Chapter 6: Beef Cattle

Beef cattle includes all animals of the genus *Bos* and their close relatives that are raised primarily for meat production. *Bos* animals that are utilized for milk are covered in Chapter 7: Dairy Cattle. As ruminants, beef cattle are capable of utilizing a wide range of feedstuffs and consequently are maintained in an array of situations ranging from extensive grazing to confined feedlot pens and intensive laboratory environments. Regardless of the housing system, basic needs for food, water, shelter, and comfort should be met.

FACILITIES AND ENVIRONMENT

Ideal Thermal Conditions

Under most environmental conditions, temperature represents a major portion of the driving force for heat exchange between the environment and an animal. However, moisture and heat content of the air, thermal radiation, and airflow also affect total heat exchange. Thus, a combination of environmental variables contributes to the conditions (effective or apparent temperature) to which an animal responds.

Under conditions in which relative measures and comparisons of the effect of different environmental variables could be determined, the apparent ambient temperature at which animals can cope has been defined with a reasonable degree of accuracy; however, variation does exist among animals. Environmental conditions that provide maximum comfort (thermal comfort zone, **TCZ**) and require little or no energy expenditure for maintenance depend on cattle age, metabolic size, and/or body mass and surface area. The TCZ generally ranges between 15 to 25°C for most cattle less than 1 mo old; between 5 and 20°C for a mature beef cow consuming a maintenance diet; and between −10 and 20°C for yearlings with ad libitum access to energy-dense feedlot diets. Based on physiological responses (Beatty et al., 2006) and heat load thresholds (Gaughan et al., 2008), *Bos indicus* and some heat-tolerant *Bos taurus* cattle breeds (Gaughan, et al., 1999) have a TCZ at least 5°C greater than typical *Bos taurus* cattle.

Encompassing the TCZ is the thermoneutral zone (**TNZ**). Within the TNZ, an animal can maintain homeostasis through normal physiological and metabolic processes, which may require minimal expenditure of energy when the animal is exposed to conditions outside the TCZ (Hahn, 1985; Young, 1985). The TNZ generally ranges between 10 and 30°C for most cattle less than 1 mo old; between −15 and 28°C for a mature beef cow consuming a maintenance diet; and between −35 and 25°C for yearlings with ad libitum access to energy-dense feedlot diets. Even though the upper end of the TNZ for most *Bos taurus* cattle is between 25 and 30°C, for high-producing cattle with high intakes of metabolizable energy the upper limit may be closer to 20°C on sunny days when little or no wind is present (Brown-Brandl et al., 2006). When given sufficient time, cattle acclimate and adapt to colder or hotter conditions. It should be noted that cattle that are adapted to −35°C may be uncomfortable (show signs of heat stress) at 10°C. Thus, the TCZ and TNZ serve only as guidelines to describe the limits within which cattle are comfortable and can adapt to, respectively. Independent of these guidelines, performance standards that indicate a problem with the thermal environment include, in cold weather, shivering, huddling, and loss of body condition/weight; and in hot weather, panting, sweating, and a reduction in feed intake. Primary factors that affect thermal comfort include feed/energy intake and body condition/fat cover.

Thermal Indices

At the present time, the temperature-humidity index {**THI**; THI = 0.8 × ambient temperature + [(% relative humidity/100) × (ambient temperature − 14.4)] + 46.4} 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, 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). A THI between 70 and 74 is an indication to producers that the potential for heat stress in livestock exists (LCI, 1970). In particular, when THI values are above 70 by 0800 h, it is recommended that managers of confined cattle that have high metabolic heat loads (e.g., feedlot cattle) initiate or prepare to initiate heat-stress management strategies before cattle become exposed to the excessive heat load (Mader et al., 2000). A THI of 84 or above can cause death, especially in feedlot cattle that are within 45 d of slaughter and consuming high-energy finishing diets.

