Chapter 3: Husbandry, Housing, and Biosecurity

Proper management is essential for the well-being of the animals, the validity and effectiveness of research and teaching activities, and the health and safety of animal care personnel. Sound animal husbandry programs provide systems of care that permit the animals to grow, mature, reproduce, and be healthy. Specific operating procedures depend on many factors that are unique to individual institutions. Well-trained and properly motivated personnel can often achieve high quality animal care with less than ideal physical plants and equipment.

FACILITIES AND ENVIRONMENT

Environmental Requirements and Stress

Domestic animals are relatively adaptable to a wide range of environments (Hale, 1969; Craig, 1981; Sossinka, 1982; Curtis, 1983; Price, 1984, 1987; Fraser, 1985; Yousef, 1985a,b,c). Domestication is a continuing process. Genetic strains of animals selected for growth or reproduction in different environments under varying degrees of control are used currently for much of the production of livestock and poultry (Siegel, 1995). These strains of animals are sometimes very different from the breeds or strains from which they were originally derived (Ollivier, 1988; Craig, 1994; Havenstein et al., 1994a,b). Agricultural animals may be kept in extensive environments (e.g., pasture or range) where they reside in large areas (e.g., acres or square miles) outdoors. They may also be kept in intensive environments (e.g., in houses, pens, or cages) where they are confined to an area that would not sustain them were the environment not controlled and where food, water, and other needs must be provided to them. Individual animals may be moved during their lives from extensive to intensive systems or vice versa. Species requirements for domesticated animals are thus variable and depend both on the genetic background of the animals and their prior experience.

Criteria of Well-Being

Various criteria have been proposed to identify inappropriate management and housing conditions for agricultural animals. For example, in poultry, significant feather loss that is not associated with natural mating or natural molting is widely accepted as an indication that birds are experiencing stressful conditions. More sophisticated measures of stress are not necessarily superior and may even yield confusing results and lead to inaccurate conclusions (Moberg, 1985; Rushen, 1991; Rodenburg and Koene, 2004). For instance, plasma corticosteroid concentrations of hens residing in spacious floor pens may be similar to those in high-density cages, even though other criteria may indicate that the caged hens are adversely affected by their environment (Craig and Craig, 1985; Craig et al., 1986). During stressful social situations, resistance to virus-induced diseases may be depressed, but resistance to bacterial infections and parasites may be increased (Siegel, 1980; Gross and Siegel, 1983, 1985).

Some researchers have placed emphasis on behavioral criteria of well-being (Wood-Gush et al., 1975), although others have pointed out the difficulties of interpretation involved (Duncan, 1981; Craig and Adams, 1984; Dawkins, 1990). In the same way, some researchers (Craig and Adams, 1984) have suggested that depressed performance of individuals, independent of economic considerations, is a relatively sensitive reflector of chronic stressors, but Hill (1983) was less convinced using the same parameters.

Animal well-being has both physical and psychological components (Fraser and Broom, 1990; Duncan, 1993; Fraser, 1993). No single objective measurement exists that can be used to evaluate the level of well-being associated with a particular system of agricultural animal production. There is consensus, however, that multiple integrated indicators provide the best means of assessing well-being (Curtis, 1982; Mench and van Tienhoven, 1986; Rushen and de Passillé, 1992; Mason and Mendl, 1993; Mitlöhner et al., 2001). Indicators in 4 categories are generally advocated: 1) behavior patterns; 2) pathological and immunological traits; 3) physiological and biochemical characteristics; and 4) reproductive and productive performance of the individual animal. A judgment as to the balance of evidence provided by these indicators has been used, when available, as the basis for the recommendations in this guide.

D. C. Hardwick postulated (cited in Duncan, 1978) and Duncan (1978) developed the idea that an acceptable level of animal welfare exists over a range of conditions provided by a variety of agricultural production systems, not under just one ideal set of circumstances. Improvements in certain environments may increase animal well-being somewhat, but any point in the range would still be considered acceptable with respect to animal welfare. Good management and a high standard of stockmanship are important in determining the acceptability of a particular production system (Hurnik, 1988) and should be emphasized in agricultural animal research and teaching facilities.

Macroenvironment and Microenvironment

Animal well-being is a function of many environmental variables, including physical surroundings, nutritional intake, and social and biological interactions (Hafez, 1968; Curtis, 1983; Yousef, 1985a). Environmental conditions should be such that stress, illness, mortality, injury, and behavioral problems are minimized. Particular components of the environment that need to be taken into account include temperature, humidity, light, air quality, space (including complexity of space), social interactions, microbe concentrations, noise, vermin and predators, nutritional factors, and water. See Chapter 4: Environmental Enrichment for further information

Physical conditions in the room, house, barn, or outside environment constitute the macroenvironment; the microenvironment includes the immediate physical and biological surroundings. Different microenvironments may exist within the same macroenvironment. Both microenvironment and macroenvironment should be appropriate for the genetic background and age of the animals and the purpose for which they are being used. Domestic animals readily adapt to a wide range of environments, but some genetic strains have specific needs of which the scientist should be aware and for which accommodation should be made.

Even in relatively moderate climatic regions, weather events such as floods, winter storms, and summer heat waves may require that animals have access to shelter. If trees or geographic features do not provide enough protection, artificial shelters and (or) windbreaks or sunshades should be provided (Mitlöhner et al., 2001, 2002; Johnson et al., 2008; Marcillac-Embertson et al., 2009).

Genetic Differences

Some strains of agricultural animals may have requirements that differ substantially from those of other stocks of the same species (Gross et al., 1984). Some strains of pigs, for example, are particularly susceptible to stress because they carry a gene that causes malignant hyperthermia when they experience even mild stress (Bäckström and Kauffman, 1995). Transgenic animals may also have special needs for husbandry and care (Mench, 1998). Practices to ensure the well-being of special strains should be established independently of those made for the species in general. Refer to Chapter 4: Environmental Enrichment for more detailed information on enhancement of animals' physical or social environments.

