title 7, entitled "Agriculture" contains most of the regulations used by the USDA regarding animals on the farm. These include regulations for the marketing of animal products. The USDA performs most of its regulatory duties through its division of Animal and Plant Health Inspection Services (APHIS) which is set out in CFR Title 9 "Animals and Animal Products". Examples of APHIS activities include:

**Animal Welfare:**

As discussed above, the Federal Animal Welfare Act itself does not regulate animal agriculture. Code section 9 CFR 3, implements much of the requirements and purposes of the Animal Welfare Act. This CFR section contains Subpart F and Subpart F covers warm-blooded animals other than dogs, cats, rabbits, etc. Thus, Subpart F does regulate farm animals and places requirements on the animal caretakers in some circumstances. Subpart F contains sections that relate to transportation and requires a number of criteria (safe ambient temperatures, ventilation, lighting, etc.) for animal well-being. A thorough discussion of the common management systems and practices used to comply with these federal regulations are discussed later in this report.

**Livestock:**

This includes horses, mules, zebras, cattle, bison, sheep, swine, and poultry. As described in Code section 9 CFR 71, APHIS has extensive regulations concerning these animals. The regulations in this section cover diseases such as scabies, pseudo-rabies, anthrax, and many other communicable diseases. In addition, the regulations also cover many other areas related to these animals, including testing by veterinarians; sanitation conditions in yards, pens, trucks, trains, boats, and other facilities; disinfection requirements; and recordkeeping.

**Cattle:**

Section 9 CFR 72 describes extensive regulation over cattle infested with ticks and tick fever.

**Swine and Poultry:**

Title Nine (9) of CFR also contains the National Poultry Improvement Plan regulations (discussed below), the Swine Health Protection regulations, the Rules under the Virus-Serum-Toxin Act, and other applicable sections.

**Horses:**

Code section, 9 CFR 11, contains horse protection regulations. These are applicable to horses at an auction, sale, exhibition, show, or otherwise on public display. The regulations are very extensive, requiring unlimited access to inspectors of the horses and records relating to each horse.  While they do not directly cover horses on a farm, they are applicable to animal agriculture in that the regulations do cover sales and auctions of horses.

**Animal Food Products:**

CFR Title 7 contains the Rules and Regulations relating to the Secretary of Agriculture and the USDA. Regulations relating to the Agriculture Marketing Service of the USDA, which relate to milk marketing in the "upper Midwest marketing area", and regulations under the Agricultural Marketing Act of 1946 are also contained in these sections.  The latter include livestock grading and certification, inspection and grading of eggs, and other similar animal food products.

**MINNESOTA STATUTES**

Proceeding through levels of authority from federal statutes to federal regulations leads to state statutes.  In Minnesota, three statutes are central to animal welfare, health, and animal agriculture:

Minnesota Statute 35.01 et. seq., Animal Health (Minn Stat 35.01 et. seq. ),

Minnesota Statute 343.01 et. seq., Prevention of Cruelty (Minn. Stat. 343.01 et. seq. ), and

Minnesota Statute 116.01 et. seq., Pollution Control Agency (Minn. Stat. §116.07 ).

**Animal Health:**

Minn. Stat. 35.01 through 35.96 creates the Minnesota Board of Animal Health.   The principal duty of the 5-member Board of Animal Health as described in the statute is to "protect the health of Minnesota domestic animals".   This statute provides considerable detail to define the activities of the board and what it should do to protect the health of Minnesota domestic animals.  The statute includes sections on diseased animals, quarantine and killing of diseased animals, transportation of livestock and poultry, testing and vaccinations of cattle offered for sale, and rendering plants.  The statute also gives the Board rulemaking authority to promulgate Rules in the Minnesota Code of Agency Rules.

Some sections of the statute get quite specific.  For example, Minn.Stat. 35.76 states that "No person may feed garbage to livestock or poultry until it has been thoroughly heated" Garbage is defined under Minn.Stat. 35.73 Subd. 4.

The Board of Animal Health in Minn. Stat. 35.92 Subds. 1-5 is given authority to enforce the statute and the Board's promulgated Rules. The Board's state budget is $2.3 million dollars. The Board employs three (3) inspectors to enforce the statute and its Rules. These three inspectors are assigned to cover 36,000 cattle farms, 11,000 hog farms, 3,000 sheep farms, 650 turkey farms, and 350 chicken farms. On those farms are a total of approximately 1.2 million to 2 million Minnesota animals. In the most recent annual data available, the Board inspectors did approximately 2,000 inspections for non-compliance. Of these inspections, 98% were for non-compliance with swine pseudo-rabies testing. In the most recent reported year, only one (1) fine was levied against a Minnesota farmer and that was related to allowing dead animals to remain unburied.

**Prevention of Cruelty:**

Minn. Stat. 343.01 et. seq. (Minn. Stat. 343.01 et. seq. ), is Minnesota's animal cruelty statute. Major amendments to the statute took place in 1987 when the legislature created the Minnesota Federated Humane Societies (Federation). The Federation is a private, non-profit, Minnesota corporation whose principal duty is to assist in the enforcement of animal cruelty laws. The Federation receives no state funds. The Federation trains and appoints State Humane Agents under the statute. These agents work with local law enforcement to enforce the cruelty laws. The Federation is often involved as an investigating agency when significant cases of animal abuse, cruelty and neglect occur with pets or agricultural animals.

The Minnesota Statute (Minn. Stat. 343.20 Subd. 2.) defines animal as "Animal means every living creature except members of the human race". Thus, the Minnesota cruelty statute covers all animals in Minnesota, including those in animal agriculture. This differs from the Federal Animal Welfare Act as discussed above. The statute uses a common definition, one used in many other states, to define animal cruelty. Simply stated, it is any act or omission that causes unnecessary or unjustifiable pain, suffering or death to an animal (Minn. Stat. 343.20 Subd. 3).

While Minn.Stat. 343.01 et. seq. covers all animals in Minnesota, the statute provides weak penalties for violations, no matter how severe. For example, a farmer who neglects to feed his animals to the point that they starve to death is subject to a possible misdemeanor penalty only of $700.00 and a possible 90 days (See Minn.Stat. 343.21 Subd. 9 and MinnStat. 609. 02 Subd. 3). Several bills have been introduced in the Minnesota legislature over the past ten years to increase penalties to a felony level (See Minn.Stat. 609.02 Subd. 2 and 609.0341 Subd. 2), but none have been passed into law.

All animals in Minnesota that are not living in the wild, or are in the ownership or possession of a human, are the personal or "chattel" property of the human owner (See Wilson v. City of Eagan, 1980, 297 N.W. 2nd 146). This is consistent with federal law as discussed above (See Francione, G., "Animal, Property and the Law", 1995 Temple Univ. Press).

In Minnesota, there are unanswered legal questions on this point. Because the animals are the sole, individual property of the owner, to what extent can the state interfere with

the right of ownership?  Could the state, for example, enact a statute or rule requiring dairy farmers to release their dairy cows to pasture once a day?  Could the state require poultry producers to stop artificially inseminating their birds and only allow natural reproductive processes to occur?  Could the state mandate what drugs are to be given a farmer's animals?

Minnesota law, with the exception of disease control section cited below, does not currently regulate what have often been called "husbandry" practices, or are referred to generally in this report as management systems.

Minn. Stat. 343.21 also makes it a crime to "…overdrive, overload, …or cruelly work any animal when it is unfit for labor…".  Minn. Stat. 343.21 Subd. 2 states that no one may deprive an animal of necessary food, water or shelter.  Subd. 3 states "No person shall keep any cow or other animal in any enclosure without providing wholesome exercise and change of air."

Minn. Stat. 343.21 Subd. 4 states "No person shall feed any cow on food which produces impure or unwholesome milk".  The statute defines impure and unwholesome milk "…all milk obtained from diseased or unhealthy animals, or from animals fed on any substance which is putrefied or fermented."   This statute may be in conflict with the use of animal wastes (manure) as feed, which is discussed more fully later in this report.  This statute also highlights the need for healthy animals, as milk from an unhealthy cow is legally deficient.

Minn. Stat. 343.24, defines animal cruelty in transportation.  This section places various requirements on those shipping animals and livestock.  The sections are designed to promote the humane treatment and well-being of the animals while in transport.

Minnesota law follows the federal lead and excludes farm animals from some of the humane requirements of Minnesota law.  For example, the Minnesota statute on seizures of animals for animal cruelty, (Minn. Stat. 343.235) does not allow the seizure of animals raised for food or fiber without a warrant, no matter what the circumstance.  In contrast, seizure of pets (dogs, cats, etc.) can occur without a warrant if circumstances threaten the life of the animal.  An additional Minnesota Statute (Minn. Stat. 346.43 – Animal Humane Treatment Standards) defines humane conditions for animals in Minnesota. This statute excludes farm animals from its requirements.

**Pollution Control:**

Minnesota Statute Minn.Stat. 116.01 et. seq. (Minn. Stat. §116.07 ) and more specifically Minn.Stat. 116.07 ("Powers") and Subd. 7 which covers animal lot permits regulates pollution control.   Under this statute, the Minnesota Pollution Control Agency (MPCA) is directed "to improve air quality" by a variety of means, with the overall goal of reducing all forms of pollution.  In Minn. Stat. 115.01 et seq., the MPCA is also granted the authority to regulate water quality.  Under these statutes, the MPCA regulates animal feedlots, pollution runoff from farms, and other forms of pollution from animal units.

The MPCA employs Nine(9) feedlot inspectors in Minnesota.  There are approximately 16,000 licensed feedlots in Minnesota and an estimated 40,000 to 45,000 total feedlots. The Nine inspectors issue about 15 enforcement actions per year.  In the 1995-1998 period, no feedlots were closed by the MPCA.

Under Subd. 7, the MPCA may delegate to Minnesota counties the responsibility for processing applications for livestock feedlots, poultry lots, or other animal lots.  The statute (Subd. 7 (3) (k)) also allows counties to adopt ordinance standards for animal feedlots that are more stringent than the standards issued by the MPCA.  Just recently (May 1999), the Minnesota Court Appeals decided a case that interpreted these sections (See Stearns County Alliance v. MPCA, C7-98-2203).

## MINNESOTA REGULATIONS

Similar to the federal government, the state of Minnesota and its agencies have issued Rules and Regulations governing the production of livestock in Minnesota.  The Minnesota Department of Agriculture promulgates in section 1500 through 1572, the Minnesota State Board of Animal Health in sections 1700 through 1720, and the MPCA in sections 7000 through 7150.  In a clear distinction from the Statutory Requirements, for its purposes the Minnesota Department of Agriculture defines "animal" as "cattle, sheep, swine, or goat" (Minn. R. 1540.0010 Subp. 2).

Like the federal regulations, the Minnesota regulations are also numerous and lengthy.  A detailed description of these regulations is beyond the scope of this document, but they can be summarized.  In general, the regulations cover aspects of meat inspection, poultry and eggs, transportation, exhibitions, and disease control.

**Minnesota Department of Agriculture**
Livestock (MN.R.1515 et. seq.)
Poultry and Eggs (MN.R. 1520 et.seq.)
Dairy Industry (MN.R. 1525 et. seq.)  - contains a 350-word definition of "dairy product"
Milk, Milk Products, and Standards (MN.R. 1530 et. seq.)
Cheese and Cheese Products (MN.R. 1535 et. seq.)
Meat Inspection (MN.R. 1540 et.seq.)
Meat, Fish and Poultry Industry (MN.R. 1545 et.seq.)
Genetically Engineered Organisms (MN.R. 1558 et. seq.).

**Minnesota State Board of Animal Health**
Importation of Livestock and Poultry (MN.R. 1700 et. seq.)
Diseases of Domestic Animals (MN.R. 1705 et. seq.)
Diseases of Poultry (MN.R. 1710 et. seq.)
Livestock Exhibitions and Markets (MN.R. 1715 et. seq.)
Animal Carcasses (MN.R. 1719 et. seq.).

**Minnesota Pollution Control Agency**
Ambient Air Quality Standards (MN.R. 7009 et. seq.)

Animal Feedlots  (MN.R. 7020 et. seq. )
Solid Waste (MN.R. 7035 et. seq.).

The extent of compliance to all these regulations by Minnesota animal agriculture is greatly unknown.  With only a very few inspectors employed by the combined state agencies, to oversee the thousands of farms and the over one-million farm animals, it is difficult to imagine that even statistics on compliance could be generated.

## THE UNITED KINGDOM

The first relevant legislation in the UK, with the sole purpose of preventing ill treatment of horses and cattle, was passed by Parliament in 1822 (Smith 1989).  Much later, the 1958 Slaughter of Animals Act (Minn. Stat. 343.01 et. seq. ) and the 1974 Slaughter of Animals Act governed the proper handling of animals for the red meat industry.  These Acts have been replaced by more specific codes (Smith 1989).  A Protection of Animals in Markets Order is now also in place.  The UK Brambell report in the 1960's addressed the proper treatment of farm animals.  This report led to a new section under the 1968 Agricultural Provisions Act and to the appointment of the Farm Animal Welfare Council (Macpherson 1998).

The FAWC was charged with development of welfare codes for the care and treatment of farm animals.  These codes were initially only enforced on a voluntary basis.  The work of FAWC resulted in the definitive code of recommendations for the welfare of livestock beginning with cattle in 1983 (Farm Animal Welfare Council 1983).  From 1983 to 1989 a further series of individual bulletins were developed for codes to address pigs, domestic fowl, turkeys, sheep, farmed deer and goats.  These codes are equivalent to the animal care guidelines now used in the US.

Work by the FAWC and UK Ministry of Agriculture resulted in key legislation in the late 1980's and early 1990's.  The UK was the first European nation to establish formalized legislation in Animal Welfare and Health.  The Welfare of Calves Regulations was passed in 1987.  The Welfare of Livestock Regulations established in 1990 were enforced between 1991 and 1992.  During the same period The Veterinary Surgeons Act and the Prohibited Operations Act for farm animals had a profound affect on UK animal agriculture.  These Acts detailed operations that should be carried out by veterinarians and prohibit on-farm practices such as short-tail docking of sheep and tooth grinding in animals.

Livestock practices that have been of public concern initially included intensive farming practices such as battery cages for hens, veal calves, tethered sows, and the use of sow stalls.  All of these practices are now prohibited. Public concerns about "unnatural practices"  such as castration, use of hormones and genetic engineering have been addressed by legislation (Webster 1989) as have concerns related to animal transport and slaughter.  The FAWC codes have contributed to many improvements in animal husbandry that have addressed animal needs for adequate nutrition, comfort and shelter, freedom from injury, disease and fear, and the opportunity to express normal patterns of behavior (Smith 1989).

**THE EUROPEAN ECONOMIC COMMUNITY**

The European Economic Community (Tarrant 1984) has also made great strides in promoting animal welfare and health standards, especially through the Standing Committee of the European Convention for the Protection of Animals kept for Farming Purposes.  In 1976, the Council of Europe adopted common provisions for animal protection that focused on intensive livestock agriculture.  In 1978, battery cages for laying hens were banned.

Pigs were also an early legislation focus.  In 1987, practices of multi-tier pens, sow stalls, tethered sows, weaning at less than 3 weeks of age, tail docking, and castration were all prohibited for swine production.

The European Council adopted laws related to cattle in 1988 and individual countries were requested to decide how they should be best implemented.  Many of these laws were similar to those already established in the UK.

European Council Directives for transport of animals between EEC countries were in place by 1977 (revised in 1992) and  Animal Welfare Directives related to Humane Slaughter were established in 1985 (Smith 1989).  By January 1, 1999, all intensive livestock systems in the EEC had to comply with the provisions set for pigs.

Other individual European countries, in addition to the UK, have implemented Animal Welfare and Health Laws.  For example, Germany (1971), the Netherlands (1981), and Switzerland (1981) have established such laws.  Germand and Canadian animal welfare rules, laws and regulations have been discussed and sumarized (Meyer 1996).  One of the most exacting animal welfare laws in Europe was the Swedish Animal Welfare Act developed in 1988.  The fundamental principle of this law is that technology must be adapted to the animal and not the reverse (Smith 1989).  An example is the requirement that all cattle are entitled to be able to graze.  The Act was fully implemented by 1998.  Although controversy continues in the EEC regarding use of hormones and genetic engineering in animal agriculture, the codes for animal welfare and health have been successfully adopted.

## ROUTINE PRACTICES

**INTRODUCTION**

Use of various management practices and environmental conditions by livestock production species has been estimated by the National Animal Health Monitoring System (NAHMS), through national studies conducted by the U.S. Department of Agriculture Animal and Plant Health Inspection Service.  These estimates are available at the NAHMS website (http://www.aphis.usda.gov/vs/ceah\cahm) or hard copies can be ordered without cost to requester.

From this source, estimates are available for swine operations (NAHMS, 1990, 1995), dairy operations (NAHMS, 1991, 1992, (NAHMS 1996) and beef feedlot operations (NAHMS, 1994 and one being planned for 1999), among others.  Results from these NAHMS studies show a variety of livestock production management practices in use across the U.S. Herd size and regional differences are notable, an indication of the broad differences in management strategies being employed.  In addition to the availability of summary estimates, the data sets can be obtained from USDA-APHIS under a memorandum of understanding agreement that clearly defines the use of data and outlines steps to be taken to ensure confidentiality of individual records.  Therefore, further analysis could be conducted, if needed to provide additional information about particular management practices of interest.

**MANAGEMENT**

Descriptions of many of the common practices used in animal agriculture can be found in the multiple textbooks that address farm animal management.  Example include textbooks that cover many species (Gillespie 1998) and those for individual animal species (Bath and others 1985;Van Horn and Wilcox 1992).  Ongoing research with agricultural animals continues to generate new knowledge that can be incorporated into management practices in the effort to enhance animal performance, productive efficiency, health and well-being.  As a result of this effort, management practices undergo constant evaluation and re-evaluation.  These research efforts are prompted by a variety of factors including response of the scientific community to suggestions from and concerns of producers, consumers, and government agencies.

Public interest in animal agriculture reflects their interest in the source and quality of their food and an underlying concern for animal well-being.  As a greater proportion of our society becomes more and more removed from direct contact with the farm, it becomes increasingly necessary to be able to explain the reason(s) for the common practices of aniaml agriculture.  This is especially true when certain practices are viewed as unnatural (Webster 1989).  Other management practices conducted for the long-term health and well-being benefit of the animal and/or caretaker may result in temporary pain or discomfort.

These procedures are generally only accepted as standard if they are warranted within the context of agricultural production; are performed by, or under the supervision of, capable, trained, and experienced personnel; and are peformed with precautions taken to reduce stress, pain, and infection (Albright 1997).  Current management practices in U.S. animal agriculture are discussed in relationship to animal well-being issues of discomfort, pain and stress in an Animal Welfare Compendium (Reynells and Eastwood 1997).  Guidelines for these procedures and methods should be and are revised when new information suggests improvements are needed.

**Beef Cattle**

Beef calves are usually dehorned at a young age when the horns are small to prevent significant injuries to the cattle and their caretakers.  Establishment and maintenace of a social order within a group of cattle can lead to "fights" between animals during normal daily interactions such as competition for water and feed (Goodrich and Sticklin 1997).  Fights between horned animals can lead to injury of one or both animals as a result of these interactions.  Dehorned or polled animals are much less likely to fight and when they do, the potential for injuries is greatly reduced.

Male calves are castrated to prevent physically or genetically inferior males from reproducing, to reduce the aggressive nature of intact males, and to improve meat quality.  Beef calves are castrated when they are less than 3 month of age to minimize stress.

Cattle are frequently branded, especially in western states to provide permanent identification and ownership.  This becomes especially important when cattle from more than one ranch are co-mingled on rangeland.  Hot and cold braning methods are utilized.  Hot branding inflicts pain for a short period of time and tends to be a more permanent identification than the alternative freeze branding method of identification.  Freeze branding causes hair to change color and does not cause as much pain to the animal.  Ear tag identification is more commonly used in Eastern States.  Branding is prefered in Western States because ear tags can become caught in trees and brush on the range.  The animal experiences pain and has an increased potential for infection when its ear tag is ripped out (Goodrich and Sticklin 1997).

Beef calves will normally remain with their dam until about 7 months of age.  After reaching this age, calves may be 'backgrounded' on pasture, fed a diet containing a large proportion of forage until they are moved to feedlots as yearlings (100 to 140 days in the feedlot), or may move directly to a feedlot where they will remain for 200 to 250 days.  Sometimes calves remain on pasture and are supplemented with concentrates until they attain a suitable market weight.

Feedlots are designed to provide adequate space for resting areas and to minimize animal to animal conflicts.  Cattle are fed balanced diets, are protected from the elements and have intensive health care.  Typical feedlot pens hold between 75 and 200 cattle.  Even in large feedlots, each animal interacts with a limited number of other cattle.  This allows for rapid adjustment to the feedlot environment and minimizes the stress of animal to animal interactions.  Beef cows remain on pasture or range throughout the year. Much of

this pasture and rangeland cannot be used for food crop production.  In the winter, beef cows are fed harvested forages when standing forage is not available.  The beef cow/calf segment of the industry represents the ultimate in renewable resource utilization as the animals are free to roam on pastures and ranges (Goodrich and Sticklin 1997).

**Dairy Cattle**

Assessment of Animal Welfare Issues in the dairy industry has been succintly addressed (Arave and Albright 1997).  Issues and concerns include the potential for reduced quality and quantity of individual attention in large dairy herds; dehorning of calves; prolonged stanchion-tying of cows; tail docking; separation of cow and calf; and raising calves in hutches rather than in groups.  Improved management practices have been adopted in both confinement and grazing dairy herds, regardless of size, to enhance the quality of cow care. These practices include managed rotational grazing to maintain consistent availablity of high quality pasture for grazing herds, close attention to cow comfort and facility design for confinement herds, and improved milking practices and dairy herd health management for all dairy herds.

Dehorning, castration and identification are common pratices in the dairy cattle for similar reasons described for beef cattle.  The most popular method for dehorning dairy calves is use of an electric dehorning iron under 30 days of age.  This method presents no long-term stress (Laden and others 1985).  Male dairy calves are usually castrated when they are dehorned (usually before 45 days ofage).  Surgical castration and use of an elastrator are two common methods.  The former causes less pain to the calf (Roy 1980).  Dairy animals must be permanently identified for production, health and registration records (Arave and Albright 1997).  Metal ear tags, tattoos, hide brands, and more recently transponders implanted under the skin are methods used for identification.  In other countries, such as the UK, freeze branding is acceptable but hot branding is prohibited (MAFF 1983).

The increased popularity of freestall barns (invented in 1960) thoughout the US dairy sector has contributed to the decline in the use of stanchion tie-stalls.  Freestalls typically have been designed to be wider and longer than the stanchion tie-stall.  Research in the early days of freestall use demonstrated that cows spent more time lying in comfort freestalls (10.2 hours) than they did in stanchion tie-stalls (8.8 hours).  This has been interpreted as indicating some discomfort in the latter system (Reeves and Henderson 1963).  Cows require 10 to 12 hours of resting time daily that includes time for rumination (Hodgson 1990;Albright 1993b;Arave and Albright 1997).  Freestall design continues to be improved and includes efforts to find appropriate bedding material (mattresses, sand, etc.) to provide cows with a most comfortable place to lie.  This can have a positive effect on health and reduce the propensity for udder infections.  Farms that have moved from confinement to grazing systems have often modified their stanchion tie-stall barns to develop a flat-barn milking parlor or to simply use them for winter shelter.

Tail docking is an emerging issue is the US.  The pratcice is primarily limited to cows milked in rotary and parallel milking parlors to prevent disease, improve hygiene, and

enhance ease of milking from the rear.  The practice originated in New Zealand to keep dirty tails from impeding the milking of pastured animals in rotary parlors.  The general effects of tail docking on cow well-being and behavior requires additional study (Albright 1992;Arave and Albright 1997).

A critical aspect for newborn calves is to consume sufficient colostral antibodies as soon as possbile after birth.  This provides sufficient passive disease immunity in their new environment.  On typical dairy farms, calves are separated from their dam within 24-48 hours after birth.  The ability of the calf to absorb colostral antibodies quickly diminishes to almost zero by 24 hours of-age.  Consequently on many dairy farms, calves are hand-fed sufficient colostrum antibodies as soon as possible after birth and the calf separated from its dam immediately.  Research has demonstrated that there is no direct relationship between calf mortality and the time the cow and calf remained together (Arave and Albright 1997).  These authors discussed the example of the Camargue breed in Southern France where the pregnant cow leaves the herd to deliver the calf, hides the calf for 3-4 days, and returns only to nurse for short periods of time.  Calves then join a small group of other calves that play and rest together and nursing becomes a community activity.  It is not unusual for cows to accept several calves for nursing although there is a bond between the cow and her calf shortly after birth.  Friesian calves that suckled for 7 months and then taken to a new environment required longer to adjust than artificially reared Friesian calves (4 vs 2 days) but previous rearing had no long-term effects on behavior (Veisser and others 1989).  In modern dairy cattle, maternal instincts have not been the focus of genetic selection.  Consequently the bonding between the dairy calf and its dam is not considered to be as strong as in beef cattle or other species.  Emotional upset may be lessened by early separation before bonding has occurred.  Intimate human contact during the critical period improves behavior of the cattle during sebsquent handling and milking (Craig 1981;Arave and Albright 1997).

Concerns have been expressed about the potential stress of rearing calves in individual hutches or pens vs group housing in pens.  Diseases are easier to control and intersucking can be avoided when calves are raised individually (Arave and Albright 1997).  In a study with six pairs of monzygous twin heifers, feed intake and daily gain did not differ when one twin was reared in a group and the other in a hutch (Purcell, 1988).  On some dairy farms, after calves have received sufficient colsotrum, they are raised in small groups with common nursette liquid feeding systems.

**Poultry**

The poultry industry is the largest and most highly automated, vertically integrated and intensified of the animal produciton industries.  There has been a great deal of public concern about the welfare of poultry and this has stimulated much research, especially in Europe.  The practice of battery cages for laying hens has been modified or banned all together in the European Community (Webster 1989).  Mortality of hens has increased as they moved from cages (4%) to a group litter pen (9%) or allowed to free range (16%).  Much of this mortality is due to more opportunities to express aggressive behavior and cannabilism.  As a result, a balance of well-being assessment to minimize aggression and

allow for optimal animal well-being should be a goal for management systems (Mench and Siegel 1997).

The procedure for reducing cannabilism is beak trimming which involves the removal of ½ of the beak. It is used for laying hens and less commonly in broiler chickens. It can be used for male turkeys to reduce injuries associated with aggressive behavior (Mench and Siegel 1997). Research has demonstrated that traditional hot-blade beak trimming after 5 weeks of age can result in acute and chronic pain (Cunningham and Maudlin 1996;Gentle 1986;Craig and Lee 1990). Precision trimmers that cut a small hole in the beak causing the tip to fall off are now available but this method has not been thoroughly examined from the effect of pain on the bird. Viable alterntatives to beak trimming have been related to reduced light intensity. Some evidence indicates that genetic selection could be used to decrease cannibalism in flocks (Mench and Siegel 1997;Craig and Lee 1990).

Toe trimming is sometimes used in commercial poultry production where the middle toe of laying hens may be removed to reduce eggshell damage and toes of chickens and turkeys trimmed to prevent injuries to other birds. Trimming one toe of breeder chickens does not appear to cause chronic pain when performed properly (Gentle and Hunter 1988;Mench and Siegel 1997).

**Swine**

Common practices in the swine industry include ear notching and tagging, teeth clipping, tail docking, and castration. Most procedures are performed shortly after birth when pain is considered to be minimal. Stressed pigs show signs of immunosuppression, behavioral changes, and greater disease incidence. Stress factors can differ between intensive and extensive swine systems. In both systems, good management and understanding of animal well-being concerns are critical. A positive relationship with sows that are at ease with their human handler and the number of pigs raised/sow annualy has been detected (Holden and McGlone 1997).

**ANIMAL HANDLING**

During the decade of the 1990's livestock handling practices have been much improved, although the handling of "downer" and crippled non-ambulatory animals still needs some attention (Grandin 1997;Grandin 1990a;Grandin 1990b). The leadership of Temple Grandin has had a profound impact on the ways animals are handled and how facilities are designed to improve animal well-being throughout the US livestock industry.

**Handling-Induced Animal Stress**

Livestock that are handled gently will be calmer and less stressed. Yelling and screaming stress animals. An overall understanding animal psychology will reduce stress and potential injury to animals. It was noted that cattle, sheep and hogs have wide-angle, panoramic vision that enables them to see behind them without turning heads, an important consideration when approaching or moving animals. Things that spook

animals or make them balk when moving, should be recognized and corrected.  Examples and some corrective measures have been summarized and described (Grandin 1992).