Modifications to the THI have been developed to overcome the shortcomings related to the lack of airflow and radiation heat load in the index (Mader et al. (2006). Eigenberg et al. (2005) also developed similar adjustments based on predictions of respiration rates using ambient and dew point temperature, windspeed, and solar radiation. These models have merit in that the combined effects of multiple environmental factors can be taken into account when determining animal comfort.

Gaughan et al. (2008) developed a more extensive index as a guide to the management of feedlot cattle during hot weather. The heat load index (**HLI**) incorporates black globe temperature (Buffington et al., 1981), relative humidity, and windspeed. A threshold (HLI = 86), above which cattle are less efficient at dissipating heat was developed for a reference animal (healthy black, predominantly Angus, steers without access to shade, 100 to 150 d on feed, and a summer hair coat). The threshold for a full-blood Brahman steer is 96. Also, adjustments to the threshold are possible for use of shade, clean dry pens, cattle coat color, and days on feed. The thresholds are lowered if cattle are sick (−5) or not acclimated to summer conditions (−5).

Very limited data exist for assessing environmental effects on reproduction. However, Amundson et al. (2006) found THI and daily minimum temperature to be equally good predictors of pregnancy rate at 42 d into the breeding season. However, the combination of wind speed and THI had the greatest correlation (R^2 = 0.63) to pregnancy rate.

Indices for cold stress are not as well defined as for heat stress. The wind chill index (**WCI**) has traditionally been used to derive an apparent temperature for humans. In 2001, the National Weather Service (NWS, 2008) released a new WCI that may have merit for assessing effects of wind on domestic livestock (see Chapter 3: Husbandry, Housing, and Biosecurity for discussion).

Range and Pasture Systems

Acceptable systems for grazing beef cattle on pasture and rangeland vary widely. Cow body condition is an excellent performance standard for monitoring the well-being and nutritional status of range cattle (NRC, 1996). Special consideration needs to be given to environmental factors that affect grazing beef cattle. In areas where heat stress is common, provision of shade (including man-made or natural vegetation) to decrease the solar heat load is the most practical intervention in pasture and range systems. The need for artificial shade should be assessed after careful consideration of the adequacy of naturally occurring sources. Heat stress is evidenced when respiration rates begin to increase. Prolonged increases in body temperatures will result in decreased feed intake, body condition, and weight (Robertshaw, 1987; Hahn, 1995). In areas where exposure to extreme cold is likely, provision of shelter for grazing beef cattle may be desirable. Grazing beef cows decrease grazing time and forage intake as ambient temperature decreases below 0°C (Adams et al., 1986), although such changes are small in adapted beef cows (Beverlin et al., 1989). Cattle use windbreaks to decrease wind chill and prevent exposure to blowing snow, although it has not been clearly established that windbreaks improve animal performance (Krysl and Torell, 1988). Supplementary feed should be provided during periods of heavy snow cover that preclude grazing.

An adequate supply of forage should be available to grazing cattle. Intake and performance may be decreased when the amount of standing forage is lacking (NRC, 1987), but the appropriate quantity of forage dry matter per hectare varies with the pasture or range type and the stocking rate. Guidelines for acceptable amounts of standing forage per unit of body weight at given stocking rates (herbage allowance) are available (NRC, 1987), but additional research is needed with a variety of pasture and range types. Grazing beef cattle should be provided with supplements for nutrients that are known to be deficient in pasture and range forage in particular localities. In almost all grazing environments, range cattle require free-choice access to supplemental salt as a source of supplemental sodium. Typically, these salt-based, free-choice mineral supplements will also be fortified with trace minerals.

Observation and monitoring of range cattle often occur less regularly than for other livestock. When supplemental feed is provided, cattle are usually observed at least 2 or 3 times weekly. Unsupplemented cattle on open range may be observed less frequently. However, it is recommended that range cattle be observed at least once per week. In certain areas, grazing beef cattle may be affected by predators and poisonous plants. Careful attention should be given to such problems, and efforts should be made to decrease or eliminate these adverse conditions.