Space Requirements

Floor area is only one of the components that determine the space requirements of an animal. Enclosure shape, floor type, ceiling height, location and dimensions of feeders and waterers, features inside the enclosure, and other physical and social elements affect the amount of space sensed, perceived, and used by the animals in intensive management systems (Strickland et al., 1979; Strickland and Gonyou, 1995). When possible, animals in stanchions, cages, crates, or stalls should be allowed to view one another, animal care personnel, and other activities where this would not interfere with research or teaching objectives.

Determination of area requirements for domestic animals should be based on body size, head height, stage of life cycle, behavior, health, and weather conditions. All area recommendations in this guide refer to the animal zone (i.e., the space that can be used by the animal). Unless experimental or welfare considerations dictate otherwise, space should be sufficient for normal postural adjustments, including standing, lying, resting, self-grooming, eating, drinking, and eliminating feces and urine. When animals are crowded, body weight gain and other performance traits may be depressed (Gehlbach et al., 1966; Adams and Craig, 1985), and the animals may show altered levels of aggressive behavior (Bryant and Ewbank, 1974; Al-Rawi and Craig, 1975).

Temperature, Water Vapor Pressure, and Ventilation

Air temperature, water vapor pressure, and air velocity are some of the most important factors in the physical environment of agricultural animals. In addition, factors related to animal health (i.e., infectious status) and genetics (i.e., trangenic modification) affect the thermal balance of animals and thus their behavior, metabolism, and performance.

Most agricultural animals are quite adaptable to the wide range of thermal environments that are typically found in the natural outdoor surroundings of various climatic regions of the continental United States. The range of environmental temperatures over which animals use the minimum amount of metabolizable dietary energy to control body temperature is termed the thermoneutral zone (NRC, 1981; Curtis, 1983; Yousef, 1985a). Homeothermic metabolic responses are not needed within this zone. Temperature and vapor pressure ranges vary widely among geographic locations. The long-term well-being of an animal is not necessarily compromised each time it experiences cold or heat stress. However, the overall efficiency of metabolizable energy use for productive purposes is generally lower outside the thermoneutral zone than it is within the zone.

The preferred thermal conditions for agricultural animals lie within the range of nominal performance losses (Hahn, 1985). Actual effective environmental temperature may be temporarily cooler or warmer than the preferred temperature without compromising either the overall well-being or the productive efficiency of the animals (NRC, 1981). Evaluation of thermoregulation or of heat production, dissipation, and storage can serve as an indicator of well-being in relation to thermal environments (Hahn et al., 1992; Eigenberg et al., 1995; Mitloehner and Laube, 2003).

The thermal environment that animals actually experience (i.e., effective environmental temperature) represents the combined effects of several variables, including air temperature, vapor pressure, air speed, surrounding surface temperatures, insulative effects of the surroundings, and the age, sex, weight, infectious status, transgenic modification status, adaptation status, activity level, posture, stage of production, body condition, and dietary regimen of the animal.

To overcome shortcomings of using ambient temperature as the only indicator of animal comfort, thermal indices have been developed to better characterize the influence of multiple environmental variables on the animal. The temperature-humidity index (**THI**), first proposed by Thom (1959), has been extensively applied for moderate to hot conditions, even with recognized limitations related to airspeed and radiation heat loads (NOAA, 1976). At the present time, the THI has become the de facto standard for classifying thermal environments in many animal studies and selection of management practices during seasons other than winter (Hahn et al., 2003).

The THI has further been used as the basis for the Livestock Weather Safety Index (**LWSI**; LCI, 1970) to describe categories of heat stress associated with hot-weather conditions for livestock exposed to extreme conditions. Categories in the LWSI are alert ($74 < \text{THI} < 79$), danger ($79 \leq \text{THI} < 84$), and emergency ($\text{THI} \geq 84$). Additionally, THI between 70 and 74 is an indication to producers that they need to be aware that the potential for heat stress in livestock exists.

The index {wind chill temperature index (°C) = 13.12 + (0.6215 × AT) − [11.37 × (WSPD)0.16] + [0.3965 × AT × (WSPD)0.16]}, where AT = air temperature, °C, and WSPD = wind speed, m/s, is a physiological based model and accounts for inherent errors in the earlier wind chill index (**WCI**), which was not based on heat transfer properties of body tissues. However, the old WCI closely mimicked heat loss and equivalent temperature equations reported by Ames and Insley (1975) for sheep and cattle. Equations developed by Ames and Insley (1975) accounted for heat transfer through pelts and hides sections of previously harvested animals; however, they did not account for fat cover and other regulatory processes utilized in mitigating cold stress. In addition, body heat loss due to wind will be proportional to the surface area exposed and not the entire surface area of the body. This error was also inherent in the old WCI.

A ventilation system removes heat, water vapor, and air pollutants from an enclosed animal facility (i.e., a facility in which air enters and leaves only through openings that are designed expressly for those purposes) at the same time that it introduces fresh air. Adequate ventilation is a major consideration in prevention of respiratory and other diseases. Where temperature control is critical, cooling or heating may be required to supplement the ventilation system. For certain research projects, filtration or air conditioning may be needed as well.

Typically, ventilation is the primary means of maintaining the desired air temperature and water vapor pressure conditions in the animal microenvironment. The amount of ventilation needed depends on the size, number, type, age, and dietary regimen of the animals, the waste management system, and atmospheric conditions. Equipment and husbandry practices that affect heat and water vapor loads inside the animal house also should be considered in the design and operation of the ventilation system.

Ventilation rates in enclosed facilities (MWPS, 1989, 1990a,b) should increase from a cold-season minimum (to remove water vapor, contaminants, and odors as well as modify inside temperature) to a hot-season maximum (usually around 10 times the minimum rate, to limit the increase in temperature inside the house that is due to the solar radiation load and sensible animal heat). It is important to recognize the approximately 10-fold increase in ventilation rate from winter to summer that is required in a typical livestock or poultry house. Because the animals themselves are the major source of water vapor, heat, and (indirectly) odorous matter, ventilation rate calculated on the basis of animal mass is more accurate than that based on air-exchange rate guidelines.