**Handling and Moving a Single Animal or a Group of Animals**

Cattle and sheep have a natural tendency to circle around handlers and keep them in view at all times.  For single animals it is suggested that the handler remain at the boundary edge of the flight zone and not get too close to the animal.  The most effective position for a group of animals is to stand at an angle behind the animals rather than directly behind.  For cattle, use of plastic ribbons tied to the end of a stick is as effective as electric prods more moving cattle.  Cattle with horns can cause significant injury and bruising when handled as a group.  In the case of hogs, electric prods are discouraged in favor of a soft canvas slapper or plastic paddle

**Handling Facility - Design Examples**

Solid fences in single-file chutes, crowding pens, and loading chutes should be installed to block outside distractions;

■ Crowd pen gates should be solid but sliding and one-way gates in single-file chutes should be constructed so animals can see through them;

■ A curved chute works better than a straight chute;

■ Escape gates should be installed in solid fence areas of cattle facilities for handler safety;

■ All facilities should be designed to eliminate potential bruises and injuries of animals by using rounded corners and avoiding sharp edges in the facilities;

■ Facilities should provide good footing for animals;

■ Hog gates should be hung no more than 4 inches from the floor and the gates latched at the top.  Bruise hazard zone for hogs is 12 to 30 inches from the floor;

■ The most common cause of bruising in sheep is grabbing them by the wool or hind leg;

■ Loading ramps should have no more than a 20 degree slope if permanently installed and no more than 25 degree slope for a portable of adjustable ramp.  All permanently installed ramps should have a flat landing at the top (5ft minimum for cattle and 3 ft minimum for hog ramps);

■ Bruise hazard zone for cattle is 28 to 52 inches from the floor.

**Handling Crippled and Non-Ambulatory Livestock**

Aggressive handling in pen facilities or loading and unloading from trucks can also cause injury and bruising (Grandin 1997).  A large percentage (more than half) of crippled

downed cattle (downer cow) are old dairy cows which often are emaciated and weak. The number of these 'downer cows' could be reduced if they had been transported to market in stronger physical condition (Grandin 1997). A National Cattlemen's Non-fed Beef Quality Audit conducted in 21 cow and bull slaughter plants indicated that 0.9% of cull beef cows and 1.3% of cull dairy cows were disabled and unable to walk. Severely lame cattle represented 3.4% of cull beef cows and 5.8% of cull dairy cows. These animals were in poor condition when they left the farm (Smith 1994;Grandin 1997).

It was determined that 5% of the dairy farms were responsible for 95% of the 'downer' cull dairy cow problem (Grandin 1997). Surveys reported by Grandin (Grandin 1985;Grandin 1997) indicated that 8% of 51 auction markets in the Southeast had 'downer' cows. In addition, five of 27 (18.5%) major hog and cattle packing plants mishandled non-ambulatory livestock. Good management practices can prevent 8 of 10 dairy cow 'downers' and education of dairy and beef producers in proper handling of animals will contribute much towards prevention or reduction 'downer' problems (Grandin 1997).

**Young Calves**

There is still concern about the marketing and handling of newborn dairy calves destined for market, especially male calves and female free-martins. In England and Canada, Animal Welfare Codes prohibit sale of calves under 1 week of-age (MAFF 1983;Grandin 1997). This is not the case in the U.S. as many calves are sold at less than 3 days of age. There has been much improvement recently throughout the U.S. by many dairy producers who ensure that calves receive adequate colostrum, have dry hair coats and navels, have sound legs, can walk without assistance, and are in overall good health before being moved from the farm (Grandin 1990b). Often these calves are marketed directly to neighbors or specialized calf raisers who understand the need for optimum animal care and well-being. There is still room for improvement in marketing management of these young calves as they are loaded, transported, and loaded from trucks or trailers (Grandin 1997).

**Hogs**

The incidence of 'downer' hogs, many of which are young finished market hogs, are much greater than with cattle. Old sows allowed to deteriorate on the farm to a weak and emaciated condition also become 'downers'. Producers who feed hogs under contract have been known to bring sick, decrepit hogs to the auction market to get credit for them from the contracting company. This practice should not continue (Grandin 1997). As with cattle, improved management practices should be implemented on the farm to reduce the incidence of 'downer' hogs. Breeding and selection for soundness and reduction of inherited stress genes such as Porcine Stress Syndrome (PSS) are suggested as a priority. Prompt marketing or euthanization of hogs with hernias and prolapses is recommended before they become potential 'downers' (Grandin 1997). Careful attention to facility design and proper flooring suitable for type and age of pigs will prevent some of the 'downer' problems.

**Markets and Stockyards**

Grandin (Grandin 1997) strongly suggested that downed non-ambulatory livestock at markets should be immediately euthanized, or transported to a local, convenient slaughter facility.  It was noted that many markets now have a 'no downer' policy. Some markets and slaughter plants do not allow 'downers' to be unloaded.  In order to prevent crippled or weak 'downer' livestock from being shipped for many miles, it was proposed they be sent to a local slaughter plant near to the farm or euthanized on the farm.  A number of livestock groups such as the National Pork Producers have adopted 'no downer' policies. Continued improvements should include proactive team efforts between the farm, livestock organizations, livestock markets and slaughter plants.

ALTERNATIVE LIVESTOCK PRODUCTION SYSTEMS

**Poultry:**

The U.S. Commercial poultry industry is based on the production of eggs and meat under intensive management.  About 98% of the 245 million laying hens are kept in cages. Turkey production (over 300 million) has changed from range rearing to confinement rearing on litter floors.  About 7 billion broilers and roaster chickens are produced annually mostly reared in confinement on litter floors.  Breeder poultry are typically confined in 1/3 litter and 2/3 slatted floor houses.  The poultry industry is the most intensive and vertically integrated of all animal production industries and as such has been the subject of much public concern related to welfare especially in Europe (Mench and Siegel 1997).  This scrutiny has led to system modifications based on animal well-being and behavioral criteria.  The initial focus has been on the battery cages for laying hens which have been extensively researched by ethologists, behaviorial scientists and poultry commodity organizations over the past decade (Gentle 1986;Gentle and Hunter 1988;Webster 1989;Craig and Lee 1990;Mench 1992;Appleby and others 1992;Appleby and Hughes 1995;Cunningham and Maudlin 1996).  Some European countries have mandated an increased space allowance for laying hens in cages or banned cages altogether.  Extensive systems such as avaries, straw yards and free range have been evaluated (Appleby and others 1992).  A modified cage known as the Edinburgh cage that contains perches, dust baths and nest boxes does address the natural behavioral instincts of laying hens and provides liberal space (Webster 1989;Appleby and Hughes 1995;Mench and Siegel 1997).  Hen mortality has been shown to be 4% in conventional cages, 9% in litter pens, and 16% on free range systems (Mench and Siegel 1997).  Most mortality is due to increased aggressive behavior and canabilism.  A balance between an extensive and intensive system seems appropriate for laying hens which allows for improvements in animal well-being and maintains some economic viability for the producers.

In poultry meat production  the main focus has been to develop birds genetically selected for efficient growth characteristics.  This approach has led to some animal well-being concerns which is now being extensively researched.  At present, strategic approaches are being used to modify bird growth rate during certain periods of its life.  More work is needed on improvements in animal husbandry and modifications of systems that allow

for optimal animal well-being and provide an economical return to the producer (Mench and Siegel 1997).

**Swine:**

Today, pork production in the U.S. is, for the most part, a vertically integrated industry predominated by indoor confinement systems rather than extensive pastoral settings which were more common three decades ago. Extensive swine production can be an economical low capital input component for the pig industry although land and labor requirements are greater than for confinement systems. On a per head basis, extensive systems are as profitable as indoor production, but net profit will be less because of the smaller volume and less consistent production (Holden and McGlone 1997). A survey in 1991 indicated that sows farrowing on pasture in portable houses weaned 0.8 pigs fewer pigs per litter than confined sows. Pig death losses were higher outside in wet cold weather. In mild weather, pigs raised outdoors have grown as well, if not better than, those raised inside. In hot and cold seasons, inside pigs grow faster. Farrowing sows in pens then turned out to feed and water, weaned as many or more pigs than sows confined to a stall for the entire lactation. Labor requirements to manage the sows turned out daily were greater than those kept in stalls but the former had access to more exercise and consumed more feed (Stevermer 1992;Holden and McGlone 1997).

An increasing number of today's producers are re-evaluating the viability of alternative swine production systems that may include pasture farrowing and finishing, hoop houses, utilizing straw for farrowing and finishing and Swedish deep straw-bedded systems (Bergh 1998). Evaluation criteria include economics, labor, animal well-being, productivity, environment, and marketability. Based on these criteria the alternative systems can be financially competitive for beginning, small and medium size producers and can mitigate many of the environmental concerns caused by confinement buildings utilizing liquid manure (Bergh 1998). Examples of alternative systems are discussed below.

A long-time Minnesota hog producer recently established a small intensive rotational grazing system for sows and gilts with concepts similar to that of grazing management for cattle and sheep (Bartz 1995). Sows were divided into 3 groups and grazing initiated the middle of June. Fifteen gilts and 1 boar were placed on two acres of alfalfa with orchard grass; seven 4th litter sows on 1 ½ acres of oats, rape, and field peas; and 7 sows kept in confinement and fed a coventional corn and soybean meal diet. Each grazing system was divided into paddocks and sows rotated between paddocks every 4 days. Sows on pasture were fed 1 ½ lbs corn daily. The systems were grazed through two cycles and sows were taken off pasture between September 15 (91 days on alfalfa pastures only) and October 15 (112 days on other pastures). An additional system was used from September 20 to November 10 when 7 sows and 1 boar were put on corn and non-winter hardy alfalfa pastures with a portable shade that had straw bedding. The average labor was ½ hour/day for each outside system. Overall annual feed costs/sow were reduced by $60/sow when pasture was integrated into the system compared to total confinement. Total variable costs/acre were $119.41, $292.96, and $294.96 for the

alfalfa pastures, oats/rape/field pea pastures, and corn/alfalfa pastures, respectively. Observations were that sowsa nd gilts kept outside during gestation had better appetites when they came into the farrowing barn than the confined gestating sows. The birth weight of pigs from outside sows were similar for those kept indoors. The average 21-day weight for the outdoor pigs was 2 lbs heavier/pig and pigs from sows kept outdoors reached a 230 lbs market weight 4 days faster than pigs form indoor sows. The project demonstrated the potential for using grazing in a pig enterprise.

In Sweden by 1985, the deep-bedded housing systems with individual feeding stalls and spacious area in uninsulated barns had become the conventional method of dry sow housing (Halverson 1998). These systems worked integrated well into the 1988 Swedish Farm Animal Protection Act which required phasing out of gestation crate systems. Adoption of deep-bedded systems for farrowing sows soon followed in the late 1980's (Halverson 1998). This technology has recently been evaluated in the U.S. Midwestern states.

A 70 ft x 37 ft Swedish style deep-bedded gestating and farrowing loose housing hoop structure for the Iowa State Univesity breeding herd has been recently evaluated (Kent 1998). The structure consisted of 22 ft x 16.3 ft pens for 12 breeding sows, a 14.3 ft x 16.3 ft pens for 6 gilts, and a 25.2 ft x 16.3 ft pens for 12 gestating sows. All pens included 7 ft individual feeding stalls plus a single waterer. Across a 4 ft alley from these pens were a weigh scale, 2 individual pens for boars, two spare pens and area for bedding storage etc. Drippers were installed over the feeding stalls to cool sows down in hot days. All floors were concreted. Large round bale cornstalks were used for bedding. The structure had an adjustable fabric curtain on the north end. Access for bedding was from the south end. The herd was based on Yorkshire x Landrace F1 gilts crossed with Hampshire boars. The hoop building is cleaned-out 4-5 times a year. Manure is either spread directly on the land or composted. The systems worked well in both summer and winter months. An average of 2.5 litters have been born/sow by the end of the first year with a 5-week weaning period. Heat, conception, and farrowing rates have been between 96 and 97%. Pre-weaning mortality was 20% which was considered the weakest part of the system. It was observed that the system has potential for midwest producers with close attention in adjusting management to sows' natural behavioral needs under a loose housing system (Kent 1998). Learning how to manage a commercial breeding and farrowing Swedish style deep-bedded unit is critical as shown by the change an average of 2.5 pigs lost/litter from crushing down to less than 1 pig crushed /litter in just over a year in a recently built 35 ft x 85 ft unit (deep-bedded straw on a dirt floor) on an Iowa farm (Wilson and Wilson 1998).

Post weaned growing-finishing pigs have been adapted to three 30 ft x 72 ft deep-bedded hoop structures housing 160-170 pigs/group on a Minnesota hog operation that also has a conventional 120-sow farrow to finish confinement system (Moulton and Moulton 1998). Straw, marsh grass or corn stalks are used for bedding on top of clay-based pens. An average of 3 x 170 market-pig groups are moved through the structure each year. Between 60 and 80 large 1200 lb round bales of bedding/year are needed for the system. The building costs averaged $58.80/pig space compared to $180-$200/pig space for a

conventional confinement building.  Pigs are placed in the the hoop buildings at 40 to 50 lbs weight and marketed at 240 lbs.  Feed costs at $0.07/lb average $3/pig greater for the hoop buildings compared to confinement.  Overall costs (including capital investment, variable and fixed costs) of raising 3,060 pigs/year in 6 hoop buildings averaged $102.60/pig compared $140.50/pig for raising 3,000 pigs/year in a 1,000 head confinement building.

**Beef:**

The beef cow/calf segment of the beef industry is traditionally based on pastures and range systems, much of the land being used for grazing cannot be used for food crop production (Goodrich and Sticklin 1997).  The focus of alternative systems for beef animals are based on efficient management intensive rotational grazing optimizing a forage based diet for growing finishing cattle all the way from weaning to market weight with some nutrient supplementation when pasture availability is limiting.  Improvement in technology of grazing systems, understanding of plant growth and grazing behavior of animals have contributed to effective use of livestock production from grasslands (Gerrish 1993;DiCostanzo 1994).  Traditionally, pasture has been used under intensive management or range conditions for 'backgrounding '7 month-old weaned calves until they are yearlings or older prior to being moved into a commercial feedlots for a minimum of 140 days until they reach a finished market weight.

Continuation of these lower input systems have been applied to finishing cattle on pasture in a number of states for many years.  A successful pasture finishing system in North Carolina in the late 1970's utilized steer calves wintered on accumulated or harvested forage and concentrates to gain 1 to 1.3 lbs/day.  The calves then were self-fed grain (limit to 1% body weight) during the spring and summer finishing period on good pasture (Barrick and Dobson 1978).  Cattle that are finished on pasture are typically much older because of slower gain than those that finish in feedlot on high grain diets (20-24 months or > vs. 12 to 18 months).  However, the quality of the meat from finished beef from pasture appears to be very acceptable to the consumer in countries were it is more regularly practiced than in the U.S., such as in Europe and South America.

**Dairy:**

The Minnesota dairy industry over the past 3 decades has been predominantly a confinement system emphasizing production per cow, growing and feed increased amounts of grain, reducing pasture use, and a tendency to specialize.  Cost of producing milk has continued to increase (Johnson 1994).  Confinement housing in Minnesota is rapidly changing from the stanchion tie-stall barns to naturally ventilated free-stall systems where cow comfort is of uppermost priority.  Many dairy producers may still continue to pasture dry cows and heifer but focus on a specialized confinement barn for the milking herd (Arave and Albright 1997).  However, as input costs and debt loads on many dairy farms continued to rise a renewed interest in grazing systems in the Upper Midwest occurred driven by the recognition that pasture can provide an economical source of forage for dairy cattle and the potential for reduction of overall input costs to the dairy.  The improvement in fencing technology since the dairy farm pasture days of

the 1950-60's and concerns about the environment have also contributed to the resurgence, especially the small to medium size dairy farms (Muller 1993). As an alternative system for dairying, pasture is thought of as idyllic in terms of animal welfare. As a farming practice, good nutritional management (pasture quality and availability) and animal husbandry are still most prevalent to be successful as with confinement dairying. Some of the challenges of pasture dairy farming include limited grazing season in the Upper Midwest; pasture quality and quantity; inconsistent supply of nutrients to sustain milk production throughout the grazing season; accessibility to shade and water; heat stress; rain and wind stress; insects and parasites; energy expenditure in grazing and travelling to the milking parlor, toxicity of certain soils affecting pasture and other considerations such as less time for milking cows to lie down than in confinement (Arave and Albright 1997). Despite the challenges, many producer in Minnesota have moved to grazing dairying. It has been a 'grass-roots' network resurgence with farmers continually learning from each other during pasture walks at workshops supported by other resources.

One of the more recent research studies conducted at the University of Minnnesota North Central Research and Outreach Center compared confinement and intensive rotational grazing for lactating dairy cows over two years (Rust and others 1993). They found that cows in confinement produced 5 to 8% more milk than the grazing cows, but total production costs were reduced by 30% for grazing cows. Milk production was very sensitive to pasture quality changes during the season and across the two years. Net return averaged $64.05/cow > in 1991 and $88.66/cow > in 1992 for grazing vs. the confinement system, respectively. The concept of net return/cow or per acre rather than milk production is the key emphasis for grazing dairy farms (Hanson 1995). The use of seasonal grazing has offset some of the limitations of the shorter grazing season and management challenges in Upper Midwest states. Managing seasonal grazing allows designed of calving patterns to take full advantage of available pasture, the number of cows milking during the winter months either reduced to a minimum or completely stopped, winter feed storage needs are much reduced, and provides more quality time for the farm family (Hanson 1995;Stelling 1999). In addition, the refinement of pasture systems for replacement heifers allows for further reduction in overhead costs to the dairy herd and more optimal heifer growth to first calving (Chester-Jones 1996).

In a survey summary of 29 grazing operations throughout Minnesota, emphasized the optimism for the potential of grazing dairy herds especially adopting management intensive grazing (MIG) techniques in Minnesota (Loeffler and others 1996). These 29 farms were considered typical Midwestern family dairy farms averaging 58 cows and 300 acres of land. Improved quality of life because of reduction of time spent doing chores was considered a primary benefit of adopting MIG.

**Sheep:**

As with beef cow/calf operations, the ewe and lamb flock have been based on pasture systems under intensive or extensive grazing management. Modifications are now centered on improving the understanding of grazing behavior and plant growth and their

interface (DiCostanzo 1994).  Confinement feedlots are common for market lamb production.  A balance between inside housing and pasture is often needed for the ewe flock during lambing season and in the winter months.  Much research has been conducted to genetically select breeds or crosses that will best utilize the diverse regions of the US.  Recent efforts in Minnesota at the University of Minnesota West Central Research and Outreach Center (WROC) are focusing on matching the ewe and lamb flock to their production environment by optimizing the use of a forage based intensive rotational grazing systems with an emphasis on low input systems and good pasture management (Head 1999).

An example of alternative systems for growing market lambs by grazing fall forages vs. more conventional systems were investigated by Head and Cuomo (Head and Cuomo 1998) at WROC.  August weaned lambs were assigned to feedlot or grazing diets. Feedlot lambs were fed alfalfa meal and whole corn (ALM) or alfalfa hay, whole corn and ½lb soybean meal (AC).  Grazing lambs were offered alfalfa pasture (AG – grazed from August to October 31) or turnips (T – grazed from August to November 18).  When removed from their respective pastures, grazing lambs were fed a feedlot diet until December 5, when all the study lambs were marketed.  There were no differences in lamb performance of ALM. AC or AG lambs.  Lambs that grazed turnips had the lowest gains but were on the feedlot diet less than the AG grazed lambs.  Grazed lambs had leaner carcasses and thinner body wall measurements than feedlot lambs.  The study indicated that grazing can be a viable alternative to finishing lambs in a dry feedlot if environmental conditions allow.

## INCIDENCE OF DISEASE AND SICKNESS

### INTRODUCTION

In the U.S., the primary national animal health-monitoring role is provided by the National Animal Health Monitoring System (NAHMS), conducted by the United States Department of Agriculture Animal and Plant Health Inspection Services (USDA-APHIS) (Wineland and Dargatz 1998). Its initial direction was provided by the Animal Industry Act of 1884, which directed the Bureau of Animal Industry (the APHIS predecessor) to "collect such information...as shall be valuable to the agricultural and commercial interests of the country." In the 1970's, the National Academy of Science provided direction for APHIS to re-evaluate its role in providing animal agriculture's information needs in the context of contemporary food animal production (National Academy of Sciences 1974). This report outlined the need for scientifically sound and statistically valid national information, that is also timely, accurate, and user-friendly. Collaboration of the APHIS network of federal veterinarians located throughout the U.S. with animal diagnostic laboratories and ongoing collaborations with State animal health officials were recognized strengths to enhance the development of a monitoring system.

The National Academy of Sciences vision was pursued, starting in the mid-80's and has led to the development of the current NAHMS program. This program operates differently from other APHIS regulatory programs in that producer participation is voluntary and the confidentiality of data from individual operations is assured. Data quality is critical to the validity of NAHMS national estimates and a key part of data quality is the selection of a random sample of food animal populations. Collaboration with the USDA-National Agricultural Statistics Service (NASS) allows statistical sampling of U.S. food animal operations for data collection. NAHMS conducts a needs assessment of critical information gaps involving the industry and related groups, before a study is designed. This allows the selection of the optimal study design to collect the needed data. After data collection and validation, data are analyzed and interpreted, and reports are made available via multiple formats, including the NAHMS webpage (http://www.aphis.usda.gov/vs/ceah/cahm).

### HERD SIZE

Because of management practice differences by herd size, herd size has long been used as a proxy for management practice differences between livestock production enterprises and many diseases have been reported in epidemiologic studies in relation to herd size. Examples include Salmonella shedding in swine and cattle. When related to animal health or disease, however, this information should be viewed cautiously. Larger herds are more likely to contain at least one diseased or infected animal even if the prevalence of disease is the same across herd sizes, due only to increased numbers of animals at risk. When reviewing the scientific literature, it is sometimes difficult to separate this diagnostic bias from factors that are truly related to herd size. In addition, herd size is often evaluated in epidemiologic studies as a proxy for management practices and environmental conditions which were not specifically evaluated in the study. It may be

important to include herd size in the evaluation, to best estimate effects of other specified factors, but it may not be possible to directly interpret herd size in relation to the health problem. Therefore interpretation of herd size relationship with health problems from epidemiologic studies evaluating associations between management practices and health problems at the herd level should be viewed cautiously.

Some studies have shown higher prevalence of disease (e.g., footwarts in dairy herds) and disease pathogens (e.g., Johne's disease and Salmonella in dairy herds) in larger herds (NAHMS 1996). Other studies have demonstrated certain health advantages are more common in larger size herds. For example, higher milk quality and reduced incidence of subclinical mastitis has been shown with larger dairy herd sizes (NAHMS and USDA Ag. Marketing Service). Similarly, lower incidences of clinical mastitis and metabolic diseases such as milk fever and displaced abomasum have been evidenced in larger dairy herd sizes (NAHMS 1996). In swine, the adoption of high-health techniques, such as segregated early weaning (SEW) are only possible in large herds. Because of this, modern large SEW herds have a much higher level of health than the conventional small continuous-flow herds (see following section on Prevention and Mitagation Measures).

## BEHAVIORAL VICES – POULTRY

Two vices, which appear common across all domestic poultry, are feather pecking and cannibalism. Feather pecking can result in significant loss of feathers most often along the back of the bird. Feather pecking is not associated with aggression and its activity has been hypothesized to be redirected feeding activity. As reviewed by Appleby and co-authors (Appleby and others 1992), there are many different influences on the incidence of the behavior which relate to individual bird characteristics, genetics, and environmental conditions such as housing, density, feed, and lighting. The behavior can spread rapidly as others in the flock copy the activity.

Feather pecking has been associated with cage systems but can be observed regardless of housing condition (free-range, deep litter, or cage). In either case, increasing bird density appears to be associated with more feather loss. However, an exact space requirement to reduce feather pecking may not exist due to the influence of other management and environmental conditions. Density studies conducted under similar conditions vary in the incidence of feather pecking and impact of space allotment.

In contrast to feather pecking, cannibalism is more often observed in non-cage systems. Significant losses due to cannibalism can occur in confinement as well as alternative systems such as free range. There is some speculation that it may arise from feather pecking due to the skin damage or bleeding that may occur when the feather is pulled out. Pecking at the vent of laying hens may also occur just after egg laying. Aggressive pecking (feather pulling) which draws blood can induce cannibalism. As in feather pecking, other individuals in the flock will copy the behavior. Mortality loss can be severe. The incidence, which again can be variable, appears to be related to flock size as increasing group size increases the chance for more birds to imitate the undesirable behavior. This contributed to the use of cages which restrict the access of the birds to the "pecking bird".

Beak trimming is used to reduce feather pecking and cannibalism (Cunningham 1992). At this time there are no other effective alternative methods. There is research being conducted on ways which would allow less dependence on beak trimming as a control method, such as, enhancing the environment of the cage, improving cage design, and low light intensity, (Appleby 1998;Tauson 1998) and genetic selection for strains of chickens to reduce the incidence of feather pecking and cannibalism (Muir and Craig 1998). Some management considerations include feeding of mash instead of pellets (Lindberg and Nicol 1994) and using low light intensities (Kjaer and Vestergaard 1999). However, these have limitations relative to the type of production and controls available. Research is also being conducted on obtaining better understanding of the behaviors itself that may lead to improved housing design. As indicated earlier, the behavior seems to mimic feeding behavior thus research is examining foraging behavior and its relationship to feather pecking (Hubereicher and Wechsler 1997;Hubereicher B. and Wechsler 1998;Blokhuis and Wiepkema 1998;Hubereicher B. and Wechsler 1998;Blokhuis and Wiepkema 1998).

**BEHAVIORAL VICES – SWINE**

Behavioral problems in swine include stereotypic behaviors, cannabalism, and aggression between contemporary animals. Stereotypic behaviors are activities performed by pigs that seem to serve no useful purpose to the animal. Most often, these behaviors are associated with pregnant sows housed in confinement systems. Some examples of stereotypic behaviors include bar biting, sham chewing, licking, and other mouth-based activities which may be expressed due to the sow's frustration with the limited amount of feed offered her (Appleby and Lawrence 1987). Usually, sows are restricted in their feed intake during pregnancy to avoid excessive weight gains that are detrimental to efficient farrowing performance and milk production in the subsequent lactation. Bar biting is a behavior that is not expressed in outdoor or group housing systems but that does not mean that welfare of sows in such systems is better than similar sows in confinement. Bar biting is not an appropriate behavior for sows housed outdoors because there are no bars to bite. Mench and van Tienhoven (Mench and van Tienhoven 1986) warned that the absence or presence of a particular behavior in relation to animal welfare must be interpreted in the context of the production setting. Den Hartog et al. (Den Hartog and others 1993) reported that sows housed in stalls, confined to stalls with a girth tether or housed in groups demonstrated no significant differences in the incidence of stereotypic behaviors. They suggested that stereotypic behaviors expressed by sows are a result of the feeding system rather than the housing system.

Cannibalism is most often expressed as tail biting and ear biting in growing-finishing pigs and is more prevalent in confinement systems compared with extensive systems. The suspected causes of these behavioral vices are many. Our limited understanding of this problem is derived primarily from anecdotal evidence. There are very few controlled studies that have characterized the causes and solutions to problems of tail biting and ear biting. A basic premise is that cannibalism occurs when environmental stressors compromise the pig's comfort. Poor air quality, overcrowding, insufficient access to feed or water, and dietary mineral deficiencies have all been suggested as causes of tail biting.

These suspected causes can all be corrected through improved management; however, these changes in management are not always 100% effective in correcting the problem. The widespread practice of docking tails in confinement systems seems to be the most effective management practice to control tail biting (Ensminger and Parker 1997;Simonsen and others 1991).

Aggression among pigs housed in groups whether in confinement or extensive systems is a constant issue for pig producers. The social hierarchy among animals creates a dominance and submissive relationship between each member of the group. With sow groups, the "boss sow syndrome" makes it difficult for producers to satisfy the nutritional needs of all females in the group because the dominant sow (the boss sow) controls and consumes more than her share of the feed. When pigs of any age from different contemporary groups are mixed, fights break out as pigs establish their social hierarchy. There is little managers can do to eliminate this aggression. McGlone et al. (McGlone and others 1986) reported that spraying androstenone (an androgenic hormone) on the noses and heads of recently mixed nursery pigs reduced aggression and transiently improved the performance of regrouped finishing pigs. Bjork et al. (Bjork and others 1988) injected pigs with amperozide (a tranquilizer) immediately before mixing strange pigs and found a reduction in fighting and fighting induced injuries. The practical significance of these studies in production settings and their efficacy with sows is yet to be determined.

In extensive systems group farrowing and lactation are common. Under this approach, a group of sows are housed together but are provided individual huts or cubicle in which they can deliver and nurture their piglets. The young litter is confined to its hut or cubicle until they are large enough to jump out the front door which usually occurs at about one week of age. All sows must farrow within one week of each other or cross robbing will occur. Cross robbing is when older, more dominant piglets suckle other sows in addition to their own dam. This behavior steals milk from the younger piglets and compromises their ability to obtain nourishment and grow normally. The pork producer can virtually eliminate this problem by ensuring that all sows in a group farrow as close to the same day as possible.