Availability of fresh, unfrozen water is critical for grazing beef cattle, and distance to water should be given consideration in pasture and range systems. If cattle are required to travel long distances to water in hot, dry climates, animal performance and utilization of pasture forage can be affected (Fusco et al., 1995). Holechek et al. (1995) recommended that distance to water be no greater than 1.6 km (1 mi) in rolling, hilly country and in undulating, sandy terrain. This recommendation was decreased to 0.8 km (0.5 mi) in rough country, increased to 2.4 km (1.5 mi) in smooth, sandy terrain, and increased to 3.2 km (2 mi) in areas with flat terrain. Thus, the distance to water for grazing cattle should not exceed 3.2 km, and every animal should have the opportunity to drink ad libitum at least once per day.

Feedlot and Housing Systems

Beef cattle used in research or teaching may be housed in intensive management systems, either indoors or in open lots, with or without shelter. Facilities for beef cattle should provide cattle with opportunities for behavioral thermoregulation (e.g., access to a windbreak, sunshade, mound, or roofed shelter). Management of dairy beef is similar to other cattle, although, some feeding, housing, and marketing regimens are unique to Holsteins (NCR 206, 2005).

Proper airflow and ventilation are essential in intensive facilities. In feedlots, cable or wire fencing has minimal effect on natural airflow in summer. However, high airflow rates are undesirable during periods of low temperature, and tree shelterbelts and other types of windbreak can decrease the rate of airflow past the cattle. An 80% solid windbreak 3 m (10 ft) high (minimum recommended height) decreases wind speed by half for about 45 m (150 ft) downwind and controls snow for about 8 m (25 ft); a similar windbreak 4 m (13 ft) high decreases wind speed by half for about 65 m (200 ft) downwind and controls snow for about 10 m (30 ft). A windbreak is recommended in mounded, south-sloping feedlots in the northern United States to provide dry resting areas with low air velocities. Caution should be exercised when placing cattle in sheltered areas in the summer because of the adverse effects of restricted airflow on cattle reared in hot environments (Mader et al., 1999).

During potentially stressful heat episodes (nighttime THI do not fall below 70), panting scores (1 = elevated respiration rate, 2 = drool or saliva present on side of mouth, 3 = open mouth breathing observed, and 4 = tongue and neck extended with open mouth breathing) can be utilized as an excellent indicator of stress levels experienced (Mader et al., 2006). When cattle are beginning to experience panting scores of 2 or greater some means of cooling may be needed. Cattle learn to take evasive action to alleviate heat stress and such competition for cooler areas in a pen or around the water trough increases even during cooler days in which heat alleviation methods (e.g., sprinkling) are not utilized (Mader et al., 2007). When this occurs evidence of crowding is observed, which exacerbates the heat stress problems. Wetting the ground or floor of holding facilities can be an effective method of cooling cattle managed in unshaded, outdoor units where surface vegetation is sparse or nonexistent (Mader, 2003; Mader and Davis, 2004). Direct wetting of cattle during extreme heat is also an effective practice and is often used as an emergency measure. Benefits of sprinkling are enhanced if sprinkling is started in the morning, before cattle experience high heat loads (Davis et al., 2003). Generally, a daily application of 0.5 to 1.0 cm of water is sufficient to cool pen surfaces. However, applying 1.25 to 1.50 cm every other day is acceptable and will not sufficiently contribute to mud build-up in normally dry pens. In areas with high evaporation rates (>1.0 cm of water/day), additional water may be needed, which can serve to cool pen surfaces as well as eliminate potential dust problems. The size of the area needed to be sprinkled would be similar to the shade area recommendations. As a routine protective practice, wetting can be efficiently accomplished by utilizing a timer to provide 5 to 10 min of spray during each 20- to 30-min period. Fogger nozzles are often mistakenly recommended for wetting animals. Fogger nozzles are less effective than sprinkler nozzles because of the barrier formed by the fine droplets (mist). These droplets adhere to the outer hair coat of the animal, causing the heat for evaporation to come from the air rather than from the body. Mitlöhner et al. (2001) reported that misting cattle was not as effective as shade in decreasing heat stress, and in some cases, caused respiration rate to increase compared with nonmisted cattle.