Relative humidity is ordinarily the parameter used to manage the air moisture content. Hot weather ventilation rates should be sufficiently high to maintain the relative humidity below 80% in an enclosed animal house (Curtis, 1983; Hinkle and Strombaugh, 1983) except for situations in which high relative humidity does not cause animal health concerns. Conversely, ventilation rate during cold weather should be sufficiently low to ensure that the relative humidity does not fall to a level that causes animal health concerns, unless needs for air quality or condensation control necessitate a higher rate. Atmospheric humidity does not ordinarily become a significant factor in effective environmental temperature until the air temperature approaches the temperature of the animal's surface, in which case the animal will depend almost entirely on evaporative heat loss to maintain thermal equilibrium with the environment.

The use of fans to promote air movement can be beneficial during hot weather if there is too little natural air movement. Direct wetting is effective in decreasing heat stress on cattle and pigs; however, it can cause the death of poultry. Wetting is best accomplished by water sprinkled or dripped directly on the animals. Misters and evaporative coolers specifically designed to reduce air dry-bulb temperature are also used to reduce heat stress on agricultural animals.

Correctly designed and maintained sunshades protect animals from heat stress by reducing solar radiation load. Trees, if available, are ideal sunshades. Artificial, roofed shades are acceptable.

Mechanical ventilation requires proper design and operation of both air inlets and fans for proper distribution and mixing of the air and thus for creating uniform conditions throughout the animal living space. Mechanical ventilation, with fans creating static pressure differences between inside and outside the house, brings in fresh air and exhausts air that has picked up heat, water vapor, and air pollutants while passing through the building. Mechanical ventilation, if properly designed, provides better control of air exchange for enclosed, insulated animal houses in colder climates than does natural ventilation. The effectiveness of natural ventilation in cold climates will depend on the design and orientation of the enclosure, as well as the species and number of animals housed and the stage of their life cycle.

Natural ventilation uses thermal buoyancy and wind currents to vent air through openings in outside walls or at the ridge of the building. Natural ventilation is especially effective for cold animal houses (i.e., houses in which no heat is supplied in addition to animal heat) in moderate climates; however, insulated walls, ceilings, and floors are often recommended to minimize condensation. The air exchange rate needed to remove the water vapor generated by animals and evaporation of water from environmental surfaces often brings air temperature inside such houses down to values near those outdoors. If waterers and water pipes are protected from freezing, the practical low operating temperature is the point at which manure freezes, although this temperature would be too cold for some species or stages of the life cycle. Automatic curtains or vent panels, insulated ceilings, and circulating fans help to regulate and enhance natural ventilation systems.

During cold weather, ventilation in houses for neonatal animals should maintain acceptable air quality in terms of water vapor and other pollutants without chilling the animals. Air speed should be less than 0.25 m/s (50 ft/min) past very young animals. There should be no drafts on young poultry or pigs.

During hot, warm, or cool atmospheric conditions, ventilation of animal houses should maintain the thermal comfort of the animal to the extent possible. Ideally, the ventilation rate should be high enough to prevent indoor temperature from exceeding outdoor temperature (temperature rise limit; Curtis, 1983) by more than 3°C (5°F) when the atmospheric temperature is above 32°C (90°F) for small animals and above 25°C (78°F) for larger ones. In arid and semi-arid regions where the potential for evaporative heat loss is great, air temperature may peak at over 43°C (110°F) for 1 or 2 d or longer without affecting animal well-being if animals have been acclimatized by chronic exposure.

Ventilation system design should be based on building construction and the rates of water vapor and heat production of the animals housed (Curtis, 1983; Hinkle and Strombaugh, 1983). The frame of reference is the animal microenvironment. For example, the outdoor calf hutch is a popular accommodation for dairy replacement heifer calves in most parts of the continental United States. Although the hutch provides a cold microenvironment for calves during winter in northern latitudes, the calf is nonetheless comfortable if cared for correctly (MWPS, 1995). In closed houses during hot periods, additional ventilation capacity (up to 60 or more air changes/hour) may be necessary.

In enclosed animal houses, both environmental temperature and air quality depend on the continuous functioning of the ventilation system. An automatic warning system is desirable to alert animal care and security personnel to power failures and out-of-tolerance environmental conditions (Clark and Hahn, 1971), and consideration should be given to having an on-site generator for emergency use.

The relative air pressures between animal areas and service areas of a building housing animals should be considered when the ventilation system is designed to minimize the introduction of airborne disease agents or air pollutants into the service area. Advice of a qualified agricultural engineer or other specialist should be sought for the design of and operating recommendations for ventilation equipment.

Air Quality

Air quality refers to the nature of the air with respect to its effects on the health and well-being of animals and the humans who work with them. Air quality is typically defined in terms of the air content of certain gases, particulates, and liquid aerosols, including those carrying microbes of various sorts.

Good ventilation, waste management, and husbandry usually result in acceptable air quality. Ammonia, hydrogen sulfide, carbon monoxide, and methane are the pollutant gases of most concern in animal facilities (Curtis, 1986). In addition, OSHA (1995) has established allowable exposure levels for human workers with 8 h of exposure daily to these gases. The concentration of ammonia to which animals are exposed ideally should be less than 10 ppm and should not exceed 25 ppm, but a temporary excess should not adversely affect animal health (Von Borell et al., 2007). Comparable concentrations for hydrogen sulfide are 10 and 50 ppm, respectively. The concentration of carbon monoxide (arising from unvented heaters) in the air breathed by animals should not exceed 150 ppm, and methane (which is explosive at certain concentrations in air) should not exceed 50,000 ppm. Special ventilation is required when underfloor waste pits are emptied because of the potentially lethal hazards to animals and humans from the hydrogen sulfide and methane gases that are released.