Vocalization is sometimes viewed as indicating a problem in certain husbandry practices and especially so in confinement systems. Examination of swine vocalization revealed several factors played a role (Xin and others 1988). Vocalization was recorded via a microphone after 10-15 minute for the pigs to adjust to the presence of the recorder. The data were processed using a signal processor for sampling rates of 10 to 20 Hz. Vocalization occurred for several reasons which were categorized as follows:

Prior to feeding of hungry breeding-gestation sows who were anticipating feed – *Food Anticipation;*
Breeding sows in heat while in their own pen – *In Heat;*
Greeting response of breeding sow to mate (boar) – *Mate greeting;*
Farrowing sows – *Farrowing;*
Sow response to piglets suckling – *Nursing;*

Processing piglets, i.e., castration, teeth clipping, ear notching, and tail removal – *Processing;*
Isolation of piglets with human disturbance – *Isolation;*
Startled response of nursery pigs by sudden appearance of people in the facility – *Startled.*

As the stress of the animal became more severe, the duration and frequency of the vocalizations increased. The processing of piglets was most severe followed by food anticipation, sows in heat, isolation of piglets, startling of nursery pigs, and farrowing. Nursing and mate greeting responses were considered to be non-stressful indicating calls. This information can be applied to the understanding of animal well-being.

### BEHAVIORAL VICES – CATTLE

Behavioral vices in cattle are related to the social structure established within a group and is frequently expressed as a tendency to follow group leaders and their tendency to be inquisitive (Albright 1993b). Depending on the livestock system and particular stimuli, beneficial (following leaders to a feedbunk, milking parlor, to and from pasture etc.) or detrimental (stampede) behavioral patterns may be expressed (Baker 1981). A knowledge of the physiological needs of cattle go hand-in hand with animal well-being, animal health, animal management and system design.

Cattle alternate between eating, ruminating, defecating, urinating, and postural changes (getting up and lying down). Grazing cattle will have 3 to 5 periods of grazing during the day, the longest and most intensive just after dawn or before dusk. They will graze for 6 to 12 hours and use 20,000 to 40,000 bites to consume their feed. This depends in part on the availability of pasture. They ruminate for 6 to 8 hours/day and typically walk over 2 miles daily (Hodgson 1990). Cattle prefer to defecate and urinate in areas where they rest and congregate. This includes areas typically frequented such as under shade or near their source of food and water. Good pasture management and strategic placement of water/feeding areas will improve distribution of manure nutrients across paddocks. Proper management will also prevent excessive wasteage of pasture due to refusal to consume pasture from manure contaminated areas (Gerrish and Patterson, 1994).

In confinement, cattle will eat for 4 to 6 hours per day and ruminate for time periods (6 to 8 hours) similar to those of grazing cattle. Confined cattle expend 10 to 20% less energy than cows on pasture. An example of the breakdown of daily behavior by a high producing dairy cow (Beecher Arlinda Ellen, the world milk production record holder at one time) in confinement has been documented (Albright 1993b). Within a 24 hour period, she spent 6.25 hours consuming feed, almost 14 hours resting (she ruminated for 7 ½ hours while resting) and she defecated 12 times and urinated 7 times.

In both indoor and outdoor systems, young, less-experienced animals need to learn feeding and water locations. Thus, these locations must be placed to encourage their accessibility (Albright 1993b). A number of research studies have been conducted to evaluate cattle behavior (Arave and others 1974;Friend and Polan 1974)(Fraser and Herchen, 1979)(Curtis and Stricklin 1991;Albright 1993b;Reynells and Eastwood 1997).

Every group of cattle contains those that are totally dominant, medium dominant, or totally submissive.  Dehorned or naturally polled cattle are much less likely to be involved in fights that result in injury (Goodrich and Sticklin 1997).

Mixing a group of cattle will cause aggressive behavior until a social order is established (Friend and Polan 1974).  Once an order is established, the feeding drive becomes dominant and cows in the group will conform to the established social order. In pasture situations, cows will follow their group leaders as these more dominant cows satisfy their own needs in an independent manner.  In controlled feeding situations the dominant cows will spend more time eating than cows lower in the established social order.  This behavior becomes more apparent in competitive situations when feed availability is limited (Manson and Appleby 1990).

Less physiological stress is placed on dairy cows, for example, if  the feeding area in a confined system allows cows to consume feed in the natural head-down grazing position.  This head position stimulates saliva production.  Poorly designed feeding areas with elevated bunks will cause more feed sorting and feed tossing which results in animal stress, feed waste, and reduced feed intake (Albright 1993b).  When one cow eats, her expressed behavior stimulates others to follow.  The dominant animal in the group initiates this and serves as a social facilitator (Curtis and Houpt 1983).  When cattle are moved to new locations (pens or paddocks), it is best to move them as a group to minimize the stress of  social adjustments.  Differences among cattle in their expression of behavioral patterns and temperament will be determined in part by their experiences as a young animal.  Consistent, gentle handling throughout their productive life (Curtis and others 1988) contributes to the development of cattle that are comfortable with their surroundings.

**PARASITES**

**Introduction**

Many different kinds of parasites affect agricultural animals in North America.  Some of the parasites are host specific, meaning they are associated with just one kind of host animal; these probably "came along" while their hosts were being domesticated in the Old World. In contrast, others evolved with wild animals in North America, and expanded their host range to include domesticated animals when Europeans immigrated to this continent.  From an ecological perspective, free-ranging animals are exposed to the greatest variety of parasites, whereas animals that are confined in drylots or indoors are exposed to progressively fewer kinds.

The effects of parasites on agricultural animals are quite varied, and depend on kind of parasite, on kind of host, on host condition, and on number of parasites per host animal (parasite density) (Campbell and Thomas 1996;Leaning and Guerrero 1987;Stromberg 1997;Stromberg and Averbeck 1999;Leaning and Guerrero 1987;Stromberg 1997;Stromberg and Averbeck 1999).  Effects include changes in host behavior and appearance, and reductions in rates of gain, lactation, wool growth, egg laying and feed conversion efficiency.  Consequently, parasites are generally regarded as threats to

animal health and well-being.  A goal of husbandry should be to minimize parasitism by preventing transmission if possible, or through treatment and control of the parasites on their hosts or in their hosts' environments.

Several types of parasites (Tables 1B5) attack each of Minnesota's principal agricultural animals.  There are too many parasites to review each host-parasite combination in detail for this review.  To simplify the coverage, it is convenient to consider them in five functional groups:

Skin inhabiting ectoparasites are host specific and spread by animal-to-animal contact.

Free living flies are less host specific and develop as immatures off their host in various substrates in the environment.

Internal parasites are host specific and can be grouped according to route of spread. They can be acquired by

- ingestion of feed that was contaminated earlier with feces (fecal-oral route),
- ingestion of intermediate hosts such as earthworms, or
- sexual contact with other infected animals.

The purpose of this review is to summarize what is known or can be inferred about the factors that affect diseases caused by parasites in these functional groups in Minnesota.  It should be stated at the outset that many individual farms have routine parasite monitoring and control programs, but there are no systematic reporting systems for any of Minnesota's animal industries.  The following summaries are based mainly on personal observations of the authors, on frequencies of cases submitted to the University's diagnostic labs, and on reports and inquiries from producers, veterinarians and Extension personnel throughout Minnesota and neighboring states.

**Swine**

**Skin Inhabiting Parasites:**

Itch mites (*Sarcoptes scabiei*) and hog lice (*Haematopinus suis*) cause mange and pediculosis, respectively, and these two parasites are endemic in Minnesota swine herds. Itch mites can cause pruritus, dermatitis and economically significant reductions in growth rate, feed conversion and piglet survival (Arends and others 1990;Arlian 1989;Davis and Moon 1990;Dobson 1971;Arlian 1989;Davis and Moon 1990;Dobson 1971).  Herd prevalence in Minnesota ranged from 5% in summer to 21% in winter (Davies and others 1996), as determined by slaughter check-backs for herds that probably were better managed than average.  Prevalence of hog lice has not been quantified, but they are widely prevalent elsewhere (Wooton-Saadi and others 1987;Sabiiti and others 1979;Sabiiti and others 1979).  Pediculosis is apparently benign (Bynum Jr. and others 1978;Davis and Williams 1986;Davis and Williams 1986).

Mites and lice are vulnerable to control with a variety of acaricides and insecticides that can be applied by injection, spray, pour-on, or feed additive.  Resistance has not been documented.  Efficacy depends mainly on whether or not all animals in the unit receive treatment, and on thoroughness (effective dose) of application.  Availability of effective controls has made it possible to eradicate these parasites from closed herds.  Because these parasites are host specific and spread mainly by contact, it is reasonable to expect that prevalence has more to do with whether a given herd was established from parasite-free stock and has remained closed to contact with other herds, and less to do with housing style, animal density and farm size, *per se*.

Table 1.  Important parasites of swine in Minnesota, compiled from various sources.

| Type of parasite | Site of attack | Route of spread | Prevalence, by style of housing* | | | |
| | | | Pasture | Open front bedded pens | Concrete or slat-floor (indoors) | Crates (indoors) |
|---|---|---|---|---|---|---|
| Mites and lice (2 spp) | External | Contact | + | + | + | + |
| House fly | External | Flight | + | + | + | + |
| Aquatic biting flies (>20) | External | Flight | + | + | - | - |
| Swine roundworm | Internal | Ingested | + | + | + | - |
| Lung worms | Internal | Ingested earthworm | + | + | - | - |
| Kidney worms | Internal | Ingested | + | - | - | - |
| Gastrointestinal (GI) worms | Internal | Ingested or penetrate | + | - | - | - |
| Coccidia | Internal | Ingested | + | + | + | - |

*Prevalence codes: + = important or common; - = rare or absent

**Free Living Flies:**

The house fly (Musca domestica) is a cosmopolitan species that breeds readily in decomposing organic matter around pastured and penned swine (Table 1).  One experimental study showed that house fly had no effect on hog growth and feed conversion (Campbell and others 1984).  House flies are important, however, as potential vectors of diarrheal pathogens (GEIS Topic IV.K) and as nuisance pests of humans (GEIS Topic III.L).  House flies breed wherever spoiled feed and swine manure accumulate and remain moist (30-80% water).  As reviewed elsewhere (GEIS Topic III.L), premise sanitation is the key to reduction of house fly and stable fly populations, and many insecticides are available for temporary population suppression.  House flies are notoriously resistant to many of the available compounds.  Effects of housing type, animal density and farm size on prevalence of house flies has not been studied directly, but the authors' impressions are that prevalence of these two flies depends more on availability of breeding sites than on anything else.

Aquatic biting flies in Minnesota consist of many species of blood sucking mosquitoes, horse flies, deer flies, blackflies and biting gnats that originate as larvae in wetlands and other aquatic sources (Williams and others 1985).  Swine housed outdoors are exposed to attack, just like all other kinds of vertebrates, whereas those housed indoors are protected by exclusion (Table 1).  None of these biting flies is known to vector pathogens of any

importance to swine in Minnesota, and their direct effects on swine health and well-being have not been studied.

The stable fly, which can aggregate around swine housed outdoors, does not breed readily in hog manure, so this species is much less problematic with swine than with cattle and horses.  One experimental study indicated that attack by stable fly did affect piglet behavior, but did not affect growth rate or feed conversion (Moon and others 1987).

**Internal Parasites:**

Swine are hosts to a variety of internal parasites, many of which spread from pig to pig via fecally contaminated feed (Table 1).  Others spread by more specific routes involving intermediate hosts such as earthworms, or direct penetration of the skin by mobile larvae contacted in the environment.  Consequently, prevalence of these parasites depends greatly on how animals are housed; transmission is most likely among pastured swine, whereas transmission is more limited with pigs housed on concrete or in raised crates.  These settings minimize contact with soil and contamination of feed with feces.

Perhaps the most prevalent internal parasite in the North Central states is the swine roundworm (Drummond and others 1981b;Kennedy and others 1986).  This worm spreads through contaminated feed, so prevalence is greatest with pastured hogs, and as density (stocking rate, animals per unit area) increases, so does prevalence.  If animals are housed indoors on concrete or raised crates, where contact with manure is limited, then prevalence is potentially lower, because source of infection is minimized.  Similarly, transmission of coccidia that cause scours is minimized when young animals are raised in crates that minimize fecal-oral transmission.

A variety of antiparasitic drugs are available for control of internal parasites of swine, and these are administered as feed additives, oral drenches, pour-ons or injections.  As with the skin inhabiting parasites, availability of effective products makes it possible to minimize disease severity and eradicate internal parasites from closed herds.

**Cattle:**

Dairy and beef cattle are housed in similar settings and are hosts for the same kinds of parasites, and they can be reviewed jointly.

**Skin Inhabiting Parasites:**

Skin inhabiting mites (2 species) and lice (4 species) can infest cattle and cause mange and pediculosis, respectively.  Each disease involves pruritus, dermatitis and economically significant reductions in growth rate, feed conversion and lactation rate (Campbell and Thomas 1996).  All are easily controlled with a variety of parasiticides, and resistance has not been detected.  As with swine, skin inhabiting parasites can be eradicated from closed herds, and prevalence has more to do with whether a given herd is closed than with anything else.

**Free Living Flies:**

Four kinds of free living flies are associated with cattle (Table 2). The most ubiquitous ones are the stable fly and the house fly, both of which develop as larvae in decomposing organic debris (GEIS Topic III.H). Stable flies and house flies are most abundant around confined cattle, but stable flies will disperse readily from confinement breeding sites to surrounding areas, so they are abundant on pastured cattle, too. Stable flies cause noticeable irritation (leg stamping and bunching) and measurable reductions in growth rate, feed conversion and lactation (Campbell and Thomas 1996;Thomas and Skoda 1992;Thomas and Skoda 1992). House flies, in contrast, are known to be a nuisance, but they have not been shown to affect animal health. Two other kinds of flies (horn fly and face fly) develop in isolated dung pats, so these species predominate on grazing cattle and are rare around confined herds. Horn flies reduce calf weaning weights, whereas face flies are secondary mechanical vectors of *Moraxella bovis*, the causative agent of bovine pinkeye (Campbell and Thomas 1996). Finally, cattle outdoors are exposed to attack by a wide variety of blood feeding, aquatic flies, few of which will enter buildings and attack cattle indoors.

Table 2. Important parasites of cattle in Minnesota, compiled from various sources.

| Kind of parasite | Site of attack | Route of spread | Prevalence, by style of housing* | | | |
|---|---|---|---|---|---|---|
| | | | Pasture | Drylot (outdoors) | Tie or free stall (indoors) | Slat or scrape floor (indoors) |
| Mites and lice (6 spp) | External | Contact | + | + | + | + |
| Stable fly | External | Flight | + | + | + | + |
| House fly | External | Flight | - | + | + | + |
| Dung breeding flies (2) | External | Flight | + | - | - | - |
| Aquatic biting flies (>20) | External | Flight | + | + | - | - |
| Cattle grubs (2) | Internal | Flight | + | - | - | - |
| Lung worms | Internal | Ingested | + | - | - | - |
| Abomasal worms | Internal | Ingested | + | + | + | - |
| Gastrointestinal (GI) worms | Internal | Ingested | + | - | - | - |
| Tapeworms | Internal | Ingested mite | + | + | + | + |
| Flukes | Internal | Ingested | + | - | - | - |
| Coccidia | Internal | Ingested | + | + | + | + |
| Trichomonas | Internal | Sexual | + | + | + | + |

*Prevalence codes: + = important or common; - = rare or absent

**Internal Parasites:**

As with swine, style of housing has a great influence on transmission of internal parasites (Table 2). Cattle grubs were once common among cattle outdoors during summer, and caused substantial losses due to slaughter condemnation and hide injury. However, their prevalence has been greatly reduced through use of systemic insecticides administered in fall. Grubs were never abundant among dairy cattle housed indoors, because egg laying adults are reluctant to enter buildings. Lungworms and gastrointestinal worms are

transmitted by the ingestion of infective larvae on herbage in fecally contaminated pasture. As animal density (stocking rates) increase, the potential for increased contamination and ingestion increase. Cattle housed elsewhere are much less exposed to infection. The abomasal worms are also transmitted by the ingestion of contaminated forage, but potential for carryover from prior grazing and subsequent expression of disease in confined settings is greater than with the other gastrointestinal parasites. Anthelmintics can reduce internal parasite burdens, and in turn reduce rate of pasture contamination. If coupled strategically with pasture rotation, it is possible to minimize disease caused by these pasture borne parasites.

Tapeworms (*Moniezia* sp.) are transmitted when cattle ingest feed that is contaminated with an oribatid mite that is the intermediate host for the immature tapeworms. The oribatid mite occurs in all styles of housing. Cattle are also intermediate hosts for other kinds of tapeworms, which occur in their muscle, and can lead to condemnation at slaughter. Prevalence of tapeworms and effects on cattle health are not well documented.

Cattle flukes can occur in animals that graze in marshy areas. Fluke eggs are shed in feces, larvae infect and develop in snails, and then exit to grass where they encyst before being ingested by grazing cattle. Flukes have a significant impact on cattle growth and productivity. Transmission is prevented if cattle are prevented from grazing on marsh grass.

Coccidia in cattle are distinct from those in other species, but their transmission by fecal-oral route is the same. Animal density is important, but as animals are moved to confinement the chance of infection decreases significantly.

*Trichomonas foetus* infects the cattle reproductive tract and causes abortion. Infection occurs during intercourse and is totally independent of stocking density, relying on infected anal contact. There is not treatment for this disease.

**Sheep**

**Skin Inhabiting Parasites:**

Sheep (Table 3) are known to be infested by mites and lice elsewhere in the world, but mites have been eradicated from North American sheep flocks, and lice are rare for reason(s) that are not clear.

Table 3.  Important parasites of sheep in Minnesota, compiled from various sources.

| Kind of parasite | Site of attack | Route of spread | Prevalence, by style or housing* | |
|---|---|---|---|---|
| | | | Pasture | Drylot (outdoors) |
| Stable fly | External | Flight | + | + |
| House fly | External | Flight | - | + |
| Wool maggots (2 spp) | External | Flight | + | - |
| Aquatic biting flies (>20) | External | Flight | + | + |
| Sheep nose bot | Internal | Flight | + | + |
| Lung worms | Internal | Intermed hosts | + | - |
| Abomasal worms | Internal | Ingested | + | - |
| Gastrointestinal (GI) worms | Internal | Ingested | + | - |
| Tapeworms | Internal | Ingested | + | + |
| Flukes | Internal | Ingested | + | - |
| Coccidia | Internal | Ingested | + | + |

*Prevalence codes: + = important or common; - = rare or absent

## Free Living Flies:

Both stable fly and house fly are associated with sheep in Minnesota, but effects on health and well-being have not been studied.  Wool maggots are larvae that cause grisly infestations on skin of mature sheep.  Egg laying females are attracted to soiled wool, so infestations are more common on ewes than on feeder lambs (in drylots), whose fleeces are generally shorter and cleaner.  Sheep housed outdoors are attacked by aquatic biting flies, but effects on health and well-being have not been assessed.  Biting gnats (*Culicoides* sp.) elsewhere in the US spread blue tongue virus, but the gnats here are refractory to infection by the virus.

## Internal Parasites:

Sheep nose bots reside in the nasal passages of sheep housed outdoors, but infections are benign.  This parasite was widely prevalent at slaughterhouse surveys in North Dakota (Meyer 1999).  Other internal parasites are similar to those found in cattle, with the exception that sheep have several additional lungworms.  These lungworms are acquired by ingesting snails and slugs, which are the intermediate hosts.  Thus, pastured animals are at greater risk than those in drylots.  In contrast, transmission of sheep tapeworms is equally likely in both settings because the oribatid mites that are the intermediate host are available in both environments.

**Horses**

**Skin Inhabiting Parasites:**

Horses have their respective species of mites and lice, which cause dermatitis, hair loss and pruritus.  Outbreaks are rare, and usually associated with cases of extreme neglect.

Table 4.  Important parasites of horses in Minnesota, compiled from various sources.

| Type of parasite | Site of attack | Route of spread | Prevalence, by style of housing* | |
|---|---|---|---|---|
| | | | Pasture | Stable (indoors) |
| Mites and lice (3) | External | Contact | + | + |
| Stable fly | External | Flight | + | + |
| House fly | External | Flight | - | + |
| Face fly | External | Flight | + | - |
| Aquatic biting flies (>20) | External | Flight | + | - |
| Horse stomach bots (3 spp) | Internal | Flight | + | + |
| Gastrointestinal (GI) worms | Internal | Ingested | + | - |
| Large bowel worms | Internal | Ingested | + | - |
| Tapeworms | Internal | Ingested mite | + | + |
| Trichinella | Internal | Ingested muscle | + | - |

*Prevalence codes: + = important or common; - = rare or absent

**Free Living Flies:**

Stable fly and house fly are common around horses.  Their biology and management is the same as with cattle.  Face fly adults occur on pastured horses, cause noticeable irritation, and transmit eye worms (*Thelazia* spp.).  Because this fly breeds exclusively in fresh cattle dung pats, face fly problems on horses are restricted to situations where cattle are present in neighboring pastures.  Aquatic biting flies, especially blackflies and horse flies, can interfere with horse comfort and equestrian pleasure.  These insects are reluctant to enter buildings.  One mosquito is known to transmit Western Equine Encephalitis virus from birds to horses in Minnesota. Fortunately, effective vaccines are available.

**Internal Parasites:**

Horse stomach bots (Knowles and Wilkins 1998) are widely prevalent, as judged from necropsies.  Adult females glue their eggs to hairs on the legs and heads of horses, and will enter buildings, so prevalence is independent of housing.  Larvae reside in the stomach, attached to the mucosa, but infections are benign.  Nonetheless, treatment by oral drench or injection is a routine part of fall horse care.

Other gastrointestinal parasites include the large bowel worms.  These are the primary pathogens and consist of large and the small strongyles.  The large strongyles (i.e. *Strongylus vulgaris*) may be very pathogenic, potentially causing death.  The small strongyles (of which there are over 30 different species) are less virulent, but can cause

clinical parasitism (sick horses).  All of these worms are acquired from fecally contaminated pasture, so they are more abundant among pastured horses than among stabled ones.  Many of these worms have developed resistance to some anthelmintics, so it is now necessary to alternate between classes with different modes of action.

The more specialized parasites can occur in both pastured and stabled horses.  With tapeworms, the intermediate host, an oribatid mite, occurs in both environments.  Similarly, *Trichinella spiralis* requires a rodent as an intermediate host.  A number of foreign countries are unwilling to import horsemeat from the U.S., in part because this parasite is endemic in this country.

**Poultry**

**Skin Inhabiting Parasites:**

Broiler chickens and turkeys are generally free of skin inhabiting mites and lice.  It may be that these meat birds simply do not live long enough to become noticeably infested.  It may also be that source populations of mites and lice have been eradicated from breeder flocks, or that production flocks are prevented from becoming infested by all-in, all-out housing in closed facilities.  The lack of exposure to infected, wild birds clearly contributes to this low level of infestation.

In marked contrast, northern fowl mite (Kells and Surgeoner 1997) is a chronic problem in many laying hen flocks in Minnesota and elsewhere in North America that consist of multi-age birds.  This mite's host range includes all forms of poultry, pigeons and sparrows, and it has noticeable effects on hen comfort and productivity.  Populations in California, Arkansas and Atlantic Seaboard states are known to be resistant to several acaricides.

It is not clear why this mite is peculiarly troublesome in caged layer flocks, but it appears to be more prevalent in units that contain birds of multiple ages.  Canadian workers (Kells and Surgeoner 1997) found that mites were imported into study barns on pullets at time of stocking, and spread among barns on egg handling equipment.  Once a few birds in a house were infested, the mites reproduced rapidly among adjacent cages, suggesting crowding and cage design predispose caged layers to mite outbreaks.  Although, it is known that resistance to mites increases with hen age, and that susceptibility varies among some lines of breeding hens units that contain birds of multiple ages have older birds with these mites.  Thus it appears that mite outbreaks could be traced to factors other than housing.

**Free Living Flies:**

Poultry housed in open sided barns and on pasture are attacked by several species of aquatic biting flies, but their effects on bird comfort and productivity have not been assessed.  One species of mosquito (*Culex tarsalis*) vectors western encephalitis virus among birds, including poultry, but infections in poultry are benign.  Mosquitos do serve as a vector for pox virus.  Blackflies are known to vector protozoa that cause duck

malarias in Minnesota, and a form of turkey malaria in the Gulf Coast states but not in Minnesota.

**Internal Parasites:**

Although poultry are hosts for a wide variety of internal parasites, the most important ones are coccidia.  Birds raised on pasture or barn litter are more exposed to infection than birds housed in wire cages, and coccidia have a very significant impact on growth and productivity.  Similarly, gastrointestinal worms, tapeworms and flukes can affect poultry health and are more prevalent among flocks on pasture or litter, where fecal contamination of feed and intermediate hosts are more accessible.  Contemporary birds (broilers) grow more rapidly than their ancestors.  Their shorter life cycle is less than that of the fluke worm which makes this less of a problem for the contemporary broiler.

Table 5.  Important parasites of poultry in Minnesota, compiled from various sources.

| Type of parasite | Site of attack | Route of spread | Prevalence, by type of bird and style of housing* | | | | |
|---|---|---|---|---|---|---|---|
| | | | Egg layer | Broiler | | Turkey | |
| | | | High or low-rise (indoors) | Pasture | Litter barn (open sides) | Pasture | Litter barn (open sides) |
| Northern fowl mite | External | Contact | + | - | - | - | - |
| Aquatic biting flies (>20 spp) | External | Flight | - | + | + | + | + |
| Gastrointestinal (GI) worms | Internal | Ingested | - | + | - | + | - |
| Tapeworms | Internal | Intermed host | - | + | + | + | + |
| Flukes** | Internal | Ingested | - | + | + | + | + |
| Coccidia | Internal | Ingested | - | + | + | + | + |

*Prevalence codes: + = important or common; - = rare or absent
**Birds serve as an intermediate host.  Contemporary broilers have a life cycle that is less than that of the worm cycle.

**BOVINE SPONGIFORM ENCEPHALOPATHY (BSE)**

Bovine Spongiform Encephalopathy (BSE or mad-cow disease) is a transmissible, slow progressing, fatal, nervous disorder of adult cattle.  It is characterized by the formation of holes in the nerve cells and results in a chronic degeneration of the brain (a spongy brain disease).  The first known case of BSE was diagnosed by a veterinarian in the UK in April 1985 (Lanchester 1996).  The first account of the disorder was published in the British Journal, Veterinary Record in October, 31, 1987 and by the end of 1987 there had been 420 cases of confirmed cases of BSE (Lanchester 1996).  The disease became a National Notifiable disease by the Ministry of Agriculture, Fisheries, and Food (MAFF) in the UK in June 1988.  The events surrounding the increased awareness of BSE, the need for clear and timely explanation of risks, and the importance of effective communication of scientific information on potential health problems have been summarized (Powell and Leiss 1997;Ratzan 1998).

Affected cattle may display changes in temperament, such as nervousness or aggression; abnormal posture; in coordination and difficulty in rising; decreased milk production; or

loss of body weight despite continued appetite.  The incubation period (time from when animal becomes infected until it first shows the disease signs) is from 2 to 8 years.  Following onset of clinical signs, deterioration is rapid and the infected animal dies, or is destroyed, anywhere from 2 weeks to 6 months.  Most cases in the UK occurred in cattle from 3 to 5 years of age.

The symptoms are similar to other rare, neurological disorders that affect humans and other animals.  The most common of these is scrapie, which causes sheep to compulsively scratch themselves.  The epidemiology of BSE in the UK suggests that it is linked to feeding cattle rendered protein produced from the carcasses of scrapie-infected sheep.  Scrapie has been endemic in the UK for centuries and rendered products from sheep have been used in cattle rations in the UK for decades.

The transmissibility of the disease is linked to infectious proteinaceous particles known as prions or "slow viruses" which are more difficult to destroy than normal viruses.  As infectious agents, prions are extremely resistant to heat and normal sterilization processes (Pratt 1996).  In the early 1980's, rendering plants in the UK stopped using a steam-heat enhanced solvent extraction process to enhance the yield of tallow and fat from carcasses because of safety concerns for the workforce.  This change in processing is considered a causal factor in the outbreak of the disease (IFST 1999;Pratt 1996;Lanchester 1996).  The prion has only been found in brain tissue and spinal cords of cattle infected with BSE.

The disease became an epidemic in the UK.  From April 1985 to April 1999, some 176,433 cases of BSE were confirmed in the UK (IFST 1999).  The number of new UK cases peaked in 1992 at 36,682.  In contrast, only 911 non-UK cases of BSE had been detected by May 1999 (IFST 1999).  Confirmed cases of the disease have been reported in domestic cattle in Ireland, France, Portugal, and Switzerland and in cattle exported from England to Oman, the Falkland Islands, Germany, Denmark, Canada, and Italy.  In March 1996, the European Union banned the export of British beef. This ban was lifted in November 1998 (IFST 1999).

Implementation of a number of measures reduced new cases dramatically.  By April 30, 1999, new cases had declined to 599.  These measures included a prohibition in 1988 of the use of rendered by-products derived from ruminants as a feed for ruminants in the UK.  A nation-wide slaughter and destroy policy for animals clinically diagnosed with BSE and offspring of infected cattle was implemented in 1988.  The reduced number of cases indicates the program is on target for the epidemic to come to an end very quickly (IFST 1999).