Shade for cattle can provide the margin of survival for animals that are unconditioned to a sudden heat wave with high solar radiant loads in central and southern regions of the United States. Mader et al. (1999) found limited performance benefits of utilizing shade in the north-central region of the United States, in contrast to the findings of Mitlöhner et al. (2001) where shade was effective in southern regions. Also, use of shade in northern climates may be costly and logistically prohibitive because of snow load requirements (unless shade is taken down after summer), potential mud problems under shade (low evaporation rates), and the low percentage of time that cattle may actually benefit from using the shade. However, benefits of using shade for maintaining animal comfort will almost always be found in any area or location in which abnormally hot or hot and humid conditions arise or persist, including northern climates, and when cattle have not had the opportunity to acclimate. Mitlöhner et al. (2001, 2002) found excellent results when shades were provided for feedlot cattle reared in the south-central region of the United States, an area where more consistent benefits of shade would be expected to be realized. For optimum benefits shades should be 3.6 to 4.2 m (12 to 14 ft) high in areas with clear, sunny afternoons (e.g., southwestern United States) to permit maximum exposure to the relatively cool northern sky, which acts as a radiation sink. In areas with cloudy afternoons (e.g., eastern United States), shades 2.1 to 2.7 m (7 to 9 ft) in height are more effective, as they limit the diffuse sky radiation received by animals beneath the shades. The amount of shade required for young cattle is 0.7 to 1.2 m^2 (7.5 to 13 ft^2) per animal, whereas larger cattle need 1.8 to 2.5 m^2 (19.4 to 27 ft^2) per animal. Shades are strongly recommended for sick cattle or for animals in hospital pens.

Cold housing can be provided for beef cattle. Open sides of any cattle building need to face away from prevailing winds. Such structures are ventilated by natural airflow, and the resultant winter temperatures are typically 2 to 5°C above outdoor conditions as a result of body heat. Totally enclosed housing requires ventilation to maintain the air temperature at acceptable levels and to minimize the accumulation in the air of water vapor, noxious gases, other odorous compounds, and dust. Ventilation systems may be either natural or mechanical.

Type of pen surface affects dustiness during hot dry weather and mud or manure build-up during wet periods. Good drainage of outside pens is imperative. Dirt pens should be regularly cleaned of animal waste residues and maintained to minimize accumulation of water. A hard surface apron in front of the feed bunks and around water troughs and shelters should be considered in dirt pens. Mounds should be provided in dirt pens for cattle to lie on during inclement weather (Table 6-1). Accumulation of mud in a pen or on the cattle can influence maintenance requirements and thermal balance. Properly designed pens with adequate slope are extremely important for minimizing mud and related health and behavior problems. In areas where slope or drying conditions are limited, adding mounds is very useful for keeping cattle clean and dry. Under hot-humid conditions, mounds aid in preventing animal crowding and improve exposure to airflow for the animals that utilize them. Additional information on feedlot/drylot pen design and layout has been published by Pohl (2002) and Henry et al. (2007).

For hard-surfaced pens, materials should be durable, slip-resistant, and impervious to water and urine; easily cleaned; and resistant to chemicals and corrosion from animal feed and waste. Concrete floors should be scored or grooved during construction to improve animal footing. Properly designed slotted floors are self-cleaning. Fences, pen dividers, walls, gates, and other surfaces must be strong enough to withstand the impact of direct animal contact. Configuration and treatment of contact surfaces must minimize or eliminate protrusions, changes in elevation, and sharp corners to minimize bruising and injuries and to improve the efficiency of cattle handling.