Many factors affect airborne dust concentration, including relative humidity, animal activity, air velocity, and type of feed. Dust concentration is lower at higher relative humidities. High animal activity and air velocities stir up more particles and keep them suspended longer. Fat or oil added to feed reduces dust generation (Chiba et al., 1985). Microbes and pollutant gases may attach to airborne dust particles.

The allowable dust levels specified by OSHA (1995) are based on exposure of human workers for 8 h daily without facemasks; allowable dust levels are 5 mg/m3 for respirable dust (particle size of 5 μm or less) and 15 mg/m3 for total dust. Although animals can tolerate higher levels of inert dust with no discernible detriment to their health or well-being (Curtis and Drummond, 1982), the concentration of dust in animal house air should be minimized.

Concentrations of microbes in the air should be minimized. Dust and vapor pressure should be controlled. The ventilation system should preclude the mixing of air from infected microenvironments with that from microenvironments of uninfected animals.

Lighting

Lighting should be diffused evenly throughout an animal facility. Illumination should be sufficient to aid in maintaining good husbandry practices and to allow adequate inspection of animals, maintenance of the well-being of the animals, and safe working conditions for personnel. Guidelines are available for lighting systems in animal facilities (MWPS, 1987b).

Although successful light management schemes are used routinely in various animal industries to support reproductive and productive performance, precise lighting requirements for the maintenance of good health and physiological stability are not known for most animals. However, animals should be provided with both light and dark periods during a 24-h cycle unless the protocol requires otherwise. See Chapters 6 through 11 for references on lighting and photoperiod in individual species. Red or dim light may be used if necessary to control vices such as feather-pecking in poultry and tail-biting in livestock.

Provision of variable-intensity controls and regular maintenance of light fixtures helps to ensure light intensities that are consistent with energy conservation and the needs of animals (as they are understood), as well as providing adequate illumination for personnel working in animal rooms. A time-controlled lighting system may be desirable or necessary to provide a diurnal lighting cycle. Timers should be checked periodically to ensure their proper operation.

Excreta Management and Sanitation

A complete excreta management system is necessary for any intensive animal facility. The goals of this system are as follows:

- To maintain acceptable levels of worker health and animal health and production through clean facilities;
- To prevent pollution of water, soil, and air;
- To minimize generation of odors and dust;
- To minimize vermin and parasites;
- To meet sanitary inspection requirements; and
- To comply with local, state, and federal laws, regulations, and policies.

The planning and design of livestock excreta management facilities and equipment are discussed by MWPS (1993).

A plan should be followed to ensure that the animals are kept reasonably dry and clean and are provided with comfortable, healthful surroundings. Good sanitation is essential in intensive animal facilities, and principles of good sanitation should be understood by animal care personnel and professional staff. Different levels of sanitation may be appropriate under different circumstances, depending on whether manure packs, pits, outdoor mounds, dirt floors, or other types of excreta management and housing systems are being used. In some instances, animals may be intentionally exposed to excreta to enhance immunity. A written plan should be developed and implemented for the sanitation of each facility housing agricultural animals. Building interiors, corridors, storage spaces, anterooms, and other areas should be cleaned regularly and disinfected appropriately.

Waste containers should be emptied frequently, and implements should be cleaned frequently. It is good practice to use disposable liners and to wash containers regularly.

Animals can harbor microbes that can be pathogenic to humans and other species. Hence, manure should be removed regularly unless a deep litter system or a built-up manure pack is being employed, and there should be a practical program of effective disinfection to minimize pathogens in the environment.

For terminal cleaning, all organic debris should be removed from equipment and from floor, wall, and ceiling surfaces. If sanitation depends on heat for effectiveness, the cleaning equipment should be able to supply water that is at least 82°C (180°F). When chemical disinfection is used, the temperature of wash water may be cooler. If no machine is available, surfaces and equipment may be washed by hand with appropriate detergents and disinfectants and with vigorous scrubbing.

Health and performance of animals can be affected by the time interval between successive occupations of intensive facilities. Complete disinfection of such quarters during the unoccupied phase of an all-in, all-out regimen of facility management is effective for disease management in some situations.

Programs of pasture-to-crop rotation for periodically resting the pasture and programs that permit grazing by other animal species can aid in the control of soil-borne diseases and parasites. Spreading of manure on pastures as fertilizer is a sound and acceptable management practice but may spread toxic agents and infectious pathogens (Wray and Sojka, 1977). Caution should be exercised with manure of animals infected with known pathogens, and other methods of waste disposal should be considered.

Animal health programs should stipulate storage, handling, and use criteria for chemicals designed to inactivate infectious microbes and parasites. There should be information about prevention, immunization, treatment, and testing procedures for specific infectious diseases endemic in the region.

Where serious pathogens have been identified, the immediate environment may need to be disinfected as part of a preventive program. Elimination of moist and muddy areas in pastures may not be possible, but prolonged destocking is an available option. Drylot facilities may need to be scraped and refilled with uncontaminated materials. Thorough cleaning of animal housing facilities may be followed by disinfection. Selection of disinfection agents should be based on knowledge of potential pathogens and their susceptibilities to the respective agents (Meyerholz and Gaskin, 1981a,b).

Some means for sterilizing equipment and supplies (e.g., an autoclave or gas sterilizer) is essential when certain pathogenic microbes are present and for some specialized facilities and animal colonies. Except in special cases (e.g., specific-pathogen-free animals), routine sterilization of equipment, feed, and bedding is not necessary if clean materials from reliable sources are used. In areas where hazardous biological, chemical, or physical agents are being used, a system for monitoring equipment should be implemented.

FEED AND WATER

Animals must be provided with feed and water in a consistent manner, on a regular schedule, in accordance with the requirements established for each species by the NRC (1985, 1988, 1994, 2001, 2007) and as recommended for the geographic area. When exceptions are required by an experimental or instructional protocol, these must be justified in the protocol and may require approval by the Institutional Animal Care and Use Committee (**IACUC**). Feeders and waterers must be designed and situated to allow easy access without undue competition (NRAES, 1990; Lacy, 1995; Pirkelmann, 1995; Taylor, 1995).