Related transmissible spongiform encephalopathy (TSE) disorders include scrapie in sheep and goats, transmissible mink encephalopathy, feline spongiform encephalopathy, chronic wasting disease of mule deer and elk, and three rare diseases in humans (Kuru, Creutzfeldt-Jakob Disease- CJD, and Gertsmann-Straussler Syndrome).  Evaluation of more recent CJD cases in the UK identified a new variant of the disease (v-CJD).  The prion protein from individuals with this variant of the disease has a similar molecular structure as the BSE prion.  This at least raises the concern that BSE could have been transmitted to humans (Collinge and others 1995).  However, there remains no direct

evidence of a link between BSE and CJD (IFST 1999).  In addition, there is no scientific evidence that sheep scrapie can be transmitted to humans either occupationally or by eating sheep meat (IFST 1999).  Surveillance of CJD in the UK indicates an average incidence of 50 cases per years during the 90's (IFST 1999).  This agrees with the annual rate of CJD cases of 1 in 1 million for other European countries and the US (IFST 1999;Lanchester 1996).

No cases of BSE have been detected in the U.S.  The USDA Animal Health and Plant Health Inspection Service (APHIS) has become very proactive to ensure that the disease is not established in the United States (Pratt 1996).  The USDA/APHIS restricts importation of live ruminants and ruminant products from countries where BSE is know to exist.  Import restrictions have been imposed on other products derived from ruminants such as fetal bovine serum, bone-meal, meat and bone-meal, blood-meal, offal, fats, and glands except for special permits for scientific research only (Pratt 1996).  Trained BSE Veterinarians have found no evidence of BSE in 93% of the 499 cattle imported cattle from England between 1981 and 1989.  Efforts are continuing to trace the other 7%.  A large effort involving APHIS veterinary pathologists, field food safety inspectors, and other trained investigators in numerous state diagnostics labs and animal health services, are conducting surveillance activities.  In the US, rendering companies can no longer pick up deceased or destroyed sheep.  The National Animal Feed Industry has implemented a ban on use of animal protein byproducts from processed sheep.  These are pro-active measures that will ensure continued supply of safe food in the U.S.

## AIR QUALITY

### INTRODUCTION

Air quality is part of the environment that affects animals health and well-being.  Other environmental characteristics include temperature (i.e., dry-bulb, surrounding surface, dew-point), moisture (i.e, air, surfaces, bedding/litter), light (i.e., intensity, photoperiod length, color characteristics, uniformity), nutrition, and many other factors.

Clean dry air is comprised of many gases including nitrogen (78%), oxygen (21%), argon (0.9%), carbon dioxide (0.03%), and trace amounts of neon, helium, methane, sulfur dioxide, hydrogen, krypton, xenon, and ozone (ASHRAE 1997).  Atmospheric air contains these gases plus water vapor and miscellaneous contaminants, some from natural sources and some the result of human activity.

Airborne contaminants can be categorized in numerous ways.  The categories used for this report are; gases and odors, particulates or dusts, and biogenic particles.  O'Neill and Phillips (O'Neill and Phillips 1992) created a list of 168 compounds identified in livestock wastes or the air around them.  The list is in the GEIS Air Quality and Odor report. Dusts in and around animal facilities include bits of feed, dried skin, hair or feathers, dried feces, and soil particles (Koon and others 1963;Anderson and others 1966;Curtis and others 1975;Heber and others 1988;Alegro and others 1972;Sweeten and others 1988;Sweeten and others 1998;Anderson and others 1966;Alegro and others 1972;Sweeten and others 1988;Sweeten and others 1998).  Feed was found to be the primary component of the dust (Curtis and others 1975;Heber and others 1988). Biogenic particles include bacteria, viruses, fungi spores, amoebae, algae, pollen, plant parts, insect parts and wastes, endotoxins and mycotoxins.  Endotoxins are naturally occurring substances in the cell walls of gram negative bacteria that are released when the microogranisms die.  Mycotoxins are toxins produced by fungi.

Air quality within animal facilities depends on many factors including the ventilating system and air exchange rate, temperature, relative humidity, manure system and management, bedding use, feed form and quality, feeding system, and animal activity.  Many air quality studies have reported contaminant concentrations measured in livestock facilities.  Some of the studies are summarized in the following sections.  It should noted that many of these studies are from European research, climates and some specifics that may differ significantly from US or Midwest conditions.  It should also be noted that both indoor and outdoor animal units (as well as agronomic fields and other situations) have periods where dust and microbe contents in the air are less than, equal to, or greater than the levels established by regulations such as the EPA clean air act.  For example, a recent study demonstrated that methods to reduce particulate matter (dust particles and associated fungi) are needed on certain days to enhance animal and worker health and well-being within indoor and outdoor pig production units (Morrow-Tesch and others 1999).

**DUST CONCENTRATIONS IN ANIMAL BUILDINGS**

There is a large amount of literature reporting dust concentrations in animal buildings. Sampling techniques and building conditions vary widely.  The results indicate that animal buildings can be quite dusty.  Inhalable and respirable dust concentrations within various cattle, swine, and poultry facilities have been reported (Table 1) in Europe (Takai and others 1998).

Inhalable dust was collected using an IOM (Institute of Occupational Medicine, Edinburgh) dust sampler, which represents the dust inhaled through a human's nose and mouth (Mark and Vincent 1986).  Respirable dust was measured using a cyclone in series with a filter. The cyclone removes most of the particles with an aerodynamic diameter of 5 microns or more.  The remaining respirable dust captured on the filter represents the dust that can penetrate deeply into the respiratory tract and the lungs.  Both samplers are commonly used in personal dust sampling.

Table 1.  Mean inhalable and respirable dust concentrations in English, Dutch, Danish, and German livestock buildings (Takai and others 1998).

| | Mean inhalable dust concentration ($mg/m^3$) | Mean respirable dust concentration ($mg/m^3$) |
|---|---|---|
| Cattle Buildings (dairy and beef) | | |
| England | 0.22 | 0.15 |
| The Netherlands | 0.30 | 0.09 |
| Denmark | 0.39 | 0.04 |
| Germany | 0.65 | 0.05 |
| Overall mean | 0.38 | 0.07 |
| | | |
| Pig Buildings | | |
| England | 1.87 | 0.24 |
| The Netherlands | 2.43 | 0.25 |
| Denmark | 2.76 | 0.26 |
| Germany | 1.95 | 0.18 |
| Overall mean | 2.19 | 0.23 |
| | | |
| Poultry Buildings | | |
| England | 3.31 | 0.51 |
| The Netherlands | 4.58 | 0.58 |
| Denmark | 4.52 | 0.64 |
| Germany | 2.22 | 0.19 |
| Overall mean | 3.60 | 0.45 |

Overall, airborne dust levels were higher in pig and poultry buildings than in cattle buildings (Takai and others 1998).  Statistical analysis indicated that the interaction between country and housing type was significantly different for both inhalable and respirable dust concentrations.  Dust concentrations in cattle buildings were not affected

greatly by season.  Inhalable dust concentrations in both pig and poultry buildings were significantly affected by country, housing type, season, and sampling period (day versus night).  Respirable dust concentrations in pig barns were not affected by country.  Respirable dust concentrations in poultry buildings were not affected by sampling period.  Inhalable and respirable dust concentrations were lower in caged layer buildings compared to those in percheries (laying hen facilities with litter flooring and perches).  Inhalable and respirable dust concentrations in broiler barns were generally comparable to those in percheries in England and The Netherlands but slightly lower in Denmark.  Ventilation and feeding practices, bedding materials, manure handling all affect dust concentrations (Takai and others 1998).

Total dust concentrations in turkey barns in Minnesota ranged from 0.4 to 13.8 mg/m$^3$ across two studies (Mulhausen and others 1987) (Reynolds 1994).  Concentrations were highest in the winter.  Respirable dust concentrations ranged from 0.1 to 2.6 mg/m$^3$ (Reynolds 1994).  Total dust concentrations in broiler barns in North Carolina ranged from 0.02 to 11 mg/m$^3$ (Jones and others 1984).  Respirable dust levels ranged from 0.02 to 0.62 mg/m$^3$.  Bird age, litter age, and animal activity were factors (Jones and others 1984).  Total and respirable dust concentrations in caged layer barns in Sweden were comparable or less than those in barns without cages (alternative housing) (Martensson 1995).  Total dust concentrations in the conventional caged layer barns ranged from 1.3 to 2.7 mg/m$^3$ while respirable dust concentrations ranged from 0.08 to 1.04 mg/m$^3$.  Corresponding total and respirable dust concentrations in the alternative barns ranged from 2.6 to 4.1 mg/m$^3$ and 0.08 to 1.13 mg/m$^3$, respectively.

Total dust concentrations in an Italian horse stable ranged from 0.26 to 10.82 mg/m$^3$ with a mean concentration of 1.95 mg/m$^3$.  Respirable dust concentrations ranged from 0.03 to 1.46 mg/m$^3$ with a mean of 0.38 mg/m$^3$ (Navarotto and others 1994).

Research in swine buildings indicates that total dust concentrations are higher in finishing barns than either nursery or gestation barns. Donham et al. (Donham and others 1986) reported mean total mass dust concentrations to be 3.2 mg/m$^3$ in farrowing units, 5.2 mg/m$^3$ in nursery units, and 15.3 mg/m$^3$ in finishing buildings.  The respirable fractions were 20%, 13.4%, and 12.4% of the total dust in the farrowing, nursery, and finishing buildings, respectively.  Maghirang et al (Maghirang and others 1997) reported a mean total dust concentration of 0.72 mg/m$^3$, ranging from 0.12 to 2.14 mg/m$^3$ in a test swine nursery.  The respirable fraction ranged from 2 to 30% of the total dust, with an overall mean of 11%.

## GAS CONCENTRATIONS IN ANIMAL BUILDINGS

Groot Koerkamp et al (Groot Koerkamp and others 1998) reported on ammonia concentrations in cattle, pig, and poultry houses in England, Denmark, The Netherlands and Germany.  Mean ammonia concentrations in the cattle buildings were below 8 parts per million (ppm).  Mean values ranged from 0.3 to 7.7 ppm.  The maximum concentrations ranged from 1.7 to 20.1 ppm.  Mean ammonia concentrations in pig buildings were between 4.3 and 18.2 ppm..  Maximum concentrations in pig buildings ranged from 14.3 to 59.8 ppm.  Mean ammonia concentrations in poultry buildings

ranged from 1.6 to 29.6 ppm.  Maximum ammonia concentrations in poultry buildings ranged from 14.5 to 72.9 ppm.  The data suggests that health risks would be greater due to ammonia in the pig and poultry buildings than in the cattle buildings (Groot Koerkamp and others 1998).

Ammonia concentrations in pig buildings in Minnesota were less than 30 parts per million (ppm) averaging only 10-15 ppm (Jacobson and others 1996).

Ammonia levels in turkey grower barns in Minnesota were higher in the fall and winter season compared to the spring and summer (Mulhausen and others 1987).  Seasonal average values ranged from 10 to 35 ppm.  Mean ammonia concentrations in turkey buildings ranged from 1.9 ppm in brooder barns in the summer to 46.2 ppm in grower barns with hens in the winter (Reynolds 1994).  Concentrations of carbon monoxide, hydrogen sulfide, nitrogen dixoide, and methane in turkey grower barns were below detectable levels (Mulhausen and others 1987).  Mean sulfur dioxide concentrations in turkey barns ranged from 0.13 to 0.36 ppm (Reynolds 1994)

Ammonia concentrations in three broiler barns in North Carolina had average concentrations around 25 ppm ranging from 6 to 75 ppm.  Carbon dioxide concentrations ranged from 500 to 1,000 ppm.  Carbon monoxide, hydrogen sulfide, nitrogen dioxide, oxides of nitrogen (NOx), methane, mercaptan, formaldehyde, and hydrocarbons concentrations were all below the detection limits of the detector tubes used (Jones and others 1984).

**BIOGENIC CONCENTRATIONS IN ANIMAL BUILDINGS**

Researchers have reported biogenic concentrations for bacteria, fungi and endotoxins. Concentrations differ depending on animal species, manure system and management, bedding use, feed form and quality, feeding system, animal activity, and management. Microbial emissions can come from the animals, bedding, feed, manure or exterior (outside) sources.

Airborne endotoxin concentrations measured in cattle, pig, and poultry buildings in Europe are summarized in Table 2 (Seedorf and others 1998).  In general both inhalable and respirable concentrations were higher in poultry buildings than pig buildings than cattle buildings.  Generally daytime concentrations were higher than nighttime concentrations.

Table 2. Mean airborne endotoxin concentrations (ng/m$^3$) in different animal buildings at day and night.

| Species | Inhalabel endotoxin concentration (ng/m$^3$) | | Respirable endotoxin concentration (ng/m$^3$) | |
|---|---|---|---|---|
| | Day | Night | Day | Night |
| Cows | 15.1 | 7.4 | 0.6 | 1.6 |
| Beef cattle | 11.8 | 13.6 | 1.0 | 1.3 |
| Calves | 48.7 | 63.9 | 6.3 | 6.7 |
| Sows | 114.6 | 52.3 | 8.3 | 7.4 |
| Weaners | 186.5 | 157.4 | 17.7 | 18.9 |
| Fattening pigs | 135.1 | 109.1 | 13.0 | 11.4 |
| Layers | 860.4 | 338.9 | 58.1 | 29.6 |
| Broilers | 785.7 | 784.2 | 35.1 | 71.8 |

Seedorf et al (Seedorf and others 1998) measured airborne microorganism concentrations in animal buildings, mostly in Germany. The highest mean bacterial concentrations were measured in broiler buildings where the mean concentration was 6.43 logrithim of colony-forming-units per cubic meter of air (log cfu/m$^3$). Mean bacterial concentrations in layer and pig houses ranged from 4 to slightly over 5 log cfu/m$^3$. Mean bacterial concentrations in cattle barns were generally slightly over 4 log cfu/m$^3$. Mean daytime Enterobacteriaceae concentrations ranged from 3.2 to 4.5 log cfu/m$^3$. Mean daytime fungi concentrations were 3.8 for cattle, 3.7 for pigs, and 4.0 for poultry log cfu/m$^3$, respectively with similar values for nighttime (Seedorf and others 1998).

Hartung (Hartung 1994) noted some generalities in a review regarding airborne microbes in poultry buildings. Airborne microorganisms found in poultry buildings, as in most livestock facilities include: staphylococci, streptococci, pseudomonas, E. coli/Enterobacter, fungi, molds and yeasts. Of the fungi, several different species were found B some of which considered to be allergenic (Penicillium, Aspergillus, Cladosporium, and Alternaria) (Hartung 1994). Airborne bacteria concentrations in three broiler barns in North Carolina were around 150,000 cfu/m$^3$ (Jones and others 1994). Fungi concentrations were 10,000 cfu/m$^3$. Endotoxin concentrations ranged from 0.77 to 61 ng/m$^3$ in the total dust samples and from 0.71 to 15 ng/m$^3$ in the respirable dust.

Because methods of microbial determination (i.e., bacteria and/or fungi) and differentiation (i.e., fungi species), sampling times and sites differed between studies, there may be limited value in reported quantities of airborne particulates as absolute values. For instance, three papers reported widely varying airborne microbial concentrations in egg layer houses for layers in cages: range of 360 to 3781 Colony Forming Units (CFU's) per liter of air (Hartung 1994); range of 17 to 5860 CFU's per liter of air (Loeper and others ); and, range of total bacteria of 290,000 to 680,000 CFU's per cubic meter (Clark and Rylander 1983).

The effects of independent variables can be assessed when measurements are taken using the same standard procedures for specific comparison purposes. For instance, the type of poultry and housing shows an effect on airborne microorganism concentrations. Hartung

(Hartung 1994) indicated that airborne microorganisms in houses with chicken layers on litter (bedding) had approximately 5 times the concentrations compared to chicken layers in cages, perhaps reflecting the difference in hen activity and contributions of the litter material.

In the Midwest US season has a significant affect on airborne microorganisms in turkey houses. Mulhausen et al. (Mulhausen and others 1987) found that airborne Aspergillus concentrations in a turkey barn in Minnesota never exceeded 73 colony forming units per cubic meter ($cfu/m^3$), which was less than background levels found in two ambient air studies (Alvo 1980;Jones and Cookson 1983;Jones and Cookson 1983). Reynolds et al. (Reynolds 1994) found that mean bacteria concentrations in turkey barns that ranged from 300,000 to 38,700,000 $cfu/m^3$. Higher levels of bacteria, approximately 5 fold, (Debey and others 1995) and higher levels of Aspergillus, approximately 3.5 fold (Janni and others 1985) were found in rearing facilities in the winter compared to summer. The large difference is most likely due to ventilation rates targeted toward keeping barns warm in the winter and heat removal in the summer time.

There is limited research information on microbial populations as affected by feed type, animal activity, bedding type and management, manure handling system, stocking density, air temperature, and relative humidity. Bedding provides environmental conditions appropriate for bacterial growth and fungal spores (Beran 1991). Populations change with bedding use. Fungi populations in fresh and used litter in broiler houses had different specie populations. Aspergillus spp. and Scopulariopsis brevicaulis were predominant in the litter after one cycle of birds (Dennis and Gee 1973). Research reported by Jones et al (Jones and others 1984) for broiler farms in North Carolina indicated airborne fungal counts were an order of magnitude higher in a house with fresh litter compared to a flock housed on old litter (same age birds).

**ANIMAL RESPONSE**

An animal's response to airborne contaminants will depend on the dose of contaminant absorbed, inhaled, or ingested and the impact that the contaminant has on the animal. Dose through the respiratory tracts is extremely difficult to measure because it depends in part on animal activity, environmental temperature, and respiration rate. Exposure is typically used as a surrogate for dose. Exposure describes the contact between the animal and contaminant in terms of contaminant concentration and duration of contact. Exposure also describes the contact in terms of the surfaces that are exposed to the contact (i.e., eyes, skin, respiratory tract, other).

Animals exhibit their responses to airborne contaminants in many ways and through various biological systems. Changes in production (e.g., average daily gain, feed conversion) or reproduction are common response indicators. Other indices include health, morbidity, mortality, and thermal comfort. Animals can also exhibit physiological and behavioral changes. Responses can be seen in the respiratory, circulatory, immunological, and thermoregulatory systems. Individual responses vary, requiring extensive studies to develop the statistical base to describe the probabilistic response of the animal population. The number, diversity, and interactions of response

variables to multiple stressors, including air quality, makes quantification of the effects difficult at best (Janni 1989).

The impact of airborne contaminant on animals raised for food has been very difficult to assess.  There are a number of published papers dealing with this issue, but there is no consensus to date as to whether airborne contaminants at levels found commonly in animal facilities has an impact on animal health and performance.  The potential direct impact on animal (swine, cattle, and poultry) health can be:

■ physical impairment of mechanical defense mechanisms by dust (e.g. immobilization of the cilia layer that transports mucus and foreign bodies out of the respiratory tract),

■ chemical irritation of the membranous lining of the respiratory tract by gases (e.g. impairment of the cellular defense mechanisms against respiratory bacterial or viral pathogens),

■ infection with bacteria or viruses that have a pathogenic potential for the animal respiratory tract (e.g. Streptococcus, Staphylococcus, Pasteurella and Haemophilus).  These may be spread from animal to animal or from animal unit to animals in other units by transference.

**Particulates:**

Airborne particulate or dust is considered to be a health risk for workers exposed over a prolonged period of time.  Although there are no data available to demonstrate specific effects of dust on the health of pigs, cattle, or poultry (Heber and others 1988), it is known that dusty environments are associated with decreased health.  For example, dust accumulates in the airsacs of turkeys whether they are housed indoors or outdoors (D.A. Halvorson, personal communication).  Assignment of the associated reduction in health to the dust, to the attached fungi, or to other factors is problematic and not yet resolved.  Pigs exposed to ammonia, hydrogen sulfide, and airborne dust at concentrations at or higher than those typically found in pig finishing houses had little effect on body weight, rate of gain, or respiratory tract structure (Curtis and others 1975).

Animals have the ability to clear particles from the lungs after inhaling but the pattern of clearance will vary with distribution of the particles as reflected by a rapid clearance of 30-60 minutes and a slower clearance lasting a number of hours.  Particles remaining after 24 hours have been shown to be trapped in the lung alveoli and terminal non-ciliated bronchioles (Webster 1990).  Effects of particle size and distribution in lungs of 2 and 8 month-old calves have been investigated and summarized (Table 3).

Table 3.  Effect of age and particle size on percentage distribution of particles in the
respiratory tract of 2 and 8 month-old calves[a]

| Age | Lung Region | Particle Size, Microns | | |
|---|---|---|---|---|
| | | 2.0 | 3.3 | 5.0 |
| 2 months | Nose | 2 | 6 | 12 |
| | Airways | 15 | 34 | 32 |
| | Alveoli | 60 | 47 | 26 |
| | Exhaled | 13 | 13 | 30 |
| | | | | |
| 8 months | Nose | 9 | 17 | 34 |
| | Airways | 34 | 43 | 55 |
| | Alveoli | 32 | 24 | 6 |
| | Exhaled | 21 | 16 | 5 |

[a]Adapted from Webster (Webster 1990).

These data (Table 3) illustrate that the smaller particles penetrate more deeply into the
lungs.  The nose was not a very good filter of inhaled particles. The younger calf had a
higher percentage of particles in the alveoli.  Inert particles, such as might be found in
dust, may remain in the alveoli for months.  Other research studies have indicated that the
majority of inhaled particles enter parts of the lung that are least sensitive to enzootic
pneumonia in calves.  However, it has been suggested that these particles move through
the lungs along lines of least resistance and will cause the regional distribution of
enzootic pneumonia (Davies and Webster 1989).

A hypothesis was tested in mice to find out how inhaled dust particles may compromise
the resistance defenses of the respiratory tract and cause build up of bacteria that may
cause pneumonia problems in farm animals such as enzootic pneumomia in calves and
atrophic rhinitis in pigs (Gilmour and others 1989a;Gilmour and others 1989b). Mice
were exposed to controlled doses of inert dust (titanium dioxide) over a 4 weeks period (2
and 20 milligrams/cubic meter) vs clean air, and then challenged with an aerosol of
Pasteurella haemolytica (PH; causes primary and secondary pneumonia in young farm
animals).  The number of  PH bacteria were similar initially and over the next 7 days
were effectively cleared in mice exposed to clean air and the lower dust dose. The PH
bacteria multiplied 4-fold by 24 hours in mice exposed to the higher dust dose. After 7
days the PH bacteria had been cleared to lower concentrations that the initial PH
challenge but higher than the clean air and lower dust dose levels.  It was suggested that
the level of PH bacteria found after 24 hours with the higher dust dose is not outside the
limits found in animal housing and emphasized that the 'natural' animal house dust
would be potentially more damaging to the lungs than the inert titanium dioxide (Webster
1990).

**Gases:**

Animals housed in intensive production systems (essentially housed indoors) such as those commonly found in Minnesota, are exposed to a number of different atmospheric gases at levels that are higher than those found outdoors.  Although many gases were identified in and near animal housing systems only two, ammonia and hydrogen sulfide, have been studied extensively for their effect on animal health.  Many of the other gases are at trace levels and are not normally considered to limit farm animal productivity (Scott and others 1983).  Concentrations of carbon monoxide, hydrogen sulfide, nitrogen sulfide, and methane were below detectable levels in Minnesota turkey barns (Mulhausen and others 1987).

Studies on the effect of ammonia on swine have yielded mostly negative results, when studied with levels found in commercial farms (Jacobson and others 1985).  Pigs exposed to ammonia and hydrogen sulfide concentrations at typically found in pig finishing houses had little effect on body weight, rate of gain, or respiratory tract structure (Curtis and others 1975).  A couple of studies have shown that pigs exposed to high ammonia concentrations, greater than 50 ppm, develop more lung lesions due to Ascaris larvae migration and more Atrophic Rhinitis lesions when challenged with the causative organism for this disease (Hamilton and others 1999).  Studies performed at farm ammonia levels have also found negative effects on growth, up to a 1-6% difference in feed efficiency in gilts.  However, these studies compared two different production systems.  The differences observed could have therefore been the result of less microbial exposure and not only the effect of the presence of ammonia (Dierkman and others 1993;Dierkman and others 1997;Dierkman and others 1997).

Studies on turkeys have shown that ammonia can affect turkeys.  Nagaraja et al. (Nagaraja and others 1983) found that prolonged exposure to ammonia at concentrations as low as 10 and 40 ppm damaged tracheal tissues in turkeys.

Hydrogen sulfide ($H_2S$) is a very toxic gas, as mentioned previously, which is also derived from the decomposition of manure.  Unlike ammonia, which is water soluble and lighter than air, $H_2S$ is heavier than air and tends to stay in the lowest points in a barn such as the pit area.  As with the human safety concern when manure in pits or tanks are agitated and pumped onto cropland, the sudden death of housed animals in these confined barn has been reported (Curtis 1981).  A few (estimated to be 5 to 10 per year) of these occur each year in Minnesota, even though numerous organization, including the University of Minnesota Extension Service, recommends that buildings be empty of animals when deep pits are agitated and pumped.

**Biogenics:**

Airborne endotoxins, microbes, and pathogens are other airborne contaminants that may pose a health risk to animals housed inside buildings.  Although colony forming units (CFU) have been measured in animal facilities, especially poultry units, the significance of this microbial exposure on the impact of health and performance of poultry is not well established.  As noted by Hartung (Hartung 1994) this could be due to several

possibilities. A different mechanism is in affect for response to the airborne microorganisms. One would be the effect where specific microbes (pathogens) cause respiratory disease if present in the environment in sufficient number to cause infection. The other may be a non-specific effect where the immune system is stimulated by exposure and over time it is compromised (Hartung 1994).

Another reason why it is difficult to separate the impact of microbial insult from that of other air contaminants, such as dust and ammonia, is that pathogens may attach themselves to dust particles thus making it difficult to distinguish or isolate the impact they have on an animal. For example, on-farm air quality monitoring of turkey flocks and their performance has indicated higher rates of carcass condemnation for turkeys marketed in the winter as compared to the summer (Debey and others 1995;Janni and Redig 1986;Janni and Redig 1986). This carcass condemnation is most often attributed to air sacculitis indicative of respiratory disease. However, overall air quality in the winter season is poorer with higher observed levels of ammonia, dust, bacteria, and fungi.

Many poultry veterinarians are of the opinion that the microbes are opportunistic and that other conditions need to be present in order to allow infection to occur which is supported by research. Barnes (Barnes 1982) cites evidence that reproduction of respiratory disease is difficult in a research laboratory using the infectious agent alone. Poss (Poss 1994) has indicated that respiratory disease in turkeys is often preceded by exposure to ammonia and dust, which reduces defense capabilities of the respiratory system. In fact Janni and Redig (Janni and Redig 1986;Janni and Redig 1986) found that direct exposure of turkeys to aspergillus spores did not cause the expected development of aspergillosis in turkeys. Rearing of turkeys in the presence of varying levels of ammonia without dust exposure also resulted in no negative effects. However, exposure of poultry to ammonia followed by challenge to respiratory diseases often worsens infection rate (Anderson and others 1966;Nagaraja and others 1984;Nagaraja and others 1984). Dust is of concern due to the association of some bacteria and virus with dust particles of respirable sizes (Carpenter 1986). Once the disease organisms are introduced to the flock, dust may play a role in the transmission among the birds.

Thus the interaction of the air contaminants and other environmental conditions may be as important as defining the airborne microbial environment. As indicated in a review (Halvorson and Noll 1989), there are many factors in the environment and management of poultry houses that could affect respiratory disease. Litter moisture, ventilation rate, environmental temperature, heat stress, vaccination programs, and water sanitation.

**INDOOR CONFINEMENT**

**General:**

Animal housing must provide an acceptable environment that meets the needs of the animals occupying the structure. The environment in livestock facilities is often incompletely defined and difficult to characterize definitively (Hahn and others 1983). Hahn et al. (Hahn and others 1983) defined environment in a broad sense to include all non-genetic factors influencing an animal.  The environment includes all conditions except those imposed by heredity and includes external factors (e.g., temperature, light, moisture, social factors) as well as internal factors (e.g., nutrition, disease organisms, parasites) (CAST 1981b).  With such an inclusive definition for the term environment it is practically impossible to completely and quantitatively measure an animal's environment.  For this discussion on animal housing, the environment will be limited to the following characteristics:

Temperature (dry-bulb air and surface)
Moisture (air and surfaces)
Air velocity (drafts)
Light (intensity, color characteristics, photoperiod length, uniformity)
Space
Airborne contaminants (dust, gases, and biogenic particles).

These characteristics do not completely define an environment.  For example, dry-bulb air temperature, the temperature commonly measured with either liquid-in-glass or digital thermometers, is commonly used to represent the entire thermal environment.  However, air temperature does not describe the radiant environment, heat gain or loss by radiant heat exchange to surrounding hot and cold surfaces.  Also, air temperature alone does not describe the thermal effect of both evaporative cooling from animals with wet coats and convective heat exchange from animals in drafts.  In some cases these other environmental characteristics can have a significant effect on an animal's effort to maintain homeothermy (i.e, constant core body temperature).

The desired environmental conditions are a management decision based on animal well-being, economics, and management preferences.  Desired conditions usually depend on species, animal age, and season.  As environmental conditions approach the boundaries of the desired conditions, animal care givers need to decide whether to implement corrective actions (i.e., change ventilation rates, open or close curtains, add bedding, adjust thermostats) to maintain desired environmental conditions.  In many instances short-term excursions beyond the desired environmental limits are not a cause for significant concern.