Proper lighting permits inspection of animals in feedlots and other cattle housing systems and provides safer working conditions for animal care personnel. Maintenance of facilities (e.g., repair of fences and equipment) should be timely and ongoing.

FEED AND WATER

Diets for beef cattle should be formulated according to the recommendations of the NRC (1996). Formulation of diets should consider factors such as environmental conditions, breed or biological type, sex, and production demands for growth, gestation, or lactation.

Feed and water should be offered to cattle in ways that minimize contamination by urine, feces, and other materials. Feed bunks should be monitored daily and contaminants or spoiled feed should be removed. In most situations, feed should be available at all times. However, restricted feeding of high-energy diets may be practiced to meet maintenance requirements or targeted levels of production. When restricted feeding is practiced, feed must be uniformly distributed in the bunk to allow all cattle to have simultaneous access to the diet. When high-energy diets are fed, increased attentiveness should be given to possible occurrence of diet-related health problems such as grain overload, lactic acidosis, and bloat. Abrupt changes in diets should be avoided. Feed deprivation for more than 24 h should be avoided, and feed deprivation for any length of time must be justified in the animal use protocol.

Cattle can vary considerably in body weight and condition during the course of grazing and reproductive cycles. Feeding programs should allow animals to regain the body weight that is lost during the normal periods of negative energy balance. Confined cattle should have continuous free access to a source of water, except before surgery or weighing if the research or animal care protocol requires such restriction. When continuous access to water is not possible, water should be available ad libitum at least once daily and more often if hot weather conditions exist or cattle have high levels of metabolizable energy intake for purposes of achieving high output (growth or milk). Under winter range conditions, Degen and Young (1990a, b) found that snow can be used as a water source for beef cows and growing calves. However, there was evidence that the snow resulted in reduced water intakes as evidenced by compensatory water intake when water was reintroduced following 84 d of consuming water in the form of snow. When snow was the only source of water, total water intake reductions averaged approximately 10% among the cattle groups.

The quantity and, possibly, quality of water available will influence animal comfort, especially under hot conditions. Evaporation of moisture from the skin surface (sweating) or respiratory tract (panting) is the primary mechanism used by the animals to lose excess body heat in a hot environment. Estimates of daily water requirements for beef cattle are reported in NRC (1996). During summer months, in particular, waterer space available and water intake per animal becomes extremely important. Under these conditions, Mader et al. (1997) found that as much as 3 times the normal waterer space (7.5 vs. 2.5 cm of linear space per animal) may be needed to allow for sufficient room for all animals to access and benefit from available water. Additional waterer space recommendations are provided by MWPS (1987).

Table 6–1. Floor or ground area and feeder space recommendations for beef cattle used in agricultural research and teaching[1,2,3]