Sufficient water must be available to meet the animals' daily needs under all environmental conditions. Water troughs, bowls, or other delivery devices must be cleaned as needed to ensure adequate intake and to prevent transmission of microbial- or contaminant-associated disease. Non-municipal water sources should be periodically tested for quality by an approved agency or laboratory.

Large supplies of feed should be stored in appropriate, designated areas (MWPS, 1987a). Bulk feed storage containers and feed barrels must be well maintained and the lids kept securely in place to prevent entry of pests, water contamination, and microbial growth. Containers should be cleaned as needed to ensure feed quality. The area around the containers such as the auger boot area should be cleaned regularly. Feed in sacks should be stored off the floor on pallets or racks, and each sack should be labeled with the contents and manufacture date or use-by date. All feedstuffs should be maintained in such a manner as to prevent contamination by chemicals and/or pests. For example, open feed sacks should be stored in closed containers, and mixing devices and utensils, feed delivery equipment, and feeders/feeding sites should be cleaned regularly to ensure adequate feed intake and prevent transmission of microbial- or contaminant-associated disease. Feed placed in carts or in other delivery devices should be fed promptly or covered to avoid attracting pests. An effective program of vermin control should be instituted in feed storage areas. Animal care personnel should routinely inspect feed to identify gross abnormalities such as mold, foreign bodies, or feces; such feed should not be fed until the abnormal components are removed or the feed is determined to be safe. Toxic compounds (Osweiler, 1985) should be stored in a designated area away from feed and animals to avoid accidental consumption.

Social Environment

Agricultural animals are social by nature and social isolation is a stressor (Gross and Siegel, 1981; Marsden and Wood-Gush, 1986). Agricultural animals that normally live in herds or flocks under natural conditions that are used in research and teaching should be housed in pairs or groups when possible. Considerations involved in implementing social housing for agricultural animals are discussed by Mench et al. (1992). If social housing is not feasible because of experimental protocols or because of unpreventable injurious aggression among group members, singly housed animals should be provided with some degree of visual, auditory, and (or) olfactory contact with other members of their species. Socialization to humans and regular positive human contact is also beneficial (Gross and Siegel, 1982; Hemsworth et al., 1986, 1993). In some instances, one species can be used as a companion for another species (e.g., goats and horses; Gross and Siegel, 1982; Hemsworth et al., 1986, 1993). Temporary isolation is sometimes required for an animal's safety (e.g., during recovery from surgery), but the animal should be returned to a social setting as soon as possible.

Separation by Species

Agricultural animals of different species are typically kept in different enclosures to reduce interspecies conflict, meet the husbandry and environmental needs of the animals, and facilitate research and teaching. However, some research protocols or curricula require species to be co-housed. Facility design and husbandry practices influence whether this can be accomplished in a manner that assures the well-being of the animals. Mixing of compatible species (e.g., sheep and cattle) can often be accomplished more easily in extensive production situations than in intensive housing situations. Some species can carry subclinical or latent infections that can be transmitted to other species that are housed in close proximity, causing clinical disease or mortality. Therefore, a qualified veterinarian or scientist should recommend appropriate health and biosecurity practices if species are to be co-housed.

Separation by Source or Age

Animals obtained from different sources often differ in microbiological status. It is usually desirable to keep these animals separated, at least until microbiologic status is determined (e.g., serologic testing, microbiologic culture, fecal flotation) or steps (e.g., vaccination, deworming, treatment, culling) are taken to protect against disease transmission. Separation of animals of different ages may also be advisable to reduce disease transmission and control social interactions. Placing animals in groups of similar age or size may allow more uniform access to feed and reduce injuries. All-in, all-out schemes are examples of age-group separation that are designed to minimize disease risk. However, mixed-group housing is acceptable if disease risk is low, husbandry practices are good, and social interaction is acceptable or necessary (e.g., calves nursing cows). A qualified veterinarian and animal facility manager should work together to devise housing configurations and husbandry practices that assure animal health and well-being while also meeting research and (or) teaching goals.

HUSBANDRY

Animal Care Personnel

The principal scientist or animal management supervisor should make all animal care personnel aware of their responsibilities during both normal work hours and emergencies. A program of special husbandry procedures in case of an emergency should be developed.

It is the reserach facility management's responsibility to ensure that personnel caring for agricultural animals used for research or teaching are appropriately qualified or trained. This responsibility may be delegated to an IACUC. Qualification by experience and (or) training must be documented. The animal facility manager must ensure that all animal care personnel are aware of their responsibilities during and outside normal work hours. Protocols for emergency care must be developed and made available to all personnel.

Observation

Animals in intensive accommodations should be observed and cared for daily by trained and experienced caretakers. Illumination must be adequate to facilitate inspection. In some circumstances, more frequent observation or care may be needed (e.g., during parturition, postsurgical recovery, confinement in a metabolism stall, or recovery from illness). Under extensive conditions, such as range or pasture, observations should be frequent enough to detect illness or injury in a timely fashion, recognize the need for emergency action, and ensure adequate availability of feed and water. A disaster plan must be developed for observing animals and providing care during emergency weather or health situations. Regardless of accommodations, animal observations should be documented and husbandry or health concerns reported to the animal facility manager or attending veterinarian as appropriate.

Emergency, Weekend, and Holiday Care

There must be a means for rapid communication in case of an emergency. In emergencies, facility security and fire personnel must be able to contact staff members responsible for the care of agricultural animals. Names and contact information for those individuals should be posted prominently in the animal facility and provided to the security department or telephone center. If posting names and contact information poses privacy or security issues, a contact number for a security or command center should be used instead. The institution must ensure that emergency services can be contacted at any time by staff members.

The institution must assure continuity of daily animal care, to encompass weekends, holidays, unexpected absences of assigned personnel, and emergency situations. Staff assigned to weekends and holidays must be qualified to perform assigned duties. Cross-training of staff and establishment of standard operating procedures is encouraged to assure consistent, high-quality care. Emergency veterinary care must be readily available after daily work hours, on weekends, and on holidays.