Hahn et al. (Hahn and others 1983) defined a stressor as an environmental factor that imposes stress on an animal as evidenced by altered physiological, behavioral, immunological, or other parameters, and which may or may not alter overall performance.  Stott (Stott 1981) reviewed various concepts of stress and quoted Lee's (Lee 1965) definition of stress often used by physiologists: "(1) Stress denotes the

magnitude of forces external to the bodily system which tend to displace that system from its resting or ground state; (2) strain is the internal displacement from the resting or ground state brought about by the application of the stress." This definition is consistent with the use of the terms stress and strain in engineering (CAST 1981b).

Research on the effects of multiple stressors has been conducted on swine, turkeys and chicks. Many studies produce results that conflict with "common" field experience. This indicates the adaptability of animals. It also indicates that simplified controlled experiments do not incorporate enough stressors that exist in the field. Most experiments have been exploratory to identify the important factors and how they interact.

In confinement housing, efficient ventilation systems and sufficient air changes/hour are key factors to removal of air-borne challenges. Air changes that fall below 4 changes/hour will exacerbate the challenges from fungal spores, allergens or dusts (Webster and others 1987). Most of the organisms that can be recovered from the air are non-pathogenic, although if present in large numbers may contain a high level of endotoxins which can be deleterious to the animal. Survival time of aerosolized primary pathogens is very short, even when there are a number of infected animals in the building. However, efficient ventilation will not counteract respiratory infections if animal stocking density exceeds that recommended for the size of the facility (Webster 1990).

**Swine:**

Curtis et al. (Curtis and others 1975) conducted a study to determine the effects of exposure to ammonia, hydrogen sulfide, and dust at various levels and in combinations on the rate of body weight gain and gross and microscopic integrity of the respiratory tract of the pig. Ammonia levels were 0, 50, and 75 ppm. Dust levels were 10 and 300 mg/m$^3$. Hydrogen sulfide levels were 2 and 8.5 ppm. Only one trial ($NH_3$ - 50 ppm and 300 mg/m$^3$ of dust) produced statistically significant differences in rate of gain. With the exception of one pig with minor conjunctivitis and blepharitis (swollen eyelids) out of 100 pigs, there was no evidence of structural alteration in any organ or tissue.

Another study with ammonia (0, 50, 100, and 150 ppm) was conducted after carefully selecting the animals to reduce non-uniformity in initial pig body weights and eliminating possible crowding effects. Statistically significant effects of week and ammonia on body weight were observed. Differences in pig activity levels, coughing, nasal and lacrimal secretions, and upper respiratory tract (trachea and turbinates) tissues were also observed (Drummond and others 1980).

Further studies were conducted to determine the effects of ammonia and infections (e.g., *Bordetella bronchiseptica, Ascaris suum* ) on production performance and the respiratory tract health of young (four to eight week) pigs (Drummond and others 1981a;Drummond and others 1981b;Drummond and others 1981b). Body weights of *Bordetella*-infected pigs correlated with infection and age but not ammonia concentration. This unexpected result was explained as possibly having been due to the increased mucus production due to the infection, which may have also protected the upper respiratory tract from the

ammonia.  Gross evidence of pulmonary lesions were found in 13 of 17 infected pigs (Drummond and others 1981a).  Body weights of the *A suum*-infected pigs were affected by infection, ammonia, and age.  One pig had gross evidence of pulmonary abnormality.  Liver scaring due to larval migration was varied in the ascarid infected pigs but did not appear to be affected by ammonia exposure (Drummond and others 1981b;Drummond and others 1981b).  These results indicate the ability of young pigs to adapt to and compensate for various stressors.  They also indicate the range of animal responses and number of animal response systems (respiratory, immune) that need to be evaluated.

Research to measure the effects of ventilation rate, temperature, and drafts on young pigs has generally found no statistical effect on pig performance (Boedicker and others 1984;Jacobson and others 1985;Jacobson and others 1986;Noyes 1986;Riskowski 1986;Jacobson and others 1985;Jacobson and others 1986;Noyes 1986;Riskowski 1986).  Boedicker et al. (Boedicker and others 1984) conducted studies in new swine nursery facilities using two ventilation rates (0.7 and 1.4 L/s).  The lower ventilation rate rooms used approximately 37% less supplementary heat, but there was no statistical difference in average daily feed intake, average daily gain, and feed/gain ratio.  Early weaned piglets raised in chambers with ventilation rates of 0.2 or 0.9 L/s and intranasally inoculated with *Pasteurella multocida*  and *Bordetella bronchiseptica*  did not have a statistically significant difference in performance (Jacobson and others 1985).  No piglet health performance advantage was found for either ventilation rate based on pneumonic lung lesions and only one pig had lesions (Jacobson and others 1985).  Low ventilation rates (0.2 L/s) produced very high humidities and condensation on walls but had no effect on performance (Jacobson and others 1986).  Nursery pigs exposed to drafts (0.5 m/s) from the inlet air did not have a statistically significant difference in performance and there were no clinical pig health differences compared to piglets not exposed to a draft (Noyes 1986).  Humoral antibody titer suppression, however, was found in the piglets stressed by the draft (Noyes 1986).

Riskowski (Riskowski 1986) studied the effects of air temperature (24 - 35º C) and velocity (0.11 - 0.40 m/s) on the performance, behavior, and time of digesta passage of weanling pigs.  He found that average daily gain and average feed intake generally decreased with increased air velocity and increased with decreased air temperature.  Huddling and pig lying area were affected by the thermal environmental conditions (stress) (Riskowski 1986).  Hoff (Hoff 1987) modeled the sensible heat loss (Hoff 1987) from new-born pigs exposed to a draft and the effects of a hover.  He found that hovers reducing the draft velocity and the piglets' exposure to cold surfaces could significantly reduce piglet heat loss (Hoff 1987).  These studies using various types of environmental stressors and different methods further indicate the adaptability of pigs to stressful environments.  Complex interactions are indicated as the pigs adapt to limited numbers of stressors.

Problems with outbreaks of pneumonia such as enzootic pneumonia in pigs, are often associated with a secondary bacterial infection triggered by a combination of stress in the pigs, inadequate environmental control, presence of airborne dust particles, mixing of pigs, overcrowding of pigs, and poor pen dis-infection between batches of pigs

(Whittemore 1993). Use of 5% soybean oil added to the feed has been shown to reduce airborne dust particles (Gore and others 1985). Similar results have occurred from use of a wet feeding system or strategically placing nipple waterers that wet the feed when pigs are drinking (Whittemore 1993).

**Turkey:**

Respiratory health of tom turkeys raised in the winter is a concern to producers because of the economic losses in terms of morbidity, mortality, weight, feed conversion, and processing plant condemnations due to air-sacculitis. Jacobson and Jordan (Jacobson and Jordan 1978), Janni et al. (Janni and others 1984;Janni and others 1985;Janni and Redig 1986;Janni and others 1985;Janni and Redig 1986) and Mulhausen et al. (Mulhausen and others 1987) reported results of environmental and air quality measurements in turkey production facilities. The purpose of these studies was to determine background levels, factors affecting concentrations, and correlations between respiratory disease agents and processing plant condemnations. Similar background level studies have been conducted for layers (McQuitty and others 1985) and broilers (Jones and others 1984).

Results from the field monitoring indicate that large numbers of bacteria and particulate are found in confinement turkey barns. Aerosol concentrations depended on relative humidity, bird activity, litter management, and litter moisture content (Jacobson and Jordan 1978;Janni and others 1984;Janni and others 1985;Janni and Redig 1986;Mulhausen and others 1987;Janni and others 1984;Janni and others 1985;Janni and Redig 1986;Mulhausen and others 1987). Ammonia concentrations depended on litter management, litter moisture content, and ventilation rates (Janni and others 1985;Janni and Redig 1986;Mulhausen and others 1987;Janni and Redig 1986;Mulhausen and others 1987). Ammonia has been shown to adversely affect the normal mucociliary apparatus, resulting in excessive mucous production, matted cilia, and areas of deciliation in tracheal tissues of turkeys exposed to ammonia (Nagaraja and others 1983).

Unpublished research on the effect of ammonia and dust on turkey production and their ability to clear *Aspergullus fumigatus* spores from their respiratory tract produced unexpected results. Ammonia levels as high as 100 ppm alone and combined dust (over 8 mg/m$^3$) and ammonia (100 ppm) did not show statistical differences in production or lung clearance compared to low dust (5 mg/m$^3$) and ammonia (10 and 25 ppm) treatments. Current interpretation of these results is that these stressors were not sufficient in themselves to cause reduced performance. The turkeys were able to compensate for these stressors. Turkeys in commercial facilities exposed to additional stressors would be expected to have significant reductions in production if exposed to the ammonia and dust levels used in these experiments.

**Cattle**

Attention should be made beyond stocking density and ventilation when designing and managing facilities for farm animals. For example, calves that appear to be housed in a spacious, well-ventilated barn may be predisposed to more pneumonia in cool and damp winter conditions.  Research suggests that when calves lie for long periods with slow shallow breathing, these conditions will cause inadequate pulmonary ventilation of inhaled pathogens (Webster 1990).  If the housing system encourages greater animal activity and more exposure to clean air, as may be found in some open-naturally-ventilated barns, the lungs seem to be more protected from prolonged pathogen challenge (Webster 1984).

**Multiple Stressor Interaction:**

A study on how multiple concurrent stressors interact was conducted using chicks (McFarlane 1987).  The stressors selected differed in their mode of impingment on the chicks and their ability to produce a repeatable significant growth depression.  The stressors were ammonia (0 or 125 ppm), beak-trimming (sham handling vs. trimmed), exposure to coccidiosis, random electrical shock, temperature (30.4 or 36.5° C), and white nose.  White nose was produced by a generator designed to broadcast all frequencies within the human auditory range (approximately 20 to 20,000 Hz).  The performance results indicated that the stressors added together in their negative effects on performance rather than interacting synergistically.  The histopathological results indicated that, in general, the histological integrity of the chicks was similar whether the stressors were imposed singly or concurrently with any other stressor.  Behavioral results indicated very few effects on behavior as a result of the stressors singly or in combination.  This study presents a clearer understanding of how multiple concurrent stressors interact and their effect on performance, histology, and behavior.  However, for building system designers, this information only provides guidelines for an acceptable environment.  Further work is needed to relate how an environmental control system creates or affects some of the environmental stressors studied.

SUMMARY

Although a large number of studies on the effect of air contaminants on animal health have been published, the results are inconclusive. Some effects have been shown with some gases such as ammonia, but generally at levels that were higher than those found in farm conditions.  Airborne pathogens may show the most potential for impacting animal health but even there it seems to take a combination of dust, gases, and pathogens to obtain a measurable health effect.  Some studies have been able to show adverse effects of these air contaminants, but others have not.

Air-borne respiratory diseases in farm animals involve the disturbance to the equilibrium between the host animal, the pathogen and the environment (Webster 1990).  These challenges relate to air quality and the potential for animals to inhale infectious agents which may multiply within the respiratory tract (viruses, bacteria); allergens which may induce inflammation (fungal spores etc.) or 'nuisance' dusts and gases (e.g. ammonia)

which do not directly damage the lungs but may compromise their resistance to pathogens (Webster 1990).

## USE OF ANTIBIOTICS, METABOLIC MODIFIERS, PESTICIDES AND IONOPHORES

### INTRODUCTION

Remarkable scientific advances (especially during the last 50 years) in plant and animal agriculture have enabled humans to expand their capacity to produce food to meet the growing demands imposed by the expanding world population.  For example, global food supply increased 55% from 1970 to 1995 (Bertini 1998).  These advances occurred through increased total production and through increased productive efficiency.

Increases in productive efficiency have provided more food and produced less waste per unit of input which reduces the impact of agriculture on the environment (Bauman 1992;Crooker 1999;CAST. 1998;NRC. 1999).  These remarkable advances have been achieved through an increased knowledge and understanding of nearly all aspects of agriculture.  Improvements in animal nutrition, health, management, and genetic selection have had major impacts on the advances achieved in animal agriculture.  A greater understanding of animal physiology has resulted in the development of a number of chemical compounds that are available to the producer to improve animal health and to increase the productive efficiency of animal agriculture.

Society and the scientific community can not rest on these tremendous accomplishments.  Population growth and economic growth will continue and this will continue to increase the demand for safe, nutritious sources of food.  It is expected that the combined effects of population and income growth will increase the demand for food by 30 to 50% by 2020 (Bertini 1998) and to double the demand for food over the next 30 to 40 years (Thompson 1998;Etherton and Bauman 1998).

This required doubling of global food production can occur by increasing the quantity of land used to produce food, increasing the yield of food per unit of land, by reducing post-harvest loss (Thompson 1998) or through a combination of these factors.  It is clear that a large increase in the quantity of land used to produce food would have a major impact (including reduced forest cover, reduced wildlife habitat, reduced biodiversity) on the environment (Thompson 1998).  Continued increases in the efficiency of producing food are required to sustain our ability to provide safe, nutritious food sources in an environmentally friendly manner.  Consumers will certainly continue to expect their food supply to be safe and nutritious.  In addition, concerns have been raised regarding the effects of these previous achievements on the health and well-being of agricultural animals (Broom 1995;Broom 1999;Rauw and others 1998) and these issues require additional attention.

### COMMON CHEMICAL COMPOUNDS USED IN ANIMAL AGRICULTURE

Science has provided a variety of chemical compounds that have contributed to the health and well-being of agricultural animals and to their productive efficiency.  Some types of compounds (antibiotics for example) can serve more than a single function and this

sometimes leads to confusion about the reasons for using specific compounds. Antibiotics can be used to treat bacterial infections and thus enhance the health of an animal (therapeutic use) and can be used as growth promotants to enhance the productive efficiency of an animal (sub-therapeutic use). Some antibiotics are classified as ionophores. Certain terminology can be used to describe a variety of compounds and this can also cause confusion. The term growth promotant can refer to antibiotics (subtherapeutic use), hormones (both steroid and protein hormones which differ in many ways), and (although less frequently) ionophores.

The most commonly used chemical compounds in animal agriculture have been classified by the National Research Council (NRC. 1999) as:

■ topical antiseptics, bactericides, and fungicides used to treat skin or hoof infections, cuts, and abrasions and to disinfect barns and barn equipment
■ ionophores, which alter stomach microorganisms to provide more favorable and efficient energy substrates from bacterial conversions of feeds and to impart some degree of protection against parasites
■ hormone and hormone-like production enhancers (steroid implants for meat production and bovine somatotropin for milk production)
■ antiparasite drugs (pesticides) and
■ antibiotics to control overt and occult disease and to promote growth.

The use of chemical compounds (antimicrobials, hormones, etc) in livestock production has generally been accepted and unquestioned until recently. Today's consumers are more sophisticated about the food they eat and are becoming more aware, more concerned, and more critical about food production practices. This has occurred in part due to identified problems within their food supply (BSE, the emergence of E. coli outbreaks, imports of food from countries with distrusted food hygiene, etc.) and the increased opportunity for isolated problems to affect larger numbers of individuals. As a result, the use of chemical compounds in food animals has received increased scrutiny.

Recognizing the important role that chemical compounds play in animal agriculture and the increasing public concern about these chemicals, the Panel on Animal Health, Food Safety, and Public Health, the National Research Council's Board on Agriculture and the Institute of Medicine's Food and Nutrition Board jointly initiated a project and convened a committee (Committee on Drug Use in Food Animals) to examine the benefits and risks associated with drug use in food animal production. The committee recently issued its report (NRC. 1999).

## ANTIBIOTICS

The history of human and veterinary medicine has proven that there is no way to eradicate infectious disease from the earth. "Viruses and bacteria have, due to their million-times faster multiplication, a much better capability to adapt to changing environmental conditions than humans and animals" (Nobel laureate Dr. Lederberg at the ILSI Meeting 1997 in Washington D.C.) - thus, they will always maintain their potential to cause disease. Therefore, the availability of antibiotics to livestock producers and

veterinarians for preventing and treating bacterial diseases in food producing animals must be protected (Sundlof and others 1997;McEwen 1997;Wierup 1997;Blaha 1997b;McEwen 1997;Wierup 1997).

**Issues of Concern**

Three major issues of concern, relative to the use of antibiotics, have recently emerged:

1. the public and especially the medical society (WHO, public health authorities, physicians, and bio-medical scientists) are concerned with increasing resistance in bacteria that are relevant in human diseases.  There is a strong belief (especially in Europe) that the use of antimicrobials in food animals might contribute to the problem or aggravate its magnitude (WHO 1997);
2. consumers are concerned about the possibility of residues from antibiotics, chemotherapeutics, and/or their metabolites in edible tissue which potentially leads to the intake of unwanted substances that can result in resistance or allergies (Debeuckelaere and Remy, 1997).
3. livestock producers and veterinarians are concerned with the possibility that the increasing pressure to reduce the use of antimicrobials in food animals might lead to limitations in preventing and curing infectious disease in food animals (Frost 1991;Fernandes 1996;McOrist 1997;Fernandes 1996;McOrist 1997).

These concerns have contributed to a growing discussion by the public and by scientists about food production practices and specifically about the use of antibiotics in animal agriculture.  Similar concerns can and have been raised for several of the other chemical compounds used in animal agriculture.

**Microbial Resistance**

Many scientific meetings, conferences and workshops on microbial resistance to antibiotics have occurred during the last few years.  One conference, titled the "Medical Impact of the Use of Antimicrobials in Food Animals", was held by the World Health Organization (WHO 1997) in Berlin, Germany and provided a framework for the ongoing discussion about microbial resistance to antibiotics.  Quotations from the report of this meeting include:

"Antimicrobials are vital medicines for the treatment of bacterial infections in both humans and animals."

"The magnitude of the medical and public health impact of antimicrobial use in food animal production is not known."

"Timely public action is needed to control medical problems related to the widespread application of antimicrobials outside the medical sphere."

"National policies on the use of antimicrobials in animals must balance the possible benefits to livestock production against the medical risk and public health consequences deriving from their use."

"Bacteria and genes, including resistance genes, can pass between human, animal and other ecosystems."

"Following the introduction of fluoroquinolones in food-producing animals, the emergence of Salmonella serotypes with reduced susceptibility in humans has become a cause for particular concern", and

"Reducing the need for antimicrobials is an important means of managing resistance risk".

The discussion about the use of fluoroquinolones in food-producing animals has been fueled recently by a study conducted by the Minnesota Department of Health (Smith and others 1999) that concluded the use of fluoroquinolones in poultry has created a reservoir of resistant Campylobacter (C.) jejuni.  Fluoroquinolones were approved for use in poultry in 1995 and this study (Smith and others 1999) determined that the proportion of quinolone-resistant C. jejuni isolates from humans increased from 1.3% in 1992 to 10.2% in 1998.  Quinolone-resistant C. jejuni were isolated from 14% of 91 domestic chicken products obtained from retail markets in 1997.  Molecular subtyping showed an association between quinolone-resistant C. jejuni strains from chicken products and domestically acquired  C. jejuni infections in Minnesota residents.

Fluoroquinolone-resistant Campylobacter isolates have increased in Europe since the 1980's (Piddock, 1995).  The Minnesota study (Smith and others 1999) also determined that a larger proportion of the quinolone-resistant C. jejuni infections were associated with foreign travel.  Thus, apart from the  infections with resistant C. jejuni strains that were acquired during foreign travel, the number of quinolone-resistant infections acquired domestically has increased and this is believed to be largely because of the acquisition of resistant strains from poultry.

All in all, it is generally recognized that there is an increase in cases where bacterial resistance complicates the treatment of human disease.  It is also recognized that there are several reasons for the phenomenon, with the (over) use of antimicrobials by physicians and the non-compliance of the rules for the use of antimicrobials by ambulant patients being major reasons (Levy 1997).  However, because any use of antibiotics leads to a selective pressure in favor of resistant strains (Levy 1997), the use of antibiotics in animals needs to be guided toward the "*prudent use of  antibiotics*" which has been defined as "prudent use must guarantee the highest possible effect and the lowest possible risk of resistance" (WHO 1997).

**Antibiotic Residues**

Over the last decade, the magnitude of antimicrobial residues has significantly decreased to almost tolerably few cases of  positive results. This is due to the mandatory residue

testing of  meat and milk prior to further processing conducted by USDA/FSIS and intensive educational efforts by USDA and the livestock industries (mostly as result of quality assurance programs for e.g. pork, dairy, poultry etc. on a national or state basis).

Nevertheless, there is still room for improvement, which  should be achieved more by voluntary on-farm residue avoidance programs than by increasing the sample size of residue testing in the framework of mandatory monitoring systems (Blaha 1997a;Blaha 1999).

## Use of Antibiotics in Animal Agriculture

The animal industry uses antibiotics at subtherapeutic (to promote animal growth) and therapeutic (Fernandes 1996) levels.

## Subtherapeutic Use:

Antimicrobials are fed at subtherapeutic or low dosages (typically less than 50 grams/ton of feed) to animals to promote growth in a cost-effective manner. The first report of antimicrobial enhanced growth occurred in 1946.  However, it wasn't until 1953 that supplementation of antimicrobials to the diets of livestock became a standard practice. During the next 20-30 years, a tremendous amount of research was conducted to evaluate the efficacy of antimicrobial supplementation as a growth promotant for poultry, swine, and cattle (Stockstad 1954;Robinson 1962;Visek 1978;Hays 1991;CAST 1981a;Hays 1981).  Considerable effort was devoted to defining the parameters that influence the efficacy of antimicrobial supplementation as growth promotants.  A compilation of the information generated during these decades of research has shown that feeding antimicrobials to various species of livestock under a wide variety of conditions results in:

- an increase in the rate of average daily body weight gain,
- an improvement in the efficiency with which feed intake is converted to body weight gain (gain:feed ratio),
- an increase in voluntary feed intake,
- a reduction in morbidity or the incidence of illness,
- a reduction in mortality or death, and
- lack of any consistent effect on the composition of the animal carcass.

If antimicrobials are removed from the diet before market weight is achieved, much of the advantage in average daily gain is lost (Robinson 1962).  Therefore, it is most cost-effective to continue the supplementation of antimicrobials throughout the growth phase. Additional studies have shown that when antimicrobials were fed to animals at the same production facility for extended periods of time (i.e. 10 years), the growth rate of the animals was still greater than that of the animals that did not receive the antimicrobials (Hays 1991).  However, the magnitude of the effect was somewhat reduced, apparently because the animals that were not fed the antimicrobials had an improved growth rate. This was attributed to the overall improved health of the animals at the farm (Hays 1991).

In some countries (i.e., Europe), approval for the use of antimicrobials as growth promotants has been rescinded.  In those circumstances, the efficiency of animal production practices has declined.  There is a reduction in average daily gain, a decrease in the efficiency of weight gain and an increase in morbidity and mortality, especially in the very young animals.

It is estimated that 60-80% of all cattle, sheep, swine and poultry in the United States receives antimicrobials at some point in time (CAST 1981a).  It has also been estimated that removal of antimicrobials from production systems would cost the consumer in excess of 3.5 billion dollars annually in the United States (Hays 1991).  As a consequence, current research devoted to studying the use of antimicrobials in animal agriculture has concentrated on two concurrent objectives: 1) determining how antimicrobials exert their growth promoting effects and 2) searching for a viable alternative so that antimicrobial supplementation can be halted and replaced with an effective substitute.  Little effect is directed towards assessing the efficacy of antimicrobials as growth promotants.  However, efforts continue to focus on the mechanism(s) by which antimicrobials exert their growth promoting effects (Hathaway and others 1996).  Determination of these mechanisms would assist efforts to develop viatle alternatives to the subtherapeutic use of antimicrobials.  Prophylactic or intermediate levels of antimicrobials are given to animals which have been exposed to disease or subjected to stress to prevent the animals from becoming sick.

**Therapeutic Use:**

The productivity and profitability of every livestock enterprise is dependent on maintenance of healthy livestock.  The concern for animal welfare and health is a high priority for food animal producers.  The veterinarian working with food animal producers plays a key role in providing professional guidance in the prevention and treatment of disease.  The multiple responsibilities of the veterinarian are best summarized by the veterinarian's oath.  *"Being admitted to the profession of veterinary medicine, I solemnly swear to use my scientific knowledge and skills for the benefit of society through the protection of animal health, the relief of animal suffering, the conservation of livestock resources, the promotion of public health, and the advancement of medical knowledge."*

It is well recognized by both the veterinarian and food animal producer that prevention of disease is more desirable than treatment.  As herd/flock sizes have increased, modern livestock husbandry has placed increasing emphasis on preventing disease rather than treating disease.  Development of more effective vaccines, improved nutrition, housing, and more vigilant monitoring techniques have, in general, given rise to improved herd health, greater productivity and greater productive efficiency.  However, in spite of the consistent application of best management practices, some animals will become clinically infected and will require treatment.  When clinical disease does occur and where it is deemed appropriate, antibiotics are used.  Clearly defined treatment guidelines have been provided for veterinarians and their livestock-producing clients regarding the prudent use of antibiotics in the treatment of clinical diseases in food producing animals (AVMA. 1999;Pork Quality Assurance Program ;Beef Quality Assurance Program ;Pork Quality

Assurance Program ;Beef Quality Assurance Program ).  The American Academy of Veterinary Pharmacology and Therapeutics (AAVPT) recently held a symposium (AAVPT 1998a) and identified a course for prudent use of antibiotics (AAVPT 1998b).

Prudent use of antibiotics.

Goal:  To minimize the general use of antibiotics without compromising animal health.

Sub-therapeutic use
Use alternatives to antibiotics for growth promotion effects where those exist.
Use prophylactic use of antibiotics only when used strategically and not as a general routine and when known herd health benefits can be expected.

Therapeutic use

Use for proven clinical indications.
Use at high enough (Warriss 1998) doses.
Use for as long as necessary.
Use as short as possible.
Preference is given to single animal treatment rather than treating a whole group in order to treat just a few animals.
Follow proper withholding times.
Record all drug use (growth promotant, prophylactic, therapeutic).

There is a paucity of data regarding the issue of antibiotic use in livestock relative to herd size.  Observation indicates that antibiotic use as it relates to animal health is more a matter of management quality than it is of farm size.  Thus, arguments favoring either "small" or "large" farm size will always fall short.  A California study (Bennett 1987) demonstrated that milk somatic cell count (SCC) was a positive predictor of herd management quality.  A more recent study in the Netherlands (Rougoor 1999) determined that both herd milk SCC and herd reproductive performance correlated strongly with the quality of herd management.  A U.S. NAHMS survey (Wells 1998) determined that, in general, large herds had lower milk SCC than smaller herds.  These results support the argument that farm size is not a key issue in management quality.  Financial and knowledge-based resources and overall management skills have a much larger role than farm size and greatly affect the health and well-being of animals on any farm regardless of its size.

## METABOLIC MODIFIERS

Genetic selection has provided animal agriculture with animals that are more efficient than their undomesticated predecessors (CAST 1997).  The development of metabolic modifiers has provided producers with options for further enhancing the efficiency of their animals.  These advances have contributed to the reduced fat content of animal products and enhanced the ability of consumers to obtain low-fat meat products (Gonyou 1994;Gonyou 1994).  Recent advances in molecular biotechnology, genetics and an increased understanding of the specific roles of metabolic modifiers (hormones, growth

factors and their modulators) and their interactions with management techniques and the animals environment will provide much of the biological foundation for these continued increases in efficiency of producing food (Crooker 1999). The primary metabolic modifiers currently available for animal agriculture are steroid implants for growing beef cattle and bovine somatotropin (NRC. 1994) for lactating dairy cattle. Hormones and metabolic modifiers are not used in poultry.

**Steroid Implants:**

Steroid implants contain naturally occurring and/or synthetic estrogens and androgens (NRC. 1994;Hafs and Zimbelman 1994;NRC. 1996) and are used to improve efficiency of growth and carcass composition of meat animals. They have been used for more than 40 years and are extensively used in the production of U.S. beef with an estimated 90% of the beef cattle receiving an implant at some point in their life (NRC. 1994). This wide use reflects the significant improved performance (increased growth rate and efficiency of converting feed into tissue, increased protein to lipid content of the carcass) and economic advantage they provide (NRC. 1994;Hafs and Zimbelman 1994;NRC. 1996;NRC. 1996).

An April 30, 1999 report (http/europa.eu.int.dg24/health/sc/scv/index_en.html) from the European Union Scientific Committee for Veterinary Measures Relating to Public Health recently raised concerns about the use of naturally occurring sex steroid hormones (estradiol, progesterone, testosterone) and their synthetic mimics (zeranol, melengestrol acetate, trenbolone acetate) in growing beef cattle and their potential effects in humans. The report concludes the issues of concern include potential neurobiological, developmental, reproductive and immunological effects, as well as immunotoxicity, genotoxicity, and carcinogenicity. These conclusions have been sharply criticized (Science, 1999.284:1453) as another component in the on-going trade war between the U.S. and E.U. concerning imported beef.

The World Health Organization (WHO) and the United Nations Food and Agriculture Organization (FAO) Joint Expert Committee on Food Additives (JECFA) is composed of scientists from Europe, Australia and the U.S. They also reviewed hormone use in cattle and issued their report in February 1999. These scientists concluded the use of steroid hormones did not decrease the safety of food products from treated beef cattle.