	Calves, 180 to 380 kg (400 to 800 lb)		Finishing cattle, 360 to 545 kg (800 to 1200 lb)		Bred heifers, 360 kg (800 lb)	
Area or space	m^2	ft^2	m^2	ft^2	m^2	ft^2
Floor or ground area						
Open lots (no barn)						
Unpaved lots with mound (includes mound space)	14.0 to 28.0	150 to 300	23.2 to 46.5	250 to 500	23.2 to 46.5	250 to 500
Mound space, 25% slope	1.9 to 2.3	20 to 25	2.8 to 3.3	30 to 35	2.8 to 3.3	30 to 35
Unpaved lot, 4 to 8% slope, no mound	28.0 to 55.8	300 to 600	37.2 to 74.4	400 to 800	37.2 to 74.4	400 to 800
Paved lot, 2 to 4% slope	3.7 to 4.7	40 to 50	4.7 to 5.6	50 to 60	4.7 to 5.6	50 to 60
Barns (unheated cold housing)						
Open front with dirt lot	1.4 to 1.9	15 to 20	1.9 to 2.3	20 to 25	1.9 to 2.3	20 to 25
Enclosed, bedded pack	1.9 to 2.3	20 to 25	2.8 to 3.3	30 to 35	2.8 to 3.3	30 to 35
Enclosed, slotted floor	1.1 to 1.7	12 to 18	1.7 to 2.3	18 to 25	1.7 to 2.3	18 to 25
Feeder space when fed:	cm	in	cm	in	cm	in
Once daily	45.7 to 55.9	18 to 22	55.9 to 66.0	22 to 26	55.9 to 66.0	22 to 26
Twice daily	22.9 to 27.9	9 to 11	27.9 to 33.0	11 to 13	27.9 to 33.0	11 to 13
Free choice grain	7.6 to 10.2	3 to 4	10.2 to 15.2	4 to 6	10.2 to 15.2	4 to 6
Self-fed roughage	22.9 to 25.4	9 to 10	25.4 to 27.9	10 to 11	27.9 to 30.5	11 to 12
	Cows, 455 kg (1,000 lb)		Cows, 590 kg (1,300 lb)		Bulls, 680 kg (1,500 lb)	
	m^2	ft^2	m^2	ft^2	m^2	ft^2
Floor or ground area						
Open lots (no barn)						
Unpaved lots with mound (includes mound space)	18.6 to 46.5	200 to 500	28.0 to 46.5	300 to 500	46.5	500
Mound space, 25% slope	3.7 to 4.2	40 to 45	3.7 to 4.2	40 to 45	4.7 to 5.6	50 to 60
Unpaved lot, 4 to 8% slope, no mound	32.5 to 74.3	350 to 800	32.5 to 74.3	350 to 800	74.3	800
Paved lot, 2 to 4% slope	5.6 to 7.0	60 to 75	5.6 to 7.0	60 to 75	9.3 to 11.6	100 to 125
Barns (unheated cold housing)						
Open front with lot	1.9 to 2.3	20 to 25	2.3 to 2.8	25 to 30	3.7	40
Enclosed, bedded pack	3.3 to 3.7	35 to 40	3.7 to 4.7	40 to 50	4.2 to 4.7	45 to 50
Enclosed, slotted floor	1.9 to 2.3	20 to 25	2.0 to 2.6	22 to 28	2.8	30
Feeder space when fed:	cm	in	cm	in	cm	in
Once daily, limited feed access	61.0 to 76.2	24 to 30	66.0 to 76.2	26 to 30	76.2 to 91.4	30 to 36
Twice daily, limited feed access	30.5 to 38.1	12 to 15	30.5 to 38.1	12 to 15	—	—
High-concentrate diet, ad libitum	12.7 to 15.2	5 to 6	12.7 to 15.2	5 to 6	—	—
High-forage diet, ad libitum	30.5 to 33.0	12 to 13	33.0 to 35.6	13 to 14	—	—

[1]Primarily based on MWPS (1987).
[2]Values are on a per-animal basis in a pen environment.
[3]In favorable (e.g., dry) climates, area accommodations may be less than indicated in this table.

HUSBANDRY

Adequate care of cattle and calves is especially important for establishing and maintaining optimal immune system function. Good husbandry can minimize health problems and infectious diseases. The risk of disease and mortality in young calves is related to immune status (Postema and Mol, 1984; McDonough et al., 1994). It is critical that newborn calves nurse or ingest colostrum soon after birth. Additional information on the care of the newborn calf can be obtained from Chapter 7: Dairy Cattle.

The health of young growing cattle should be assessed regularly pre- and postweaning. Animal care personnel should be taught to recognize signs of illness and external parasites. Alert caretakers should have the ability to perceive appropriate behavior and posture (Albright, 1993). A system of monitoring calves through critical stress periods such as weaning should be established. Any sick or injured calves should be treated promptly. Daily records should be kept (e.g., calves treated and treatment). For cattle reared in close confinement (e.g., cattle in feedlots) assessments should be done at least once daily and more often if cattle have been stressed or potentially exposed to conditions in which their health could be compromised. In general, confined feedlot cattle, especially new incoming cattle, require more frequent observations than nonconfined cattle (i.e., on range or pasture) because of the greater probability of animal health being compromised due to comingling, dehydration, digestive problems, respiratory problems, and interaction of any of these factors with environmental stress. Signs of healthy calves are alert ears and clear eyes, no signs of diarrhea, and, upon arising, resumption of a normal standing posture after stretching. For feedlot cattle provided energy-dense diets, caretaker knowledge of acidosis and management regimens necessary to minimize digestive problems are essential.