In the event that weather conditions or natural disasters make feeding temporarily impossible, every attempt should be made to provide animals with a continuous supply of water. Absence of feed for up to 48 h should not seriously endanger the health of normal, well-nourished juvenile or adult cattle, sheep, goats, horses, poultry, or swine. Feed should be provided within 24 h to very young animals that are not nursing their dams.

Emergency Plans

A site-specific emergency plan must be developed to care for agricultural animals that are used for research and teaching. The goal for a plan should be to provide proper management and care for the animals regardless of the conditions. However, some conditions may be so unusual and extreme that it will not be possible to provide immediate care for the animals and to simultaneously ensure employee safety. Thus, emergency plans should define proper animal management and care and parameters to ensure employee safety.

Emergency plans should name employees or positions that are considered essential for providing proper animal management and care. Those employees should a priori understand that responding to emergencies is a condition of employment and that they will be held accountable should they fail to care properly for the animals. Plans should focus on emergencies that are most likely to occur in the specific geographic area or the research or teaching facility (e.g., heavy snow, blizzard, ice, high wind, tornado, hurricane, fire, flood, breach of physical security that disrupts care, and breach of biosecurity that threatens the animals). Emergency plans should include animal evacuation plans specific to the research or teaching facility and actions to be taken if transportation is interrupted.

Animal Identification and Records

Animals should be permanently identified by a method that can be easily read. Identification of individual animals is desirable, but, in some circumstances, it is acceptable to identify animals by group, cage, or pen. Individual birds may be wing-banded or leg-banded. Ear-notching, ear tattooing, electronic transponders, and branding may be used for individual identification of other species, and each has its advantages and disadvantages. Ear notches and tattoos are permanent and effective, but notching constitutes elective surgery and tattoos generally cannot be read without restraining animals. Electronic transponders require special sensor units or stations, but should be considered when possible. Cattle and horses are most consistently identified using freeze-branding on the hip, shoulder, rear leg, or side. In addition, when freeze branding is used on more than one breed of horse, branding is performed under the mane. Some states require that cattle be permanently identified by branding with a hot iron; however, this procedure is more stressful than freeze-branding (Lay et al., 1992). Ear and neck chain tags, although readable at some distance, can become lost and are therefore not necessarily permanent. In addition, neck chains and straps should be avoided in situations in which the animal could become entangled in a fence, rock outcropping, or other feature of the environment. Any associated pain and distress should be considered when determining the method of identification. In some cases, it may be necessary to identify animals in multiple ways (e.g., as a transgenic animal and by individual identification).

Individual records are needed for most animals. These records should include information about the animal (e.g., birth date, sex, pedigree), its source and location, its productivity (e.g., body weight, milk or egg production, milk composition on specific dates), its reproductive performance (e.g., breeding and birthing dates, young produced, semen collection dates), protocols the animal is assigned to, and its ultimate disposition. Records for individual animals or groups should also include dates of vaccination, parasite control measures used, blood testing dates and results, and notations as to whether castration, spaying, or other elective procedures have been performed. Applicable veterinary data to be recorded include dates of examination/treatment, clinical information/diagnosis, names of medications and amounts and routes of administration, descriptions of surgical procedures, and resolution of surgical procedures or illnesses. Principal scientists or animal facility managers may wish to record nutritional information. Research protocols often dictate that additional information be recorded. Refer to Chapters 6 to 11 for species-level information on species-specific identification and record keeping.

Vermin Control

Programs should be instituted to control infestation of animal facilities by vermin (e.g., flies, mosquitoes, lice, mites, ticks, grubs, rodents, skunks, and pest birds such as starlings, pigeons, and sparrows). The most effective control in facilities prevents entry of vermin into the facility by screening openings and ceilings; sealing cracks; eliminating vermin breeding, roosting, and refuge sites; and limiting access of vermin to feed supplies and water sources. Building openings should be screened with 1.3-cm (0.5-in) mesh, and ceilings with ridge vents should be screened with 1.9-cm (0.75-in) mesh to minimize rodent and bird entry. Smaller mesh sizes are recommended where they will not interfere with airflow. Mesh may need to be installed along foundations below ground level, especially with wood foundations.

Pesticides should be used only as approved (Hodgson, 1980). Particular caution should be exercised with respect to residues in feedstuffs, which could injure animals and (or) eventually pass into the meat, milk, or eggs (Willett et al., 1981). Pesticides should be used in or around animal facilities only when necessary, only with the approval of the scientist whose animals will be exposed to them, and with special care. A pesticide applicator or a commercial service may be used.

In some regions, wildlife (e.g., skunks, raccoons, and foxes) and stray cats and dogs may spread zoonotic diseases, including rabies, to agricultural animals. In high-risk locations, institutions should implement an educational program that includes training scientific and animal care personnel to recognize the signs of rabies in both wildlife and agricultural species and to handle and report potentially rabid animals. Inoculation may be advisable for humans who may come into contact with animals in regions where rabies is endemic.

Many agricultural institutions keep cats for pest-control purposes. Although the use of free-roaming cats is a traditional form of pest control for agricultural facilities, cats may limit the ability for baiting and may present hygiene or accident risks or serve as disease vectors (Van't Woudt, 1990; Van Sambeek et al., 1995; Vantassel et al., 2005). However, when cats are present, proper veterinary care and oversight should be provided to these animals. Veterinary care should include vaccinations, parasite control, and neutering.

STANDARD AGRICULTURAL PRACTICES

Sometimes procedures that result in temporary distress and even some pain are necessary to sustain the long-term welfare of animals or their handlers. These practices include (but are not limited to) comb-, toe-, and beak-trimming of chickens; bill-trimming of ducks; toenail removal, beak-trimming, and snood removal of turkeys; dehorning and hoof-trimming of cattle; tail-docking and shearing of sheep; tail-docking, neonatal teeth-clipping, hoof-trimming, and tusk-cutting of swine; and castration of males and spaying of females in some species. Some of these procedures reduce injuries to humans and other animals (e.g., cannibalism, tail-biting, and goring). Castration, for example, reduces the chances of aggression against other animals. Bulls and boars also cause many serious injuries to humans (Hanford and Fletcher, 1983). Standard agricultural practices that are likely to cause pain should be reviewed and approved by the IACUC. Recommendations regarding these practices for the different species are found in Chapters 6 through 11. The development and implementation of alternative procedures less likely to cause pain or distress are encouraged. Overall, best practices for pain prevention and control should be followed.