**Bovine Somatotropin:**

In the early 1980's, recombinant DNA techniques provided a source of bovine somatotropin (Bauman 1998) in quantities that made commercial application feasible and bST became the most investigated animal production drug ever approved by the Food and Drug Administration, Center for Veterinary Medicine (FDA/CVM) for use in the U.S. The Monsanto bST (Posilac7) data set summarized more than 800 cows and was the largest production drug data set ever reviewed by FDA/CVM. Administration of bST (Monsanto 1998) to lactating dairy cows was approved by the USA Food and Drug Administration, Center for Veterinary Medicine on November 5, 1993 as a safe, efficacious method of increasing milk yield. An economic analysis of the potential

impact of Posilac7 was issued in January, 1994 and sale to commercial dairies began on February 4, 1994. There have been a number of reports and reviews confirming the safety of use of bST to humans and to the cow (Bauman 1992;Etherton and Bauman 1998;Juskevich and Guyer 1990).

An estimated 30,000 to 40,000 dairy cows in the US and throughout the world had been used in bST research trials prior to FDA/CVM approval. The data from these studies indicate the important role of management, especially nutritional management, in determining the milk yield response to bST (Bauman 1992;Crooker and and Otterby 1991). The results are consistent with our understanding of biology and lactational physiology. The dairy cow must be healthy, consume sufficient nutrients, inhabit a comfortable environment, and be managed properly to consistently produce large quantities of milk. Stressed and improperly managed cows do not produce large quantities of milk and contribute to an inefficient dairy operation.

When the productive efficiency of an animal is increased, a greater proportion of the consumed nutrients are captured as a product. This is true whether the improvements occur through selective matings or through the use of metabolic modifiers (the growing beef animal that receives a steroid implant or the lactating dairy cow treated with bST). Because a smaller proportion of the consumed nutrients are excreted, the impact of animal waste products on the environment is reduced per unit of product produced. This occurs whether the industry chooses to produce more product or to produce the same amount of product with fewer animals. This allows the industry greater flexibility to respond to consumer demand.

It is instructive to use bST as an example of the potential environmental benefits that can be realized through continued efforts to enhance productive efficiency of agricultural animals. Although recognizing that 100% adoption of bST use was unlikely, Bauman (Bauman 1992) demonstrated the potential environmental benefit that could have been achieved in the U.S. in 1988 if 100% of the industry used bST and if the increased milk response was 12%. He demonstrated the same quantity of milk could have been produced with 1.1 million fewer cows and a substantial reduction in feed required (2.5 billion kg of corn grain and 560 million kg soybean) and waste produced (6 billion kg manure, 8 billion liters of urine, 80 million kg urinary nitrogen, and 80 billion liters of methane). Similar calculations using the average U.S. cow in 1996 (7600 kg/cow) and the extent of bST use in 1996 (Hartnell 1996) suggest the actual savings were about 20% of these predicted values. A simulation based on DHIA records indicate bST use would increase whole herd nitrogen efficiency by 5% and decrease whole herd manure excretion by 8% (Dunlap and others 1998).

These estimates of reduced environmental impact are based on animal biology and do not account for reductions associated with reductions in growing, harvesting, processing, and storing dairy feedstuffs and handling and processing dairy waste. Johnson and colleagues (Johnson and Johnson 1995) estimated 100% adoption of bST by the dairy industry in 1989 would have allowed the same quantity of milk to be produced with 6% less land, 6% less fossil fuel, and 5% less soil loss.

Concern has been raised regarding the animal health and well-being aspects of bST use. The Canadian Veterinary Medical Association (CVMA. 1998) established a panel to review the efficacy and safety of bST.  Their report (CVMA. 1998) indicated there were concerns about increased risk of clinical mastitis, lameness and a reduction in the life-span of treated cows.  They were also concerned about the possibility of injection site reactions but felt there were insufficient data to determine if this was a significant health or well-being issue.  The Scientific Committee on Animal Health and Animal Welfare in the E.U. reported (SCAHAW 1999) that use of bST decreased the health and well-being of dairy cows by increasing foot disorders, reproductive problems and production-related diseases and recommended that bST not be used.  These results are inconsistent with the numerous other reports of bST use and animal health.  They are also inconsistent with the continued use of bST by producers, the sustained increases in milk yield achieved by use of bST (Bauman et al., 1999) and the lack of change in culling of U.S. dairy cows (NASS, 1998; NAHMS, 1996).

The Vermont Public Interest Research Group and Rural Vermont recently questioned the validity of FDA's ruling that milk and milk products from cows treated with bST are safe for human consumption.  Their concerns were raised in part by an analysis of the data that was conducted by Health Canada.   After completing a comprehensive audit of the human food safety data used to support the approval of bST use in dairy cows, FDA responded (http://www.fda.gov.infores/other/RBRPTFNL.html) to the questions.  FDA indicated they believed the Canadian reviewers did not interpret the study results correctly and that there were no new scientific concerns regarding the safety of milk from cows treated with bST.

The Canadian report expressed concern that increased amounts of insulin-like growth factor-1 (IGF-1) in milk from cows treated with bST would pose a health risk to humans and the Vermont Groups were especially concerned about this relative to milk consumption by children.  FDA's initial evaluation did suggest a modest increase in IGF-1 content of milk but this was not deemed a health risk because the increases were within the normal range of concentrations in untreated cows.  Subsequent information has been reviewed by FDA which demonstrates the use of bST does not increase milk IGF-1 concentrations above those of untreated cows.

The WHO/FAO JECFA (1998) also reaffirmed earlier assessments that use of bST did not pose a risk to human food safety.  The Department of Health and Human Services' Office of Inspector General (OIG, 1992) and the General Accounting Office (GAO) audited FDA's approval of bST and found no reason to question the food safety issue. The White House Office of Management and Budget (1994) reached similar conclusions.

**PESTICIDES, ANTHELMITICS AND DISINFECTANTS**

A variety of pesticides and drugs are used to protect the health of food and fiber animals in the US and throughout the world.  The distinctions between pesticides and drugs originate in US law.  Pesticides are commercial substances and are defined in the Federal Insecticide, Fungicide, Rodenticide Act as substances intended "...for preventing, destroying, repelling, or mitigating any pest…".  Pests that can affect the health of

animals in Minnesota include insects, ticks and mites (arthropods); worms (helminths); and microbial pathogens (coccidia, fungi, bacteria and viruses).  Pesticides are products that are used in an animal's environment.  Pesticides are regulated nationally by the US Environmental Protection Agency (EPA) and within each state by the state's Department of Agriculture.

In contrast to pesticides, other drugs are used to control the same kinds of pests but are applied directly onto or into animals and, therefore, are regulated by the Food and Drug Administration (McChesney and others 1995).  The FDA also has authority to establish legal tolerances for pesticides, drugs and their degradation products in human and animal foods.  Tolerances are established to ensure food safety.  Tolerances identify the quantity (the permissible residue) of pesticide, drug, or degradation product residue determined to be well below the quantity that may have an effect in humans or animals that consume the food.

To be sold for use around or on animals, a pesticide or drug must have a label that is issued by the appropriate regulatory agency.  Before a label is issued, candidate products are required to undergo extensive research at the expense of the developing company to assess efficacy against target pests and safety to animals, applicators, and the food supply.  Once labeled, packaged products can then be sold for use by the appropriate category of applicator.  A product's label states the kind of pest that the product will control, how the product is to be applied (dose and application method), the kind(s) of substrate that can be treated, and situations in which use would be contraindicated (not recommended).  Product labels also provide additional information.

The EPA or FDA can either label a product for over-the-counter sale to the general public or they can restrict use to certified pesticide applicators or veterinarians.  The designation depends on the risks posed by the specific compound and formulation to animals and humans.  Restricted use pesticides can only be purchased and applied by certified pesticide applicators.  To become certified, individuals must complete training courses and pass certification tests.  In Minnesota, the Minnesota Extension Service conducts the training courses and the Minnesota Department of Agriculture administers the certification and recertification tests.  Drugs intended for veterinary use only are marketed through practicing veterinarians who are certified and accredited by the Minnesota's Board of Veterinary Medicine.

The safety of registered products for target animals is monitored formally by the FDA's Center for Veterinary Medicine (CVMA. 1998).  The CVM maintains a reporting system designed to capture mandatory reports from veterinarians of any adverse reactions to any products registered by FDA. This process occurs to insure that actual use of the registered products in production systems continues to be safe for humans and animals.  If problems arise, continued use of the product can be eliminated or subject to additional regulation.  Marketers probably learn quickly of adverse reactions and withdraw the associated products to prevent litigation and limit liability.  Cases of animal poisoning associated with anti-parasitic pesticides and drugs are thought to be rare.

Neither the Minnesota Department of Agriculture, the Minnesota Board of Animal Health nor any other regulatory agency monitors the use (neither frequency nor volume) of pesticides or drugs. The US-FDA conducts market surveys to assess residue levels for selected pesticides and drugs in foods but results of that monitoring are not readily available. Thus, no objective information exists concerning how patterns of use (and possible misuse) of anti-parasitic pesticides and drugs vary among animal species, housing styles or farm sizes in Minnesota or anywhere else in the US. Extent of use could be estimated through surveys of selected animal industries.

## IONOPHORES

### Introduction and Mode of Action

The Random House dictionary definition of an ionophore is "a lipid soluble substance capable of transporting specific ions through cellular membranes". This feature provides ionophores with therapeutic properties useful for both human and animal health (Pressman and Fahim 1982). The use of FDA approved ionophores in livestock agriculture incorporated at appropriate concentrations have realized many positive impacts. Animal well-being and health have been one of the primary beneficiaries of this technology.

Ionophores are compounds of moderate molecular weight (MW 200 to 2,000) that form lipid soluble complexes with polar cations of potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) and biogenic amines (Pressman 1976). Differences exist among the ionophores in their affinity for various ions. Ionophores are often described as antibiotics because they can alter metabolism (cell homeostasis) of microorganisms such that the microorganism either dies or becomes much less active. This accounts for their anti-coccidial effects in poultry and ruminants.

The unique ion transporting properties of ionophores were discovered in the early 1960's at the University of Miami laboratory of Dr B.C. Pressman. The first recognized ionophores were metabolites of microorganisms but synthetic compounds with equivalent properties are now available. Ionophores commonly used in livestock production belong to the carboxylic class of ionophores. These compounds form a ring structure which surrounds ions and facilitates their transport through cell membranes (Smedley 1984). Ionophores mediate cation transport by forming a channel within cell membranes which allow the ion to more easily move (diffuse) through the cell membrane (Smedley 1984). In the animal body, the ionophore ion transport effects may change the bioavailability, gut uptake and tissue deposition of minerals (Elasser 1984).

Use of ionophores in ruminant diets have increased apparent absorption of minerals (Zinn and others 1975;Greene and others 1986;Kirk and others 1985a;Kirk and others 1985b;Spears and others 1989;Reffet-Stabel and others 1989) and result in a sparing-effect on dietary protein (Goodrich and others 1984;Russell and others 1992). The protein sparing effect of ionophores is achieved by decreasing the rate of peptide uptake by rumen microbes (Russell and others 1992).

Effects of ionophores on rumen fermentation have been the focus of much research over the past twenty-five years.  Rumen bacterial ecology is altered by addition of ionophores to the rumen.  These alterations change the metabolic end-products (volatile fatty acids, methane, etc.) produced during the rumen fermentation process.

Changes in the production of end-products include an increase in the ratio of propionate to acetate, reduction in butryrate, ammonia, and methane production, and decreased protein degradation. (Nan Nevel and Bemayer 1977;Chen and Wolin 1979;Henderson and others 1981;Rumsey 1984;Sticker and others 1991;Johnson and Johnson 1995;Fellner and others 1997).  These changes contribute to an improved efficiency of use of dietary energy and protein, a reduced potential of acidosis and bloat in cattle fed large amounts of grain (concentrates), a decreased life-cycle of face and horn flies in feces of ionophore-fed cattle, a reduced amount of methane released to the environment, and an improvement in animal performance (Wallace and others 1980;Goodrich and others 1984;Johnson and Johnson 1995).

Although current regulations prohibit the use of ionophores in lactating dairy cattle, studies have suggested ruminal changes that result from feeding ionophores (especially those changes related to ruminal lipids) could enhance nutritional qualities of milk (Fellner and others 1997).  Further refinement of rumen fermentation manipulation to integrate ionophores and advances of genetically modified organisms for the benefit of the animal, are imminent (Wallace 1994).

**Measurements and Standards for Animal Health and Well-Being**

**Criteria for Animal Health and Well-Being:**

■ Only the ionophores approved by FDA can be incorporated in animal feeds.

■ When ionophores are used, the amounts used must be within the limits established by FDA guidelines for proper prophylactic (coccidiosis control – poultry and ruminants) and sub-therapeutic function (increased dietary energy efficiency and nutrient availability in ruminants, and enhanced animal performance).

■ Ionophores approved for non-lactating cattle include laidlomycin propionate (Cattlyst[®]; 30 to 150mg/head daily); monensin sodium (Rumensin[®]; 50 to 360 mg/head daily); lasalocid sodium (Bovatec[®]; 100 to 360 mg/head daily), and bambermycin (Gain Pro[®]; 10 to 20 mg/head daily).  Monensin sodium can be fed in combination with tylosin (60 to 90 mg/head daily) and lasalocid sodium can be fed in combination with oxytetracylcine.

■ Ionophores approved for sheep include monensin sodium and lasalocid sodium (15 to 70 mg/head daily).

■ Amounts of ionophores that can be added to the feed as anticoccidiostats for prophylactic use in poultry include monensin sodium (0.01 to 0.0121% for chickens; 0.006 to 0.01% for turkeys up to 10 wk of-age); maduramicin ammonium (0.0005 to

0.0006% for chickens);  narasin (0.006 to 0.008% for chickens) and salinomycin sodium (0.0044 to 0.0066% for chickens).

**Effects on Animal Health and Well-Being**

**Effects of Feeding Ionophores on Animal Health and Performance:**

*Cattle:*

Ionophores are well-accepted management tools for cattle production systems. Ionophores can be offered free choice in mineral mixtures and mineral blocks or incorporated in a complete ration at the appropriate concentrations.  Controlled daily feeding of an ionophore provides better results than free choice access.  (R.James, as reported by Chester-Jones, 1996).  Successful administration and use of ionophores, such as monensin, can be accomplished through use of intra-ruminal devices (Cochran and others 1990).

A Minnesota performance summary of 16,000 head of cattle indicated that those fed monensin gained 1.6% faster, consumed 6.4% less feed and required 7.5% less feed per unit gain than cattle fed diets without the ionophore (Goodrich and others 1984).  The greatest response occurred when the energy content of the diet was 1.32 Mcals/lb. Responses to a combination of monensin and growth promoting implants were additive.

A recent review of the effects of feeding ionophores to feedlot cattle found that ionophores approved for enhancing feed efficiency (laidlomycin propionate, monensin sodium, lasalocid sodium) increased both gain (9 to 12%) and feed efficiency (7 to 16%) when diets contained less than 70% grain (DiCostanzo and others 1997).  The most effective responses were obtained when the diet provided more than 200 mg lasalocid/head or more than 100 mg monensin/head each day.  The improved efficiencies had positive economic impacts on feed and non-feed costs of the beef operations.  In diets containing more 70% grain, ionophores improved feed efficiency by 4 to 7%.  A 5% increase in daily body weight gain without an alteration in daily feed intake occurred when laidlomycin propionate was fed.  Daily feed intakes were reduced 5 and 6% when lasalocid and monensin were included in the diet.

Feeding tylosin with or without monensin reduced liver abscesses in slaughtered cattle (DiCostanzo and others 1997).  Feeding 2 lbs of a ground corn supplement containing 200 mg lasalocid, 150 mg monensin, or 20 mg of bambermycin to 600 lb steers on pasture resulted in an average 17.8% increase in average daily gain compared to steers fed the supplement without an ionophore (Rush and others 1996).  The three ionophores were equally effective in improving rate of gain.

Feeding monensin with or without tylosin and lasalocid in finishing diets resulted in enhanced propionate production and energetic efficiency of feedlot cattle.  Adding 4% fat to the dietary dry matter depressed ruminal propionate production and resulted in negative associative effects which decreased cattle performance (Clary and others 1993). The severity of ruminal acidosis was reduced and feed efficiency improved when cattle

were fed laidlomycin propionate during adaptation to a 100% concentrate diet (Bauer and others 1995). In general, use of ionophores is recommended to help control feedlot bloat (Cheng and others 1998).

The differences among ionophores in their affinity for ions, the fact that no adaptation period to the ionophores is needed, and the potential for rumen bacteria to develop resistance to individual ionophores over time suggest that a daily rotation of various ionophores may be beneficial (Duff et al., 1998). A review of available data indicated no overall beneficial affect on feed efficiency occurred when ionophore use was rotated (DiCostanzo and others 1997). However, results suggested that sequencing ionophores may enhance the effectiveness of ionophores through different effects on feed intake (DiCostanzo and others 1997). Research has demonstrated that bacteria that become more resistant to one ionophore will also be resistant to the other and cross-resistance also occurs (Newbold and others 1993).

Incorporating ionophores into grain supplements for grazing growing beef heifers increases average daily gain which decreases the age at which puberty occurs. This earlier attainment of puberty can mean a younger age at first calving which will reduce the cost of raising the heifer (Bagley 1993). Ionophores can also help reduce the age of first calving of dairy heifers with similar economic benefits (Losinger and Heinrichs 1996;Hinders 1997).

Mineral metabolism is also altered when ionophores are fed. Monensin increased apparent absorption of Na, Mg, and P, and increased Mg and P retention in steers (Starnes et al., 1984).

Influence of dietary Mg (.18 vs .32% DM basis) on metabolic and growth responses of feedlot cattle to laidlomycin propionate (0 vs 11 mg/kg or 10 g/ton feed) were examined (Zinn and others 1975). The ionophore decreased ruminal degradation of feed N and microbial efficiency and increased total tract N digestibility. When dietary Mg content was increased, the proportions of propionate to acetate production in the rumen increased when laidlomycin propionate was included in the diet. When Mg content was reduced, laidlomycin propionate increased feed intake but it decreased feed intake when dietary Mg content increased. Both Mg and laidlomycin propionate increased diet energetic efficiencies. This study demonstrates the importance of understanding the interrelationships between mineral metabolism and ionophore feeding.

Methane production was reduced by laidlomycin propionate, especially when dietary Mg content was increased (Zinn and others 1975). Positive environmental effects have been implicated by reduction of methane production from cattle fed ionophores. Cattle can produce 250 to 500 liters of methane daily. Ionophore feeding can reduce daily methane production to between 50 and 100 liters (Johnson and Johnson 1995). It is worth noting that gas emissions from cattle worldwide contribute less than 2% to the total gases responsible for global warming concerns. Nonetheless, the importance of optimal nutrient management to reduce environmental impacts of beef production systems suggest that the role of ionophores in feeding programs will become even more critical in the next millennium (Kornegay 1996).

*Sheep:*

Ionophores, such as monensin, have been shown to increase feed efficiency in sheep fed high concentrate diets.  This occurs through a shift in the rumen microbial population which results in an increased ratio of propionate to acetate in the rumen which enhances energetic efficiencies (Kirk and others 1985a).  Other nutritional changes occur that may also contribute to increased performance efficiencies.  Monensin has a strong affinity for Na and K ions and increases Na concentration within the cell and K concentration outside of the cell (Pressman 1976).  Apparent absorption of P and K increased, but retention of sodium decreased in lambs fed diets containing large amounts of grain and 20 mg monensin/kg body weight (Kirk and others 1985a;Kirk and others 1985b).  In a follow-up study, lambs fed 20 mg/kg monensin retained more Mg than those fed no monensin (Kirk and others 1985b).  Monensin increased apparent absorption and retention of P and Zn.  Feeding monensin also decreased urinary, liver and bone Ca.  Ruminal Zn concentrations were decreased.  Lambs fed monensin showed alterations in divalent cation and P metabolism as well as changes in tissue and ruminal mineral levels.

Flow of digesta contents through the digestive tract and absorption of minerals in lambs fed a 70% concentrate diet containing monensin or lasalocid (23 g/ ton) were examined (Kirk and others 1994).  Calcium and P metabolism were not altered by the ionophores.  Urinary excretion of Na was decreased with lasalocid but tended to increase with monensin.  Apparent absorption of Cu and Zn were not altered by the ionophores.  Digesta flow and extent of mineral absorption in different segments of the digestive tract, particularly for pre-intestinal absorption of Mg, were affected by both ionophores.  Results also suggest that hypomagnesium may be prevented by feeding Mg and ionophores.  These results support earlier research that suggested monensin could neutralize the K-related depression of Mg absorption in ruminants that consume forage-based diets that contain large amounts of K (Greene and others 1986).

*Poultry:*

In poultry production, ionophores are a well-accepted tool used for their anti-coccidial properties.  Belgian work in broiler houses indicated that five Eimeria species were more sensitive to the anticoccidial lasalocid (90 mg/kg), than meduramicin (5 mg/kg), salinomycin (60 mg/kg), narasin (70 mg/kg), and monensin (110 mg/kg), respectively.  Lasalocid also had the most effective anti-coccidial control in a study of broiler chickens by Chapman and Haecker, 1994.  Field isolates of Eimeria species were more sensitive to ionophore feeding (monensin) after broiler chicks were vaccinated than before vaccination (Chapman 1994).

Use of antioxidants such as dihydroquinolines (Duokvin®) at 120 mg/kg diet in combination with ionophores have shown enhanced anti-coccidial efficiency against Eimeria  coccidia species.  This allowed for reduced level of ionophore incorporation.  The efficiency of this response was greater for meduramicin than monensin, salinomycin, or narasin (Varga and others 1994).  The anti-coccidial activity of a test ionophore, semiduramcin (concentration of 25 mk/kg), with broiler cockerels indicate that it had a

broad spectrum on Eimeria species control (Logan and others 1993). Another test ionophore (Ricketts and others 1992) has shown anti-coccidial efficacy and chicken tolerance (Ricketts and others 1992).

Some nutritional effects of feeding ionophores to chickens have also been investigated. Monensin has been shown to increase the K requirements of broiler chickens but had no apparent affect on their Na requirements (Hurst and others 1974;Charles and Duke 1981;Damron and Harms 1981;Cervantes and others 1982).

## USE OF PROCESSED MANURE AS FEED

### INTRODUCTION

In the US over 1.6 billion tons (over 100 million tons of waste dry matter) of animal wastes are produced annually in livestock agriculture.  It has been estimated that 50% to almost all (poultry operations) of these wastes are collectable (Webb Jr. and Fontenot 1975;Fontenot and others 1996;Fontenot and others 1996).  Animal wastes are traditionally viewed as a recyclable resource of fertilizer nutrients for soil and plants.  Use of animal wastes as feed ingredients can realize a five to ten fold relative economic advantage over using this resource as a fertilizer (Fontenot and others 1996).

Over the past three decades a great deal of work has been conducted to evaluate the proper approach to processing animal wastes prior to use as a feed to ensure animal health and well-being are not compromised (Anthony 1966;Bhattacharya and Fontenot 1975;Webb Jr. and Fontenot 1975;McCaskey and Anthony 1979;Fontenot and Jurubescu 1980;Sutton and others 1990;Fontenot and others 1996;NRC 1983;Bhattacharya and Fontenot 1975;Webb Jr. and Fontenot 1975;NRC 1983;McCaskey and Anthony 1979;Fontenot and Jurubescu 1980;Sutton and others 1990;Fontenot and others 1996).  Criteria for evaluating animal health and well-being profiles discussed for previous sections are prevalent for use of animal manure as feed.

Animal wastes have been recycled as feed for cattle, swine, and poultry.  Solid or liquid animal wastes to be recycled as feed will include a varying amount and type of bedding material.  Wastes from animals housed on dirt lots may also contain soil in addition to bedding.  Poultry wastes can occur with or without litter.  Waste from laying birds, usually does not contain litter but can contain shed feathers, spilled feed, broken eggs.  It is illegal to decompose poultry carcasses in manure.  If carcasses are decomposed in a compositing facility, the compost should not be recycled for feed.  Wastes from broiler and turkey houses will also include some spilled feed and shed feathers plus bedding material.  Spilled or unused feed frequently contributes to swine and cattle wastes, the amount varying by housing system.

Only a small amount of waste (<10%) can be collected and recycled from grazing animals.  Most of the waste used for animal feed is from confined systems.  Because of the high fiber and non-protein nitrogen content of animal wastes, only ruminants are suited for the efficient utilization of recycled animal wastes.  Recycling animal wastes as feed can be used as a tool for whole-farm nutrient management to maintain proper soil fertility profiles Fontenot et al., (Fontenot and others 1996).

**MEASUREMENT AND STANDARDS FOR ANIMAL HEALTH AND WELL-BEING**

## Criteria for Animal Health and Well-Being

■ Proper processing to eliminate potential pathogens, improve storage/handling characteristics and maintain or enhance nutritive value and palatability,

■ Defined limits of feeding that do not compromise animal performance and health, and that do not result in residues in food products from animals,

■ Precise knowledge of nutritive value prior to feeding to minimize potential detrimental effects of variability caused by type of waste and processing method.

## Processing Management Prior to Feeding Animal Wastes

Dehydration, pelleting, ensiling alone or with other ingredients, deep stacking, composting, preparation for liquid feeding, oxidation-ditch aerobic processing, and use of wastes as substrates for single cell protein production are methods that have been used for processing animal wastes for animal feed (Orr 1973;Fontenot 1981;Fontenot and others 1996;NRC 1983;NRC 1983;Fontenot 1981;Fontenot and others 1996). Dehydrating wastes in commercial dehydrators at temperatures ranging from 370 to 700ºC will eliminate pathogens and reduce or remove odor. The process does result in loss of nutrients, especially N, and the final product can be dusty. Dehydrated wastes appear to be stable for long term storage and offer a quality product for livestock feed. The process may not be economically feasible due to high energy input costs. This also applies to pelleting as the waste will have to be dried or dehydrated prior to pelleting. Pelleting wastes does provide a consistent product and prevents sorting when fed.

Liquid waste feeding systems have been evaluated for ruminants (NRC 1983). The main disadvantage is that the system has large potential for transmitting disease. Potential health problems have also been described for use of waste liquor from aerobic digestion of swine waste in an oxidation ditch. In this system, liquid waste is continuously stirred and oxygen is incorporated to promote microbial digestion (Orr 1973). After digestion, the slurry mixture is drawn-off as recycled feed for swine. Health concerns have been caused by increased concentration of intestinal worm eggs, increased nitrate concentration in the ditch liquor, and survival of potential pathogens such as Salmonella typhimurium.

Wastes have been used as substrates for protein production. Substrates include algae, yeast, fungi, bacteria, house-fly larva, and earthworms. Protein quality can be high but yield is variable. A research study conducted as part of Southern Regional Project S-202 utilized large scale cultures of algae and bacteria were on dilute swine manure suspensions to produce a protein feed and to remove the wastewater discharge (Sutton and others 1990). The harvested material contained more than >63% crude protein. These systems are more technologically complex and more difficult to integrate into typical farm operations than other processing methods.

Ensiling, deep stacking or composting offer the most practical and, usually, the most economical methods for on-farm processing and are successful in diminishing health hazards when fed. Ensiling animal waste alone or with other ingredients has been successful. This anaerobic fermentation process converts carbohydrates to lactic and other acids which reduces pH and stabilizes the product after bacterial activity ceases. The process generates heat which aids in eliminating pathogenic organisms. Moisture level is critical for proper packing and promoting the ensiling process. Poultry litter at 40% moisture gave satisfactory ensiling (Caswell and others 1978). Water would have to be added to dry broiler litter (< 20% moisture) to attain sufficient fermentation.

Mixing 70% corn silage:30% broiler or turkey litter (as is basis) has resulted in a good ensiling process (Crickenberger and Goode 1996;Fontenot and others 1996;Fontenot and others 1996). Swine waste mixed 60:40 or 40:60 with orchardgrass hay ensiled well (Berger and others 1981). Cage layer waste was successfully ensiled with wheat straw and dry molasses in a 55:35:10 ratio, wet basis, respectively (Ayangbile and Fontenot 1986a). Corn (1:1) or beet pulp (1.5:1), wet basis, were ensiled successfully with cage layer waste (Cooper and others 1978). Cattle waste mixed 70:30 to 30:70 with rye straw (wet basis) resulted in pH < 5 after 1 week indicating a good ensiling process (Cornman and others 1981). Dairy waste (fresh and stored slurry) were ensiled with wheat straw to 70 and 60% moisture levels with 5% dry molasses resulted in good ensilage with pH of 5 or less (Abazinge and Fontenot 1984).

Deep stacking is more prevalent for dry wastes such as turkey and broiler litter. Litter is deep stacked to depths of 4 to 6.5 ft to allow for heat generation which raises the temperature to approximately 60ºC and eliminates pathogens. Litter, deep stacked at 15%, 25%, and 35% moisture reached a maximum temperature of 57.5, 61.2, and 60.2ºC, respectively at a distance of 18 inches from the top of a 4 ft stack (Fontenot and others 1996). Excessive heating can decrease DM digestibility and cause N loss and insolubilization. Covering deep stacked litter with 6 mil polyethylene sheeting prevented excessive heating, prevented N loss and eliminated pathogenic organisms (McCaskey and others 1991). Composting animal wastes by aerobic decomposition until stable provides a product that can be fed. The process results in a large loss of N. Composting broiler litter (35% moisture) by stacking and mixing (initially after 2 days then at weekly intervals for 6 weeks) resulted in a 15% decrease in crude protein level, but the composted litter was utilized as well deep stacked litter by sheep (Abdelmawla and others 1988).

**EFFECTS ON ANIMAL HEALTH AND WELL-BEING**

**Comparative Nutritive Value of Animal Wastes**

The composition of processed wastes in comparison to commonly fed feeds are summarized in Tables 1 to 3. Animal wastes are a good source of protein (high level of non-protein N), minerals (high ash content) and fiber. Animal wastes tend to be lower in energy (TDN) than the selected compared feed. Relative nutritive value of wastes for ruminants in descending order are excreta of young poultry, deep litter of young poultry, swine feces, excreta of laying hens, manure solids of swine and laying hens, and cattle

waste (Fontenot and others 1996). The degree of variability in nutrient content and digestibility of animal wastes depends on animal species, animal age, feeding regimen, bedding material, animal environment, and manure handling and storage system.

Table 1. Mineral composition of animal wastes, DM basis, to be recycled as animal feed[a].

| Waste | Ash | Ca | P | Na | Cl | Mg | K | S | Fe | Cu | Co | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ----------------------------------%---------------------------------- | | | | | | | | ----------------ppm---------------- | | | | |
| Beef Waste | 18.9 | 2.34 | 1.03 | .88 | 1.32 | .4 | .5 | - | 1341 | 31 | - | 148 | 242 |
| Swine Waste | 18.0 | 3.04 | 2.59 | 2.75 | - | 1.1 | 1.9 | .3 | 3724 | 114 | 6 | 342 | 709 |
| CLW[b] | 30.4 | 8.13 | 2.22 | .46 | 1.01 | .65 | 1.63 | - | 1774 | 70 | 2 | 374 | 477 |
| Broiler Litter | 15.0 | 2.29 | 1.81 | .38 | - | .46 | 2.16 | - | - | 23 | - | - | 343 |

[a]Adapted from NRC, 1983 and Fontenot, 1981
[b]CLW = Cage Layer Waste

Table 2. Comparative mineral composition of selected feeds, DM basis[a]

| Feeds[b] | Ash | Ca | P | Na | Cl | Mg | K | S | Fe | Cu | Co | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ----------------------------------%---------------------------------- | | | | | | | | ----------------ppm---------------- | | | | |
| Grass Hay | 8.5 | .27 | .34 | .01 | .41 | .11 | 2.91 | .26 | 93 | 19 | .4 | 157 | 40 |
| Alfalfa Hay | 9.2 | 1.41 | .22 | .12 | .34 | .34 | 2.51 | .30 | 240 | 13 | .3 | 36 | 30 |
| Corn, ground | 1.6 | .03 | .31 | .01 | .06 | .11 | .33 | .14 | 30 | 5 | .4 | 6 | - |
| Corn silage | 4.2 | .31 | .27 | .03 | .18 | .22 | 1.22 | .12 | 180 | 9 | .1 | 41 | 21 |
| SBM | 6.3 | .40 | .71 | .04 | - | .31 | 2.22 | .16 | 185 | 22 | .1 | 35 | 57 |

[a]Adapted from NRC, 1996
[b]Grass and alfalfa hay, early bloom analysis; SBM = soybean meal

Table 3. Comparative protein, energy and fiber composition of selected feeds and animal wastes, DM basis[a]

| Feeds[b] | CP[c] | Fat | ADF | TDN[d] | Wastes | CP[c] | Fat | ADF | TDN[d] |
|---|---|---|---|---|---|---|---|---|---|
| | -----------------%----------------- | | | | | ----------------%---------------- | | | |
| Grass Hay | 12.8 | 2.9 | 41 | 65 | Cattle | 16.9 | 3.1 | 40.3 | 48 |
| Alfalfa Hay | 20.1 | 2.9 | 31 | 60 | Swine | 27.9 | 7.0 | 26.5 | 57 |
| Corn, ground | 9.8 | 4.3 | 3 | 88 | CLWe | 30.0 | 2.2 | 17.1 | 48 |
| Corn Silage | 8.0 | 3.5 | 28 | 75 | Broiler Litter | 30.8 | 3.3 | 24.1 | 60 |
| SBM | 52.0 | 2.3 | 10 | 84 | | | | | |

[a]Adapted from (NRC 1983;NRC. 1996;Fontenot 1981)
[b]Grass and alfalfa hay, early bloom analysis; SMB = soybean meal
[c]CP = Crude Protein
[d]TDN = Total Digestible Nutrients
[e]CLW = Cage Layer Waste

**EFFECTS OF FEEDING ANIMAL WASTES ON ANIMAL PERFORMANCE:**

**Poultry:**

Dried or dehydrated poultry waste (DPW) was incorporated up to 20% of diets fed to laying chickens without affecting egg production. Incorporation of DPW up to 30% of the diets fed to meat birds supported adequate growth. In both cases, feed efficiency decreased with DPW addition (El Boushy and Van der Poel 1994). The flavor of eggs and meat were not affected. This study supported the premise that cost:benefit ratio of drying cage layer waste precluded its common use in diets for non-ruminants. Using 10% dried broiler litter in broiler diets showed similar gains and feed conversions to a standard diet. A limited amount of processed poultry waste can be recycled back to growing birds and laying hens but is associated with a reduction in economic efficiencies of the operation. Laying hens fed 10% dehydrated cattle waste as the only source of animal protein experienced a 13.5% decrease in egg production and 11. 4% decrease in feed efficiency (NRC 1983).

**Swine:**

Economic criteria and performance must be considered when recycling swine waste as feed. Dried swine feces (DSF) was fed up to a maximum of 22% of a ration without depressing intake of finishing swine (Orr 1973). Further work showed that DSF reduced digestibility of protein and energy when included as replacement for SBM. However, DSF was a good source of minerals (Orr 1975). The use of oxidation ditch slurry for pigs was not beneficial (Orr 1975;Hugh and others 1978;Hugh and others 1978). Recycled swine waste may have a place in supplementing gestating sow diets (Johnston 1981). The digestibility of swine waste fractions fed to growing gilts were 46.7% for energy, 48% for DM; 60.1% for crude protein; and 40.9% for crude fiber (Kornegay and others 1977). Feeding 25 or 50% ensiled cattle waste, or 9, 17,or 23% DPW to growing pigs decreased gain and feed efficiency compared to a control diet (NRC 1983).

**Sheep:**

Growing lambs and ewes can utilize animal wastes when incorporated into conventional diets. Phosphorus repleted ewes utilized phosphorus more efficiently from ensiled swine waste and broiler litter supplements than those containing dicalcium phosphate and SBM. However, calcium was less well utilized from the wastes. Magnesium was well utilized by all diets (Cook and Fontenot 1985). Wether lambs fed 0, 33.3 or 66.7% deep stacked broiler litter in a diet of corn, SBM, and wheat straw digested less of DM and excreted more minerals as amounts of litter increased (Fontenot and others 1996). Excretion of all minerals was more than 79% of intake. Implications were that more minerals were excreted on the pasture and the soil as a result of feeding increased amounts of litter.

Growing lambs fed 17% DPW grew as well as lambs fed conventional diets. Lambs fed DPW, which supplied 40% of the dietary N, utilized the N as well as that supplied by SBM or urea (NRC 1983). Lambs fed ensiled swine waste with orchardgrass hay (60:40

or 40:60 ratio) digested the silage better than lambs fed orchardgrass hay (Berger and others 1981).

Limitations of feeding animal wastes to sheep include the potential for high copper intake and copper toxicity. Use of dietary molybdenum has reduced the potential for copper toxicity (Olson and Fontenot 1984). Diets containing up to 68% broiler litter have been successfully fed to growing and breeding sheep for periods of up to 60 days. Use of 50% DPW in sheep diets was considered excessive (NRC 1983). Wether lambs used the N from 70:30 corn silage:cage;layer waste as effectively as lambs fed a corn silage diet supplemented with SBM (Magar and Fontenot 1988).

## Cattle:

Animal wastes can be well utilized by cattle. Recycled steer waste in a mixture of 40 parts waste and 60 parts dry concentrate was as effective as a diet containing corn silage, ear corn and supplement for yearling steers (Anthony 1970). Feeding up to 40-50% ensiled cattle waste in a total diet provide good steer and heifer performance. Pelleted diets containing 25-30% swine waste provided adequate cattle performance (NRC 1983). Growing heifers and steers fed 30 or 45% deep stacked broiler litter with corn silage and corn (1% body weight/day) supported very acceptable animal performance by response to 60% was decreased (Table 4).

Table 4. Performance of heifers and steers fed high corn silage diets supplemented with deepstacked broiler litter[a]

|  | Level of supplement, dry basis | | | | | |
|  | 30% | | 45% | | 60% | |
| Item | Steers | Heifers | Steers | Heifers | Steers | Heifers |
|---|---|---|---|---|---|---|
| Initial wt, lb | 693.2 | 605.2 | 664.9 | 570.7 | 660.2 | 563.6 |
| Final wt, 118 days, lb | 989.2 | 873.0 | 973.0 | 829.8 | 895.4 | 785.8 |
| Daily gain, lb/day | 2.51 | 2.27 | 2.61 | 2.20 | 1.99 | 1.88 |
| Average daily intake, lb/day |  |  |  |  |  |  |
|     Corn silage | 38.9 | 38.7 | 32.9 | 27.8 | 18.4 | 19.6 |
|     Deep stacked litter | 7.8 | 7.6 | 12.1 | 10.0 | 11.9 | 12.6 |
|     Corn grain[d] | 7.8 | 6.8 | 7.7 | 6.5 | 6.9 | 6.2 |
| Dry matter intake, lb/day | 25.3 | 24.6 | 26.5 | 22.3 | 20.2 | 20.8 |
| Feed efficiency[c], lb/lb gain |  |  |  |  |  |  |
|     Corn silage | 15.5 | 17.1 | 12.6 | 12.6 | 9.3 | 10.4 |
|     Deep stacked litter | 3.1 | 3.4 | 4.6 | 4.6 | 6.0 | 6.7 |
|     Corn grain[d] | 3.1 | 3.0 | 3.0 | 3.0 | 3.5 | 3.3 |
| Dry matter/lb gain, lb | 10.0 | 10.8 | 10.2 | 10.1 | 10.2 | 11.1 |

[a]Adapted from Chester-Jones et al, (Chester-Jones and others 1984)
[b]As fed basis.
[c]Fed during last 56 days

A 3-year summary of feeding 70:30 corn silage:poultry litter with a SBM supplement to fattening beef heifers demonstrated a slightly greater daily gain but lower feed efficiency was attained when compared with heifers fed corn silage and SBM supplement. Carcass

quality favored the litter-fed heifers (McClure and others 1979). Lactating cows fed up to 23% cage layer waste (CLW) had similar milk yields as cows fed no CLW (Sutton and others 1990). Stocker cattle fed 50:50 corn:poultry litter diets had similar gains but lower feed efficiency than those fed conventional diets (McCaskey and others 1994). Turkey litter should not provide more than 33.3% of supplemental protein for growing cattle (Harvey and others ). A mixture of 30% broiler litter with 70% corn silage was well used by dry cows, lactating cows, and by growing and finishing cattle fed with hay and/or corn (Crickenberger and Goode 1996).

## ENVIRONMENTAL FORCES INFLUENCING ANIMAL HEALTH AND WELL-BEING

### Potential Hazards of Feeding Animal Wastes:

Recycled animal wastes for animal feed has the potential of exposing animals to pathogenic organisms, toxigenic molds, parasites, harmful level of pesticides, medicinal drugs, and high concentrations of trace minerals and heavy metals. Human and animal health aspects of feeding animal wastes have been reviewed (Webb Jr. and Fontenot 1975;McCaskey and Anthony 1979;Fontenot 1981;Fontenot and others 1996;NRC 1983;NRC 1983;McCaskey and Anthony 1979;Fontenot 1981;Fontenot and others 1996). Clostridium, Corynebacterium, Salmonella, Enterobacterium, Mycobacterium, Bacillus, Coliforms, Staphylococcus, and Streptococcus species have been isolated in unprocessed poultry litter. Proper processing of animal wastes alone or in mixtures at the correct moisture will dramatically reduce or eliminate organisms. In the commercial dehydration process of poultry waste, for example, there is an inverse relationship between temperature of the dehydrator and the number of organisms, and between the moisture content of the dehydrated waste and number of organisms (Chang and others 1975) (Table 5). Dehydration of broiler litter and layer waste eliminates Salmonella.

Long standing California standards for effectiveness of pasteurization of waste products require less than 20,000 bacteria and 10 coliform organisms/g dried product and no salmonella (NRC 1983). McCaskey and Anthony (McCaskey and Anthony 1979) clearly showed the elimination of Salmonella in an ensiled waste-feed mixture (Table 6). The pH dropped to less than 4.5 in this example and the ensiled temperature exceeded 25ºC. Ensiling broiler litter alone has been shown to destroy fecal coliforms at a pH of 5.5.

A minimum of 60 days is required for processing animal waste as silage to ensure it is safe to feed. Decomposed poultry carcasses found in ensiled litter caused an outbreak of botulism and it is recommended waste to be recycled should be free of carcasses (Fontenot and others 1996). A microbiological survey of poultry litter in Georgia found that it is not a source of harmful bacteria such as E.Coli 0157/H7, Staphylococcus aureus, or Salmonella typhimurium (Martin and others ).

Mycotoxins have been isolated from animal wastes, as they have in many common animal feeds, and present no greater concern. Fresh feedlot manure had greater amounts of aflatoxins (Aspergillus flavus) than partially decayed or stockpiled manure. Composted feedlot waste did not contain aflatoxin residue (Fontenot 1981). Concentrations of drugs in broiler litter taken from Virginia farms have been summarized

(Table 7).  If the drugs were in the poultry diets they were identified in the litter at somewhat variable levels.  There have been no accumulation of medicinal drug residues in cattle fed poultry litter.  A modest withdrawal period of 5 days is recommended (Webb Jr. and Fontenot 1975).  It is recommended that litter not be fed to cows producing milk or hens producing eggs for human consumption.  Pesticide residues have not been problem.

Table 5.  Effect of temperature and moisture on microbial counts of dehydrated poultry waste

| Microbes | Dehydration Temperature | Sample Moisture (Duff and others 1995) | Average Microbial Count/g |
|---|---|---|---|
| Aerobic | 260º C | >10 | 20,281,666 |
| | | <10 | 710,000 |
| | Over 260º C | >10 | 6,719,520 |
| | | <10 | 183,396 |
| Anaerobic | 260º C | >10 | 6,958,333 |
| | | <10 | 730,000 |
| | Over 260º C | >10 | 1,360,530 |
| | | <10 | 46,241 |

[a]Adapted from Chang et al. (Chang and others 1975).

Table 6.  Effect of temperature on survival of *Salmonellae* in an ensiled waste-feed mixture.[a]

| | Temperature (ºC) | | | |
|---|---|---|---|---|
| Survival After 4 Days Ensiling | 5 | 15 | 25 | 35 |
| Number of cultures[b] | 21 | 25 | 1 | 0 |
| Percent of cultures | 78 | 93 | 4 | 0 |
| pH, initial | 4.8 | 4.8 | 4.8 | 4.8 |
| pH, 4 days | 4.6 | 4.4 | 4.0 | 4.1 |

[a]Adapted from McCaskey and Anthony (McCaskey and Anthony 1975)
[b]27 salmonella cultures were used.

Table 7.  Drug residues in broiler litter.[a]

| Drug | Concentration[b] | | Number of Samples |
|---|---|---|---|
| | Average | Range | |
| Oxytetracycline (ppm) | 10.9 | 5.5-29.1 | 12 |
| Chlorotetracycline (ppm)[c] | 12.5 | 0.8-26.3 | 26 |
| Chlorotetracycline (ppm)[d] | 0.75 | 0.1-2.8 | 19 |
| Penicillin (units/g) | 2.5 | 0-25.0 | 2 |
| Neomycin (mg/kg) | 0 | 0 | 12 |
| Zinc bacitracin (units/g)[e] | 7.2 | 0.8-36.0 | 6 |
| Zinc bacitracin (units/g)[f] | 12.3 | 0.16-36.0 | 5 |
| Amprolium (ppm) | 27.3 | 0-77.0 | 29 |
| Nicarbazin (ppm) | 81.2 | 35.1-152.1 | 25 |
| Arsenic (ppm) | 40.4 | 1.1-59.7 | 41 |
| Copper (ppm)[g] | 254.7 | 132.1-329.3 | 46 |
| Copper (ppm)[h] | 50.8 | 37.3-99.4 | 35 |

[a]Webb and Fontenot (Webb Jr. and Fontenot 1975).
[b]Dry matter basis.
[c]Chlortetracycline used continuously in broiler diets.
[d]Chlortetracycline used intermittently in broiler diets.

[e]Zinc bacitracin used in broiler diets.
[f]Zinc bacitracin not used in broiler diets.
[g]Copper sulfate used continuously in broiler diets
[h]No copper sulfate added to broiler diets

The greater concentration of trace minerals found in animal wastes has been a source of animal health concern. Potential problems include mineral toxicity and accumulation of minerals in tissues or in the environment (NRC 1983). Copper and selenium are added to livestock and poultry feeds. Arsenic is added in the form of arsenicals. Heavy metals such as cadmium, lead , and mercury occur naturally in feeds. Animal wastes contain a greater concentration of these minerals than feeds because of low absorption (Fontenot 1981;Olson and Fontenot 1984). Copper content of wastes will vary with the amount added in the diet (Table 7). Sheep are particularly sensitive to dietary copper concentrations greater than 15 ppm of the diet DM. Withdrawing dietary copper for up to 140 days did not substantially reduce liver copper concentrations in ewes Olson and Fontenot (Olson and Fontenot 1984). Cattle are less sensitive to copper than sheep. Profiles of bromine, arsenic, cadmium, copper, mercury, molybdenum, vanadium, and zinc were evaluated in cattle fed 70:30 corn silage:poultry litter diets(Westing and others 1977). Only copper increased in the liver. None of the minerals were increased in the muscle tissue. Feeding molybdenum and sulfate appears to help in reducing the potential for liver copper accumulation and appears to be especially beneficial to prevent copper toxicity problems in sheep. Overall quality of edible animal products have not been compromised from feeding animal wastes (Fontenot and others 1996).

**Regulation of Feeding Animal Wastes:**

In 1980 the FDA left the regulation of feeding animal wastes to individual states (revoked 1967 article 21 CFR 500.4 to 45 FR 86272 in 1980). Today, regulation is through AAFCO (1990) for processed animal wastes. This regulation states (Fontenot and others 1996)that:

■ Waste must be processed so it will be free of pathogenic organisms,

■ If it can be documented that animals producing the wastes were not fed drugs, no withdrawal period is required, and the waste can be fed to any class of animals;

■ If it cannot be documented that the animals producing the waste were not fed drugs, a 15-day withdrawal is required prior to slaughtering animals or prior to using milk or eggs for human consumption.

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## CURRENT AND POTENTIALLY AVAILABLE PREVENTION AND MITIGATION MEASURES

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### INTRODUCTION

No other factor can affect the health and well-being of animals as severely as exposure to an infectious disease(s).  Exposure to bacterial and viral pathogens occurs frequently in the life of an animal, and can spread laterally throughout animal populations at a rapid rate.  Depending on the level of immunity within the population and the degree of management under which they are raised, the effect can be quite severe, especially if concurrent infection of multiple pathogens should occur.  The need to mitigate the effects of such pathogens and to improve the health and productivity of animals has resulted in the evolution of disease-control strategies.  Many of these strategies are applicable to all animal species and either are or would be implemented depending on the limitations imposed by the particular animal unit.  The following sections summarize the published data on health technologies commonly employed to reduce the deleterious effects of pathogens on the various species in animal agriculture.

**Animal Management**

**Swine:**

*All In - All Out Animal Flow:*

All in - all out (AIAO) animal flow has been documented to improve the performance of pigs (Scheidt and others 1990).  The ability to completely empty a room, building, or site prevents the continuous spread of pathogens from older to younger animals.  All in - all out has long been a practice of the poultry industry.  Barns of birds are routinely emptied following delivery to the slaughter house, washed, disinfected, fumigated and allowed to remain empty for a period of time to reduce microbial survival outside the host.  This technology was initially adapted by the swine industry in order to control diarrhea problems prior to weaning.  However, in the last five to ten years, the effect of AIAO on the post weaning pig performance has been extensively studied.  Studies demonstrate that such practices improve average daily gain by 7-10% ,and feed efficiency by 3 to 5 %, as well as reduce the level of  mortality and the severity of respiratory disease in the grow-finish phase (Clark and others 1991).  Furthermore, improvements up to 20% in growth rate and 25%  in feed efficiency have been documented in nursery pigs as well.

All in - all out can be practiced by room, building, or site.  Data indicate that AIAO by site or airspace results in better performance, than if a single room is emptied (McManus 1991).  While pigs ideally should be housed within a week of age of each other, two weeks of production can be grouped together.  While AIAO does not result in elimination of disease, it does however, result in a reduction in the prevalence of pneumonic lesions, as well as a reduced severity of intestinal diseases.  Conversion of large, continuous flow facilities to AIAO usually entails construction of walls to establish rooms of pigs within buildings.  Each room must be individually ventilated.  Another means of converting to

AIAO pig flow may require the reorganization of farrowing schedules, resulting in larger "batches" of weaned pigs, completely filling a facility at one time. While it does take prior planning, the effect of AIAO on post weaning performance appears to be well worthwhile.

*The F-10 System:*

F-10 stands for "farrowing to 10 weeks of age" and is a new technology recently described for the improvement of weaned pig performance (Schuiteman 1993). In this system, sows are weaned in the normal fashion, however the pigs remain in the farrowing crate until they are 10 weeks old. The farrowing crate is then modified and converted to a nursery pen. The advantage of such a system is that early removal of the sow prevents further spread of infectious agents from sows to weaners, a reduction of labor, and improved performance. While little data is available, it appears that piglets raised under the F-10 system out perform those raised under conventional measures. Improvements in growth rate of 44%, a 30% reduction in feed efficiency, and a 50% reduction in mortality have been documented. The disadvantages of such a system may include a reduction in the utilization of farrowing crate space. Therefore, the system may only be applicable to producers using batch or group farrowing schedules. Despite this limitation, pigs raised under the F-10 system appear to be capable of better performance than those in conventional nurseries.

*Multi-Site Systems:*

Prior to beginning the review of segregated early weaning, a brief review of the current production systems in the US is in order. The US swine industry currently uses either 1-site, 2 - site, or 3 - site production systems. In a 3-site production system, one-site consists of breeding, gestation and farrowing on one site, with the nursery and finishing on separate sites. Recommended distances between sites range from 1 to 3 km depending on the health status of the operation and the suspected airborne potential of various microorganisms. Two-site systems consist of breeding, gestation and farrowing on one site, with nursery/finishing on another. The main premise of both systems is that the nursery must be located on a separate site away from the breeding herd. This is important to prevent the transmission of microorganisms from the sow to her offspring. This theory has been the basis of segregated early weaning (SEW) technology and will be summarized in a later section.

Multi-site production systems have many advantages for swine producers, besides the improvement of health status. If nursery and finishing facilities are relocated on other sites, existing facilities can be remodeled to expand the size of the breeding herd, usually with reduced investment. Nurseries can be remodeled into farrowing rooms, while finishing pens can house gestating sows. Frequently, swine producers will network together, and establish off-site weaning facilities to commingle pigs from several farms. The health status between the sow farm must be similar in order to prevent the exposure of susceptible pigs to new diseases. Three-site production can be costly, and difficult for the majority of smaller commercial swine producers in the USA to use. It is usually reserved for breeding stock companies or large herds with 1,200 or more sows. The two-

site system is much easier to operate economically and appears to be just as effective. This technology, in combination with the SEW program, is beneficial to all types of procedures and results in improved efficiency of the swine enterprise. This technology will now be discussed.

*Segregated Early Weaning (SEW):*

Segregated early weaning (SEW) is a variation of medicated early weaning (Alexander and others 1980). Further reports have indicated the ability to eliminate certain pathogens and improve weaned pig performance (Harris 1990). A critical component of the program consists of hyperimmunization of the sow prior to farrowing to provide high levels of colostral antibodies against specific pathogens. This is important to reduce transmission of microorganisms between sows and pigs during lactation. The pig is then injected with a series of antibiotics to eliminate specific bacteria prior to weaning. Finally, the pig is weaned at an early age to a separate site to prevent further transmission from the sow. Recent studies have investigated the necessity of antibiotics. Under controlled conditions, it appears that age specific separation from the sow may be more important than medication (Clark and others 1994). As far as proper weaning ages, much work has been done to determine the relationship between weaning age and pathogen elimination. It currently appears impossible to eliminate certain microorganisms with early weaning. Pathogens such as *E. coli*, and Streptococcus suis may be present in the pig shortly after birth (day 1), due to colonization via contact with the mucosal surfaces, secretions or excretions of the sow (Amass and others 1996).

Transplacental transmission of PRRS virus, *Leptospira sp.*, or parvovirus may result in the presence of these specific organisms immediately following parturition. However, published data has indicated an ability to eliminate pathogens if certain weaning ages are met (Wiseman and others 1991). Weaning pigs at 10 days of age or less appears to eliminate *Haemophilus parasuis, Bordetella bronchiseptica, Pasteurella multocida* and *Mycoplasma hyopneumoniae*. The initial presence of these organisms is not detected unless weaning ages reach 15 days or more. Similarly, *Actinobacillus pleuropneumoniae* may be eliminated at 16 to 18 days of age. Finally, pseudorabies virus and transmissible gastroenteritis virus appear to be eliminated at 21-day weaning.

Upon arriving to the nursery, weaners are fed diets high in milk product and plasma protein. It is critical to limit feed five to seven times/day for the first week after weaning. Pigs are placed on a water-soluble antibiotic, chosen based on in vitro susceptibility data. Four different diets are usually fed over the eight-week nursery period. Animals are housed in single stage nurseries with plastic coated flooring at 30 to 31ºC and are sorted by size and sex.

The decision of which vaccines and medications to use depends on the individual farm diagnostic data. It is recommended that nasal swabs are collected from sows and two to three sick pigs from the nursery and finishing areas be submitted to the diagnostic laboratory for culture. Based on the sensitivity patterns of bacterial isolates, the medication can be chosen. Serology is also an important tool to determine the exposure

level of the breeding herd to specific pathogens that are targeted for eradication and assists with the development of vaccination programs for the breeding herd.

Performance following completion of SEW has been excellent, however, little information is available concerning the effect of SEW on the subsequent performance of the sow.  Recently, data from four production units in which SEW has been employed for three years has been published.  Despite a weaning age of 12 to 14 days, problems with the breeding herd have been minimal.  Little reduction in subsequent live born litter size or weaning to estrus interval was detected in four commercial swine herds when three years of early weaning data were analyzed (Dee 1995).

*On-Site Segregated Rearing:*

Despite the success of multi-site production, the ability to use such technology may be limited.  Frequently, separate farm sites are difficult to obtain due to lack of capital, overall inconvenience from the existing labor force, or a high density of swine in the surrounding area.  Although there is little published data at this time, the concept of raising pigs away from the sow, but on the same site looks promising.  If the nursery facility is located a short distance (200 to 500 m) from the breeding and finishing buildings and there are no connecting airspace (hallways) between the nursery and the other facilities, performance may be improved.  Also, strict segregation of labor is essential with only one person allowed to work in the nursery.  Shower facilities are important; however, the routine practice of changing clothes, (coveralls and footwear) prior to entry into rooms appears to be critical.  A regular program of rodent control is practiced on a monthly basis by a professional exterminator as well.  Preliminary data from an 800 sow farm raising 22kg pigs indicate a reduction in nursery mortality (2.5 to 1.5%), an increase in average daily gain (.34 kg to 4.5 kg) and an improvement in feed efficiency (1.9 to 1.5).

*Whole Herd Depopulation-Repopulation:*

Whole herd depopulation-repopulation has gained increased acceptance as a strategy to improve both health and genetic performance.  While the process can be very costly and extremely difficult psychologically, it is very effective at eliminating chronic, endemic diseases, as well as improving genetics at the same time.  Reasons to repopulate the entire farm include poor growth rate, excessive numbers of non-marketable or cull pigs, poor feed efficiency and low heterosis.  While diseases of the nursery pig are typically not severe enough to warrant whole herd depopulation, the technology will be briefly reviewed at this time.

Prior to initiation of a depopulation program, prior planning is required.  A careful evaluation of the present herd performance is necessary, including the identification of all significant disease entities currently in existence.  Commonly encountered disease problems, which lead to depopulation including pseudorabies, swine dysentery, *Actinobacillus pleuropneumoniae* and atrophic rhinitis.  Such chronic disease usually results in excessive antibiotic usage.  It is important to establish the amount of antibiotics

and/or vaccine, which are being used to treat disease, in order to assess the potential economic benefits of a whole herd repopulation.

In addition to the assessment of current health problems, an evaluation should be made of the genetic status of the herd. Problems, which indicate poor genetic performance, include low live born litter size, low weaning weights, and excessive backfat at slaughter. Finally, due to the fact that whole herd depopulation results in severe short-term capital losses, arrangements frequently must be made with a lending institution to provide an adequate level of working capital.