Sick, Injured, and Dead Animals

Sick and injured animals should be segregated from the main group when feasible, observed thoroughly at least once daily, and provided veterinary care as appropriate. Incurably ill or injured animals in chronic pain or distress should be humanely killed (see Chapter 2 and Chapters 6 through 11) as soon as they are diagnosed as such. Dead animals are potential sources of infection. Their disposal should be accomplished promptly by a commercial rendering service or other appropriate means (e.g., burial, composting, or incineration) and according to applicable ordinances and regulations. Postmortem examination of fresh or well-preserved animals may provide important animal health information and aid in preventing further losses. When warranted and feasible, waste and bedding that have been removed from facilities occupied by an animal that has died should be moved to an area that is inaccessible to other animals. More information regarding sick, injured, and dead animals is available in Chapter 2: Agricultural Animal Health Care.

HANDLING AND TRANSPORT

Additional details on the handling, restraint, and transportation of animals are given in Chapter 5: Animal Handling and Transport.

SPECIAL CONSIDERATIONS

Noise

Noise from animals and animal care activities is inherent in the operation of any animal facility. Although differences exist in perceived loudness of the same sound (Algers et al., 1978a,b), occupational noise limitations have been established for workers, and employees should be provided appropriate hearing protection and monitored for their effects (Mitloehner and Calvo, 2008).

Noise ordinarily experienced in agricultural facilities generally appears to have little permanent effect on the performance of agricultural animals (Bond, 1970; NRC, 1970), although Algers and Jensen (1985, 1991) found that continuous fan noise disrupted suckling of pigs. Sudden loud noises have also been reported to cause hysteria in various strains of chickens (Mills and Faure, 1990).

Metabolism Stalls and Other Intensive Procedures

Animals that are subjected to intensive procedures requiring prolonged restraint, frequent sampling, or other procedures experience less stress if they are trained to cooperate voluntarily with the procedure. Cattle, pigs, and other animals can be trained with food rewards to accept and cooperate with various procedures, such as jugular venipuncture (Panepinto, 1983; Calle and Bornmann, 1988; Grandin, 1989; Grandin et al., 1995).

Many studies of the nutrition and physiology of agricultural animals use a specialized piece of equipment, the metabolism stall. Successful designs have been reported for various species (Mayo, 1961; Welch, 1964; Baker et al., 1967; Stillions and Nelson, 1968; Wooden et al., 1970). These stalls give animal research and care personnel easy access to the animal and its excreta.

The degree of restraint of animals housed in metabolism stalls is substantially different from that of other methods that restrict mobility (e.g., stanchions and tethering). Animals in metabolism stalls are often held by a head gate or neck tether and are restricted in their lateral and longitudinal mobility. These differences may exacerbate the effects of restriction on animals housed in metabolism stalls (Bowers et al., 1993). Metabolism stalls should be used only for approved studies, not for the purpose of routine housing. Researchers should consider appropriate alternatives to metabolism stalls (such as determination of digestibility by marker methods) if such alternatives are available.

There should be a sufficient preconditioning period to ensure adequate adjustment and comfort of the animal to the metabolism stall before sample collection starts. The length of the preconditioning period should be subject to approval of the IACUC. At least enough space should be provided in the metabolism stall for the animal to rise and lie down normally. When possible, metabolism stalls should be positioned so that the animal is in visual, auditory, and olfactory contact with conspecific animals to minimize the effects of social isolation.

Thermal requirements of animals may be affected when they are placed in metabolism stalls. For example, the lower critical environmental temperature of an animal held individually in a metabolism stall is higher than when residing in a group because the single animal cannot obtain the heat-conserving benefits of huddling with group-mates.

Animals in metabolism stalls should be observed more frequently than those in other environments, and particular attention should be paid to changes in behavior and appetite and the condition of skin, feet, and legs. The length of time an animal may remain in a metabolism stall before removal for exercise should be based on professional judgment and experience and be subject to approval by the IACUC. The species and the degree of restraint imposed by particular stall types should be taken into consideration in making such judgments. Recommendations for particular species can be found in the appropriate chapters of this guide.

BIOSECURITY

The term biosecurity in an agricultural setting has historically been defined as the security measures taken to prevent the unintentional transfer of pathogenic organisms and subsequent infection of production animals by humans, vermin, or other means (i.e., bioexclusion). Biosecurity is also applied in the same context to agricultural animals used in the field of agricultural research, teaching, and testing. With the advent of bioterrorism and the designation of select agents, the term biosecurity has acquired new definitions, depending on the field to which it is applied. Biosecurity is now used to define national and local policies and procedures that address the protection of food and water supplies from intentional contamination and is additionally used to define measures required to maintain security and accountability of select agents and toxins. It is important to understand these concepts when using the term and to clarify that in this section we are using the term biosecurity in the context of preventing the unintentional transfer of pathogens to animals and humans through appropriate facility design, training, and precautions (i.e., immunizations). For example, personnel working in swine and poultry facilities should be immunized against influenza and receive training related to potential cross-contamination of agents between animals and humans. The USDA has published voluntary guidelines and a checklist as a resource to help the agricultural producer reduce security risks at the farm level (USDA, 2006). This publication is designed to prevent both intentional and unintentional introduction of pathogens at the farm level. A list of references and resources is also provided in this document on a variety of farm biosecurity issues. Other sources of information include reviews of biosecurity basics and good management practices for preventing infectious diseases and biosecurity of feedstuffs (Buhman et al., 2000; BAMN, 2001). All of these publications offer information and suggestions that could be evaluated for their impact on the design of an animal facility.

It is essential that the agricultural animal care staff maintain a high standard of biosecurity to protect the animals from pathogenic organisms that can be transferred by humans. Good biosecurity begins with personal cleanliness. Showering or washing facilities and supplies should be provided, and personnel should change their clothing as often as necessary to maintain personal hygiene. Disposable gear such as gloves, masks, coats, coveralls, and shoe covers may be required under some circumstances. Personnel should not leave the work place in protective clothing that has been worn while working with animals. Personnel should not be permitted to eat, drink, apply cosmetics, or use tobacco in animal facilities. Visitors should be limited as appropriate, and institutions should implement appropriate precautions to protect the safety and well-being of the visitors and the animals.

Preventing the introduction of disease agents is a continuous challenge, particularly when teaching and research facilities allow public access. Herd health and sanitation programs should be in place to minimize exposure to pathogens.

Animal care personnel in research and teaching facilities should not be in contact with livestock elsewhere unless strict biosecurity precautions are followed. To reduce inter-building transmission of pathogenic microorganisms, careful attention should be given to traffic patterns of inter-building personnel and disease organisms in feed and transport vehicles. Barriers to microorganism transmission should be considered for personnel who move between houses, including showering in, changing clothes, and the use of disinfectant footbaths as personnel move between rooms and buildings. Establishing a barrier between animals and visitors requires visitors to do some or all of the following: shower in/shower out (including washing hair), wear clean footwear (i.e., plastic boots), change to on-site clothes, and wear only on-site clothes. In addition, if personnel need to go back and forth between different phases of production, it is critical that they work from clean to dirty phases of the farm.

Boot Cleaning and Disinfection

The use of boot baths can prevent or minimize mechanical transmission of pathogens among groups of pigs. Visible organic material may be removed from boots using water and a brush or specific boot cleaning station. Boots may be disinfected by soaking in a clean bath of an appropriate disinfectant following the manufacturer's guidelines for dilution rate and exposure time. Personnel should step into and scrub their boots in the boot bath upon entry and when leaving the room/facility. It is important to frequently empty, clean, and refill the boot bath to prevent it from being contaminated with organic matter. Disposable boots may be used.

BIOCONTAINMENT

High-consequence livestock pathogens (e.g., tuberculosis, foot and mouth disease) or the vectors (e.g., mosquitoes, ticks) responsible for transmission of disease cause high morbidity and mortality, and can have a significant regional, national, and global economic impact. The use of these pathogens in agricultural research brings several challenges when designing and operating an animal facility. The design of this type of facility should strive for flexibility, effective containment of pathogens, and minimizing the risk of exposure to personnel when zoonotic agents are utilized. The use of agricultural animals in high-consequence livestock pathogen research requires a thorough understanding of a variety of regulatory requirements and the concept of risk assessment. The USDA provides a list of livestock, poultry, and fish pathogens that are classified as "pathogens of veterinary significance" in Appendix D of the book *Biosafety in Microbiological and Biomedical Laboratories* (**BMBL**; CDC, 2007). The use of these pathogens requires facilities to meet specific criteria for design, operation, and containment features, which are described in the BMBL. For the listed agents, criteria may include utilizing containment levels designated as Animal Biosafety Level (**ABSL**)-2, enhanced ABSL-3, BSL-3-Ag, or ABSL-4. Requirements for BSL-3-Ag facilities must be met when any of the listed pathogens are used in animals and the room housing the animals provides the primary containment (i.e., animals are loose-housed in the room). When the studies can be accomplished in smaller species in which animals are housed in primary containment devices, which allows the room to serve as the secondary barrier, then enhanced ABSL-3 requirements can be utilized. Enhancements to ABSL-3 should be determined on a case-by-case basis, using risk assessment, and in consultation with the Animal and Plant Health Inspection Service (**APHIS**) of the USDA. In addition to the BMBL, facility design standards have been published by the USDA to guide the design of Animal Research Service (**ARS**) construction projects and contain useful information on the design of containment facilities for agricultural research. These standards include information on containment design that addresses hazard classification and choice of containment, containment equipment, and facility design issues for the different levels of biocontainment (ARS, 2002). Although published to provide guidance for National Institutes of Health (**NIH**)-funded construction projects and renovations for biomedical research facilities, the *NIH Design and Policy Guidelines* (NIH, 2003) contain useful information on construction of BSL-3 and ABSL-3 facilities. The use of recombinant DNA molecules in agricultural research can introduce additional considerations when designing an animal facility. Published guidelines provide recommendations for physical and biological containment for recombinant DNA research involving animals (NIH, 2002). These guidelines include a supplement published in 2006 that provides additional information specific to the use of lentiviral vectors (NIH, 2006). The Agricultural Bioterrorism Protection Act of 2002 required the propagation of regulations that address the possession, use, and transfer of select agents and toxins that have the potential to pose a severe threat to plants or animals, and their products. The USDA/APHIS published the implementing regulation covering animals and animal products, which identifies those select agents and toxins that are a threat solely to animals and animal products (VS select agents and toxins) and overlap agents, or those agents that pose a threat to public health and safety, to animal health, or to animal products (CFR, 2005). Overlap select agents and toxins are subject to regulation by both APHIS and the Centers for Disease Control and Prevention (CFR, 2002). The regulations implemented by both agencies reference the BMBL and the NIH *Guidelines for Research Involving Recombinant DNA Molecules* as sources to consider when developing physical structure and features, and operational and procedural safeguards. Other issues discussed in some of these references may not directly affect containment of pathogens or safety of personnel, but should be considered as they may affect the design of a facility. For example, the use of select agents requires certain security measures to be in place that restrict access to areas where select agents or toxins are used or stored. This can include laboratories, animal rooms, and storage freezers, resulting in a significant impact on how a research facility is designed. A thorough understanding of the references cited in this section is advised before initiating the design of new biocontainment facilities or renovation of existing facilities to accommodate research with hazardous agents or toxins requiring containment.

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