The timing of the depopulation is critical. Procedures should take into account the length of downtime required, season of the year and predicted market prices. Ideally to decrease downtime, facilities are rented to insure a constant flow of pigs to market. At least 30 days of downtime are usually required on the home farm to allow for thorough cleaning, repairs and to reduce the survival of pathogens outside the host. Ideally, this should take place during periods of hot weather to take advantage of the bactericidal or virucidal effects of drying, heat and ultraviolet radiation. The clean-up procedure is very involved, and encompasses the washing of the entire swine complex including a thorough cleaning of the pit. All equipment, including feeders, crates, pens and ventilation equipment needs to be thoroughly washed with hot (90 to 94ºC), high pressure water and disinfected. Pits should be emptied, and slats lifted to obtain access to fecal material that has built up on the underside of the concrete. Finally, a rodent control program should be implemented, and maintained, ideally by a professional exterminator.

Following repopulation, improved performance is usually seen. Improvements of 10% or more in growth rate, and a five to 10% improvement in feed efficiency have been reported. Other benefits include a 10 to 20% increase in pounds marketed and a reduction in vaccination and medication costs. Problems frequently encountered during or following a repopulation consist of mismanagement of the off-site breeding project, reintroduction of a significant disease via the purchased stock, as well as the enhanced level of specific diseases such as greasy pig disease or parvovirus. Such diseases are thought to arise from a low level of immunity within the immature breeding population. Overall, whole herd depopulation and repopulation can produce both health and genetic benefits; however, due to its high level of economic and psychologic stress it is a technology that should be employed only when other options have been exhausted.

*Partial Depopulation:*

Partial depopulation consists of an adjustment in pig flow to interrupt horizontal transmission of pathogens from older, previously infected pigs, to those recently weaned. Partial depopulation (PD) was first utilized for the control of post-weaning PRRS (Dee and Joo 1994;Dee. S.A. and others 1997a;Dee and others 1997b). While PD has been primarily used in PRRS positive nurseries, it can be applied to infected finishers, as well.

The use of PD for PRRS control is bound on the principle that virus circulation exists in a specific stage of production i.e. the nursery or finisher, but is absent in the breeding herd. This specific pattern of spread is critical for success, since infection of piglets prior to

weaning results in the introduction of viremic animals to the nursery or finishing population.

Productivity and profitability in 34 nurseries before and after PD is given in Tables 1 and 2.  The advantages of PD are a minimal disruption of PD is that the technique depends on an absence of pathogen spread from the sow to the pig, prior to weaning.  In addition, it may be logistically difficult to implement in large ($\geq$ 1000 sow) herds and it requires a temporary off-site facility to house depopulated pigs.  Finally, the strategy may need to be repeated every 1 to 2 years.

*Conclusions*

All of the aforementioned strategies are effective at improving animal health, well-being, and performance.  Selection of the strategy depends on the input of the veterinarian, the financial status of the farming operation and the ability of the producer to properly manage the system once changes have been made.  Proper planning prior to execution of the plan will enhance its success, and the veterinary practitioner is in an excellent position to provide knowledge and direction to producers in need.

Table 1:  Mean differences in the performance of four study groups 12 months before and 12 months after nursery depopulation.

| Group | Number of Farms | ADG (kg) | | % Mortality | | FE | | Treatment Cost/Pig** | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After | Before | After |
| 1 | 15 | .25 | .38* | 9.7 | 2.3* | 1.83 | 1.78 | 2.88 | 1.48 |
| 2 | 6 | .25 | .34* | 14.4 | 2.0* | 2.01 | 1.85 | 4.17 | 2.05 |
| 3 | 7 | .29 | .37* | 7.0 | 1.7* | 2.06 | 1.85 | 3.63 | 2.36 |
| 4 | 6 | .26 | .41* | 10.9 | 1.2* | 1.95 | 1.70 | 2.15 | 0.55 |
| Total | 34 | .26 | .38 | 10.2 | 1.9 | 1.91 | 1.77 | 2.90 | 1.63 |

\* = ($p<.0001$)
\*\* = injectable medication and vaccination costs/pig (US dollars)

Table 2:  Difference in mean margin over variable cost per sow in four study groups 12 months before and after nursery depopulation.

| Group | Number of Farms | Before | After | Difference |
|---|---|---|---|---|
| 1 | 15 | -68 | +180 | +248 |
| 2 | 6 | -150 | +23 | +173 |
| 3 | 7 | -21 | +115 | +136 |
| 4 | 6 | -50 | +393 | +443 |
| Total | 34 | -50 | +178 | +228 |

**Cattle:**

As suggested earlier in this section, although specific diseases and disorders may differ among species, many of the practices (the biosecurity efforts) used to prevent or mitigate against negative impacts on animal health are similar across species. Thus, the cattle industry faces many of the same biosecurity issues as described for swine and poultry. Beef, swine, and poultry are frequently raised in groups and leave the farm for slaughter as a group. This provides the opportunity to conduct practices such as the all-in-all-out animal flow described for swine. Animal movement in a dairy facility is more frequently based on individual animal flow that generally prevents this type of management practice from being utilized.

A recent dairy health conference at the University of Minnesota provided several presentations that summarized ongoing efforts to prevent and mitigate negative impacts on the health of dairy cattle (Rapnicki 1999;Collins 1999;Godden and others 1999;Buelow 1999;Seguin 1999). The importance role of accurate records in making decisions was stressed as was the importance of developing and following standard treatment protocols - specific procedures to administer medications (Rapnicki 1999). This presentation highlighted the fact that both individual cow and whole herd decisions affect the health of each cow in a unit. Well-designed whole herd policies consider the impact of specific situations on all cows in the herd and thus impact the health of each cow.

*Mitigation Strategies*

For cattle, some mitigation strategies include:

■ Vaccination programs, some of which have been documented as effective in field situations.

■ Use of calf hutches for heifer rearing, to reduce exposure to microorganisms causing various contagious diseases such as Johne's disease and Salmonellosis.

■ Feeding of colostrum to newborn calves within the first 12 hours of life (Gay 1983;Wells and others 1996) to provide calves with necessary energy sources, vitamins and minerals, and antibodies to disease-causing pathogens.

■ Early separation of calf from dam, to reduce exposure to pathogens (Jenny and others 1981;Wells and others 1996).

■ Use of offsite heifer rearing systems, again to reduce exposure to pathogens causing disease, though not well documented effectiveness in improving animal health.

■ Screening cattle before introducing to operation to avoid introducing diseases such as Johne's disease, bovine viral diarrhea, and contagious mastitis.

*Biosecurity*

Biosecurity issues were addressed (Collins 1999;Godden and others 1999;Buelow 1999) and several biosecurity programs were described.  Biosecurity programs are designed to control infectious diseases, both by preventing their occurrence and by eliminating those that exist.  Specific steps of developing a biosecurity program and the importance of such a program were addressed (Godden and others 1999).  These programs include management practices that:

■ reduce the likelihood of introducing new disease from an external source
■ reduce the spread of existing disease
■ reduce the impact of the existing disease on the dairy.

Testing animals for the presence of disease and management steps taken to introduce new animals into a unit are major components of a biosecurity program.

*Major diseases of cattle*

Major infectious diseases of cattle in the upper Midwest (including Bovine viral diarrhea [BVD], Johne's disease, contagious mastitis, Salmonellosis, Mycoplasma bovis, hairy heel warts, Neospora caninum, and Bovine leukosis [BLV]) were discussed and a brief review of the epidemiology of these diseases, methods of testing for the diseases and some potential measures for prevention and control were presented (Godden and others 1999).  Other presentations in this conference described biosecurity programs and potential impact of infectious reproductive diseases such as Neospora caninum induced abortions (Seguin 1999) and of infectious mastitis such as Staph. aureus (Buelow 1999).

Johnes disease is caused by an infectious organism Mycobacterium paratuberculosis (Collins 1999;Buelow 1999).  Young calves acquire the disease by ingesting the organism.  However, development of the disease is usually slow and most infected animals do not develop clinical signs until the second or third lactation.  Evidence suggests the prevalence of the disease is increasing but the greater incidence is also due to increased testing.  In 1996, a USDA survey inidcate that 41% of the U.S. daity herds had at least one Johne's positive cow (Collins 1999).  Poor farm hygiene increases the rate of transmission among animals.  Current efforts to develop a vaccine have not been effective (Collins 1999).  Johne's is a disseminated infection and has the potential to contaminate beef products both pre and post-harvest.  Crohn's disease and Johne's disease have similar clinical signs and pathologies.  Although there is no medical consensus exists as to whether M. paratuberculosis causes Crohn's disease in humans, there is at least evidence that suggests the disease may have some similar linkages (Collins 1999)

*Poultry*

Because disease is a result of interaction of the host, environment and pathogen, health promotion methods must take all three into account. The following methods are available:

■ provide a comfortable environment

- reduce or eliminate vertical transmission
- biosecurity
- immunization
- medication

*Provide a Comfortable Environment:*

Poultry are usually kept in confinement facilities to protect them from the elements, from predators and from disease. Such confinement buildings are designed and built for the specific poultry type (broiler, layer or turkey) housed in them. Poultry in confinement suffer from less disease (Shane and others 1995;Zander and others 1997), have better livability and experience fewer environmental extremes than poultry kept outdoors. Problems can arise in confinement facilities that are associated with deficiencies in management (Shane and others 1995;Zander and others 1997) and associated with the Minnesota climate.

*Reduce or Eliminate Vertical Transmission:*

The National Poultry Improvement Plan is a voluntary program for the elimination and reduction of vertically transmitted diseases. Nearly all breeder owners and hatcheries (commercial, game bird, waterfowl, and exhibition) are participants. The voluntary plan provides purchasers with information about the health status of breeders from which they buy hatching eggs or baby poultry. This program has resulted in the near eradication of Pullorum disease, Fowl Typhoid, *Mycoplasma gallisepticum, Mycoplasma meliagridis and Mycoplasma synoviae.*

Another method to reduce vertical transmission of disease is proper hatch egg handling. Eggs must be laid in properly designed and constructed nests, the nests must be managed correctly, the eggs must be collected frequently, and the eggs must be kept clean. These practices reduce baby poultry mortality due to *E. coli*, staph, paratyphoid and aspergillosis.

*Biosecurity:*

Biosecurity is preventing the introduction of disease. The level of biosecurity practiced in a poultry operation will vary depending on the type of operation, size of the operation and the disease risk. These factors affect the potential financial loss associated with a disease introduction.

Diseases are introduced by other poultry, other birds, domestic and wild animals, insects, people and equipment.

Attempts to keep disease out include all in B all out management used particularly in broiler production, turkey brooding, and commercial pullet production. Cleaning and disinfecting of poultry houses, equipment and vehicles associated with moving poultry is a standard practice. Control of the movement of people and equipment is considered

essential to preventing the introduction of diseases.  Control of wild and domestic birds and mammals is considered essential to biosecurity.

Conceptual biosecurity is the vision that diseases that do not exist on the farm or in the flock can be kept out.  It is the basis for location of farms and buildings, the types of housing utilized and the geographic separation of farms.

Structural biosecurity is applying the concept to the farm layout, location of roads, drainage, fences etc. and provision of controlled access ways to the farm and buildings.

Operational biosecurity is what managers actually do to keep diseases out. It includes the policies, practices and procedures employed to control:

Bird movement policies and procedures
Chick delivery - records from breeders and hatchery
Pullet moving
Hen moving
Slaughter movement
Vehicle and equipment policies and procedures
Poultry moving vehicles and equipment, feed trucks, egg trucks
Clean out procedure and manure disposal
Check list

*Immunization:*

Some diseases are sufficiently common or serious to justify routine vaccination.  These include Marek's disease, infectious bursal disease, hemorrhagic enteritis, fowl pox, avian encephalomyelitis and infectious bronchitis.  There are other diseases for which vaccines are available but their use should depend on a professional assessment of their need.  Some attenuated vaccines have the potential for reversion to virulence if allowed sufficient passages through birds, so it is well to remember that vaccines can be harmful if misused.

*Medication:*

Medication can be used in poultry for prevention or treatment of disease.  Preventive medication includes the use of coccidiostats, antibacterials and anthelminthics.  Treatment medication includes treatment for coccidiosis, helminths, external parasites and bacterial diseases.

Preventive medication is usually provided in the feed and use of feed medication is strictly controlled by the U.S. Food and Drug Association (McChesney and others 1995).  Treatment medication may be administered in the feed and is then under the control of the FDA.  Medication administered by any other route may include over the counter drugs or prescription drugs.  Over the counter drugs are approved for specific use by the FDA.  Any other use of over the counter drugs and use of prescription  drugs requires a veterinary prescription.

**Facility Design and Management**

**Introduction:**

Animal facilities range from environmentally controlled buildings to pasture systems with numerous options in between. Facilities are designed to facilitate animal management, care, and handling; provide environmental conditions to promote animal health and well-being; minimize labor requirements; handle manure properly; be economical; and provide for worker safety and health. Most designs are a compromise between these competing design goals.

Two cooperative regional organizations associated with Land-Grant Universities (e.g. Midwest Plan Service (MWPS) and Natural Resource, Agriculture, and Engineering (NRAES) produce and publish handbooks and other materials that provide design recommendations for animal facilities. These handbooks are commonly used by engineers and allied professionals involved in the design of animal facilities. Proper design, construction, and management are needed to create acceptable animal facilities.

Engineered control strategies for controlling airborne contaminants can be put into three categories source control, ventilation control, and removal control or air cleaning. Two other strategies include administrative control and personal protection. These later two strategies are typically used to control human exposure by limiting the time people are exposed to airborne contaminants (i.e., administratively adjusting work schedules) and by having people wear appropriate personal protection (i.e., filter masks to limit respiratory exposure to dust). Industrial hygienists generally prefer engineered strategies.

In general implementing engineered control practices increases production costs. Implementation often depends on the cost/benefit ratio. Costs include capital (i.e., initial purchase price) and operating costs (i.e., energy, labor, supplies, and maintenance). Effectiveness, dependability, and ease and amount of maintenance are also important considerations when evaluating air quality control options.

**Source Control:**

Sources of the airborne contaminants found in animal buildings include the building occupants (i.e. animals and humans), feed, manure, bedding/litter, insects, and any chemicals used for cleaning or other purposes. Source control can be fully or partially achieved by removing some or all sources. For example, outdoor manure storage is a way of removing the gases generated by microbial transformation of the manure stored in a deep pit below an animal building.

Source control can also be achieved by manipulating the source to minimize contaminant generation. Diet manipulation is an example. More information on diet manipulation for reducing gas emissions in presented in the Mitigation and Emission Control Technologies section of the GEIS Odor and Air Quality report. Fat and oil addition to a feed can be used to reduce dust generation (Chiba and others 1985;Wilson and others 1993;Chiba and others 1987;Gore and others 1986;Mankell and others 1995;Welford and others

1992;Wilson and others 1993;Chiba and others 1987;Gore and others 1986;Mankell and others 1995;Welford and others 1992).

Dust within an animal building can be reduced by using an enclosed feed delivery system, which will reduce the amount of dust discharged into the building (Feddes and Barber 1995). Feeding system alternatives (Bundy and T.E. Hazen 1975), such as using pelleted vs. ground feed, using wet vs. dry feeders, and even the use of liquid feeding have not all been extensively evaluated in regard to how they control dust levels in animal buildings (Pearson and Sharples 1995). Cleaning surfaces with accumulated dust on a weekly basis was suggested as an option, however labor requirements and limited overall benefit limited its adoption (Dawson 1990;Pedersen 1992;Pedersen 1992).

Oil sprinkling is another dust control practice. Vegetable oils and other materials can be sprayed onto floors to prevent settled dust from being re-entrained into the air by animal activity. The method effectively reduces airborne dust levels, with few apparent side effects (Mankell and others 1995;Takai and others 1995;Takai and others 1995). Takai et al. (Takai and others ) found that dust levels could be reduced from 60 to 80% when canola oil was sprayed daily with a high pressure dispensing system in a pig nursery building. They also found that little or no health problems existed with the pigs that were exposed to this oil treatment. Zhang et al. (Zhang and others 1996) showed a similar reduction of dust by simply spraying or sprinkling canola oil once a day with a hand-held sprayer in the pens of a pig-finishing barn. Jacobson et al. (Jacobson and others 1998) used this same oil sprinkling technology (Zhang ) to determine if lowering the dust generation also reduced odor emissions from a pig nursery barn. Somewhat mixed results were found as were some disadvantages to this practice, including worker safety issues (slippery floors) and more time needed to clean the room between groups.

Another example of source control is the application of chemical and biological additives to stored manure in an attempt to change manure characteristics or transformations to reduce contaminant emissions from sources. More information on these products is presented in the Mitigation and Emission Control Technologies section of the GEIS Odor and Air Quality report.

Moisture control is a commonly used source control strategy. Dry manure will generally produce less gaseous emission but drier manure and bedding/litter may increase dust generation. Moisture control can be achieved by removing wet litter from the building, avoiding water spillage, adding dry bedding, ventilation, and heating. Moisture control is commonly used in animal buildings.

**Air Cleaning:**

Indoor air cleaning can be accomplished a number of different ways including dry filtration, wet scrubbing, and electrostatic precipitation or ion generation. Information on these methods is provided in the Mitigation and Emission Control Technologies section of the GEIS Odor and Air Quality report.

**Ventilation:**

Ventilation brings relatively clean and dry outdoor air into a building, distributes and mixes the air inside the building where it picks up heat, moisture, and airborne contaminants before the air is exhausted.  Increasing air exchange theoretically should reduce indoor air contaminant concentrations.  Although increased ventilation is valid for some units, there are some situations (Jacobson and others 1996) when dust levels were actually increased by high ventilation rates because it lowered the air humidity levels, resulting in a higher dust generation rate.  Thus, ventilation or dilution of the air inside a building may have only a limited effect (Harry 1978) in controlling dust in an environment like an animal building with so many dusty surfaces and sources.

Studies have shown some benefits by manipulating the ventilating system. Robertson, (Robertson 1989) "purged" a pig building with a high volume of air exchange for a 10 minute period to expel dust (60 % dust reduction) which can be a useful management tool for workers.  Another study (van't Klooster and others 1993) modified the inlet system, in a standard negative pressure ventilation system, to bring in fresh air in the worker's zone and exhausted air underneath the slatted floor, resulting in a 40% reduction in dust exposure to the workers.

**Control of Microbial Concentrations and Emissions:**

There is little information available on strategies specifically designed to reduce airborne microbial concentrations and emissions.  Some strategies exist to reduce microbial loads in the sources (feed and litter) however, the research does not indicate if this would impact overall airborne microbial emissions.  Feed processing technologies such as expanders, pelleting, and extrusion reduce feed microbial load by applying heat and steam.  Litter treatment with compounds to reduce ammonia emission also may have an indirect effect on lowering litter microbes by lowering the pH  of the litter (Terzich 1998).

Other strategies help prevent disease introduction onto a farm include commonly recommended biosecurity practices such as, purchase disease free stock, clean and disinfect facilities and premises, sanitize the water, and isolation practices that prevent disease introduction and spread through a farm from workers, equipment, and other animals and pests.  These management techniques are usually directed toward specific poultry pathogens but have the affect of lowering numbers of microorganisms in between flocks.

Due to the association of microorganisms with dust, technologies and management schemes to reduce dust levels may also impact microbial emissions and disease spread. Such techniques might include fat addition to feed, and oiling the litter (Taschuk and others 1991;McGovern and others 1999;McGovern and others 1999).  Others would include management of ventilation rates, temperature and humidity.  In the winter season, reducing room temperature (adjusted for the comfort of the bird) has the effect of increasing ventilation rate and increasing humidity level which helps to suppress and reduce dust levels (Noll and others 1991).  Misting systems are used to cool and suppress dust however they may not decrease airborne microbial emissions.  Willis et al (Willis and others 1987) found that the combination of misting and evaporative cooling for dust

control improved broiler performance in comparison to control groups. However, the system also significantly increased airborne bacterial concentrations while decreasing dust level.

Some recent literature on negative air ionization in preventing transmission of some poultry diseases may have eventual application. In controlled environmental chambers, use of negative air ionizers decreased transmission of Newcastle disease and salmonella from infected birds to those kept in chambers without ionizers (Mitchell and King 1994;Gast and others 1999;Gast and others 1999).

## MAJOR RELEVANT ONGOING RESEARCH

There are major research and teaching programs that emphasize animal health at most of the land-grant veterinary colleges in the U.S. These programs vary in their species of emphasis and the scope of their programs. Veterinary colleges are charged with training the next generation of veterinarians to serve production agriculture and conducting research to determine treatment and management systems that will promote animal health. Typically, these veterinary programs do not compare and contrast animal health across production systems in favor of studying health management options within a production system. It is very difficult and expensive to study interactions of production system and animal health under controlled conditions. Consequently, veterinarians must rely heavily on observational data and professional experience to promote animal health across a variety of production systems and conditions.

Several universities in North America are studying production and management practices that promote animal well-being. Specifically related to well-being of pigs, active research and education programs are currently in place at: University of Illinois, Purdue University, Texas Tech University, and the Prairie Swine Center in Saskatchewan, Canada. Several universities in Europe are also engaged in similar research programs. Specific projects are too numerous and varied to detail in this summary report. A summary of cooperative Regional Research projects (within the CSREES-USDA) that specifically address animal health topics is provided (Table 1).

Additional governmental (Federal and Stae) efforts are also ongoing. A key effort related to this GEIS topic is that by the National Animal Health Monitoring System (NAHMS). NAHMS is conducting a study to assess animal health on feedlots. Staff from NAHMS met with the National Cattlemen's Beef Association (NCBA), the American Veterinary Consultants, university faculty feedlot personnel, and regulatory officials to prioritize information needs that could and should be addressed by the 1999 NAHMS study and to develop study objectives. Quality assurance and preharvest food safety remain among the top information needs. Product quality efforts will focus on injection routes and locations, implant strategies, and management practices that affect hide quality. Preharvest food safety efforts will focus on factors associated with pathogens such as Escherichia coli (E. coli 0157), Salmonella (salmonella typhimurium DT104), and Campylobacter. NAHMS will document patterns of pathogen shedding and evaluate factors that contribute to shedding. Management practices that could help producers decrease pathogen shedding will be assessed. The study will also identify which antimicrobials are in use and the extent of their use. The study will begin in August 1999. Additional information on this project is available at their website www.aphis.usda.gov/vs/ceah/cahm.

The Food and Drug Administration, Center for Veterinary Medicine is conducting a study of the microbiological hazards associated with the food production environment which includes animal feeds. These efforts are part of an overall effort intended to develop the means to identify and characterize foodborne hazards more rapidly and

accurately, to provide tools for regulatory enforcement and to develop interventions that can be used as appropriate to prevent hazards at each step from production to consumption.  The role of FDA/CVM in this effort relates to microbial hazards associated with preharvest phases of food animal production and includes aquaculture.

Table 1.  Regional Research projects (within CSREES-USDA) working on animal health topics.

| Kind of Animal | Project Number | Title |
| --- | --- | --- |
| All | S-261 | Interior environment and energy use in livestock facilities |
| All | S-274 | Integrated management of arthropod pests of livestock and poultry |
| All | W-102 | Integrated methods of parasite control for improved livestock production |
| Cattle, beef | NCR-87 | Beef cow-calf nutrition and management |
| Cattle, both | NC-107 | Bovine respiratory disease:  risk factors, pathogens, diagnosis and management |
| Cattle, dairy | NE-112 | Mastitis resistance to enhance dairy food safety |
| Cattle, dairy | S-284 | Genetic enhancement of health and survival for dairy cattle |
| Poultry | NCR-187 | Enteric diseases of poultry |
| Poultry | NCR-191 | Avian respiratory diseases:  pathogenesis, surveillance, diagnosis and control |
| Poultry | NE-127 | Biophysical models for poultry production systems |
| Poultry | NE-138 | Epidemiology and control of emerging strains of poultry respiratory disease agents |
| Poultry | NE-60 | Genetic bases for resistance and immunity to avian diseases |
| Sheep | NCR-190 | Increased efficiency in sheep production |
| Swine, cattle | NC-62 | Enteric diseases of swine and cattle:  prevention, control and food safety |

Animal Industries are actively involved in research to promote the continued assessment of factors affecting animal health and refinement of management practices to promote improved animal health.  This includes efforts by organizations such as the Minnesota Turkey Research and Promotion Council, the National Pork Producers Council, and the National Cattlemen's Beef Association.

## RECOMMENDATIONS FOR ADDITIONAL RESEARCH AND ANALYSES

Improvements in the methods to assess animal health and well-being are needed.  This has been evaluated and debated by many people for many years, and is unlikely to be resolved by short-term projects.  Despite our current knowledge, we seem to be unable to define clearly and specifically the criteria associated with "high health" status.  There seems to be no laboratory test or battery of tests that is universally agreed upon to accurately delineate the health status of a group of animals.  Veterinarians must use a combination of animal performance records, results of postmortem exams, mortality and morbidity rates, levels of antibodies to specific disease circulating in the animal's blood (titers), presence of infective organisms in the animal or its environment, and visual appraisal to assess the health status of a group of animals.  Research that can define these standards for producers and veterinarians would be of immense value to the livestock industry and consumers.  Unfortunately, this is not a goal that can be achieved in a short period of time and may, in fact, not be possible to achieve.  Comprehensive multi-disciplinary efforts will be certainly be required to develop such an indicator.  However, the potential value of achieving this goal and the knowledge gained in pursuit of this goal clearly justify the continuation of efforts in this area.

Another research area that deserves some attention relates to the impact of housing/production system on animal health and the general aspects of animal well-being.  There are plenty of anecdotal evidence and observations in the field concerning the benefits and problems with this or that housing/production system.  Unfortunately, very few of these are documented under controlled conditions.  Under field conditions, genetics of the animals, feeding systems, management approach, disease challenges, and other conditions vary from one production site to another making it very difficult if not impossible to accurately attribute differences in animal health specifically to the housing system.  This is a very difficult area of research that needs attention.  Such a research objective can most effectively be achieved by universities working in partnership with producers and private industry.

As stated throughout this report, even less is known about the more cognitive aspects of farm animal well-being.  Research efforts in this area are also ongoing and the information gained will increase our understanding of animal biology and environmental interactions.  However, these efforts represent a smaller component of the overall effort to assess animal health and general well-being.  Comprehensive efforts involving multiple disciplines are also required to achieve informative descriptions of animal well-being.  Defining well-being without a method to measure it is, of course, insufficient [Sandoe, 1996].  By the same token, taking something we can measure and deciding that it equates to well-being is ultimately unacceptable.  Saying "we do not really know if animals are well off in this situation," is fine; saying "they are well off" based on our current limited understanding and incomplete social examination is a mistake.

Clearly, more research is needed on the subject of how much agricultural animals suffer from various practices. The non-productivity measures we have available, even if accepted uncritically as useful, all require more research before we have precise measures of animals in different settings. Furthermore, some commentators contend that to truly understand what is good or bad for a given species, we need to draw upon "full, systematic observation of a zoologist prepared to be interested in a species for its own sake, not casually for purposes of exploitation" [Midgley, 1983 (38-9)].

Following from the discussion that acceptable levels of well-being are socially constructed, social science research is needed before we can draw conclusions about whether well-being is adequate. We need answers to such questions as "are animals being treated in ways that the people of Minnesota find acceptable?" and "how much are people willing to pay in higher food prices to provide certain amounts of well-being?" Such questions can be researched using methods that are discussed in the External Costs and Benefits report.

The approach used by NAHMS to assess animal health and well-being serves as a good model for efforts in these areas. For example, there are few empirical data available regarding prevalence of the different kinds of parasites among the different housing styles and farm sizes. Cattle and swine are at risk of being parasitized by a number of organisms and housing styles range from animals outside on soil to indoors on concrete. This risk of parasitization is true for every domestic species. Closed units have the potential to eradicate and exclude a number of organisms and this exclusion should benefit animal health. However, we do not know if this actually occurs nor do we know how well the different industries are capitalizing on this potential benefit. An interesting comparison would be to do parasite surveys among grazing and confined cattle or swine and at least stratified these comparisons by farm size. Mail or phone surveys of producers or clinicians would not be sufficient. Objective measures of parasite prevalence are needed.

This effort would involve a large amount of physical labor to collect, categorize and analyze samples from individual animals on individual farms and of actually production practices utilized at each farm. However, the cost-benefit ratio could be improved by expanding this effort to include a number of other important factors (such as those described in the first paragraph in this section) to assess overall animal health. During the on-site interview to assess production practices actually utilized, an assessment of the producers actual awareness of federal, state, and local regulations that govern their industry could be determined. A concurrent assessment of the actual or potential impact of these regulations on the industry could also be obtained. Results would provide an extensive knowledge of the prevalence of various diseases, infections and the causative organisms. Results would also greatly improve our understanding of this aspect of the agricultural animal industry and could provide a foundation for informed discussion by policy makers.

One of the most important recommendations we can make is to re-enforce efforts to increase public awareness of how, when, and where, their plant and animal foods are

produced. The proportion of society that has any direct connection with agriculture continues to increase. This growing separation between producers and consumers of food results in multiple misconceptions, confusion, and controversies. Support for educational efforts to facilitate a greater general understanding of animal agriculture and how it continues to change is warranted.

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