Appropriate medication and vaccination programs should be used to reduce the incidence of disease and mortality, improve cattle health and performance, and ensure that no illegal residues occur in the carcass (Wilson and Dietrich, 1993). Treatment and vaccination schemes should be based on veterinary advice and experience.

Weaning

In typical beef cow/calf production systems, calves are artificially weaned from their dams by physical separation. This process, albeit important to the efficiency of the cowherd, can be stressful to both the cow and calf. The most common weaning procedure involves an abrupt separation of cows and calves resulting in increased walking and vocalization and decreased eating and resting (Veissier and le Neindre, 1989). An alternative to abrupt weaning and permanent separation is a period (approximately 7 days) of fenceline contact between cows and calves in adjacent but separate pastures. This weaning management alternative has been shown to decrease vocalization and walking (or pacing) and increase the time spent resting and grazing (Price et al., 2003). This fenceline weaning procedure may also decrease the incidence of calf illness (Boyles et al., 2007). Within the weaning pasture or pen, a mature cow can be included in the group of freshly weaned calves. This "trainer" cow can assist in introducing the weaned calves to the location and facilitating consumption of feed and water (Gibb et al., 2000). Despite the weaning process selected, it is important that weaned calves be provided access to clean water and a source of feed and/or forage. To encourage intake, highly palatable forage and feed sources are recommended until calves become accustomed to the separation from their dams. Additionally, feed and water sources should be placed close to the perimeter of the fenceline, because calves will typically spend a majority of their time in these areas as they seek to reunite with their dams.

Social Environment

Cattle are social animals. Each individual in the group should have sufficient access to the resources necessary for comfort, adequate well-being, and optimal performance. Mixing, crowding, group composition, and competition for limited resources are part of the social environment and in some circumstances, may be social stressors for certain cattle. Generally, cows from similar environments but from different social groups can be mixed with little or no long-term adverse effect on performance (Mench et al., 1990); however, because introduced cows may be the recipients of aggression, the number of mixing episodes should be minimized. Mixing of older cattle, especially bulls, results in more fighting than occurs when younger cattle are mixed (Tennessen et al., 1985). Fighting and mounting can be a problem associated with keeping bulls in social groups and can present a significant welfare problem if not managed carefully (Fraser and Broom, 1990; Mounier et al., 2005). Attempts should be made to keep bulls in stable social groups and to minimize mixing.

When feed, water, or other resources critical for comfort or survival are limited, or when large differences exist among cattle in size or other traits related to position in the social order, some animals may be able to prevent others from gaining access to resources. In properly designed facilities, all individuals should have sufficient access to feed, water, and resting sites to minimize the correlation between position in the social order and productive performance (Hafez, 1975; Strickland and Kautz-Scanavy, 1984; Fraser and Broom, 1990).

Proper animal care includes observation of groups and of individuals within groups to ensure that each individual has adequate access to the resources necessary for optimal comfort, welfare, and performance.

Floor or Ground Area

Area recommendations for open lots and barns are listed in Table 6-1. Every animal should have sufficient space to move about at will, adequate access to feed and water, a comfortable resting site, and the opportunity to remain reasonably dry and clean. These suggested recommendations alone do not ensure that an ideal environment exists; however, in some cases these conditions can be met with less than the recommended area. The area required is affected by type and slope of floor or soil surface, amount of rainfall, amount of sunshine, season, group size, and method of feeding.

Open feedlot pens need to be sloped to promote drainage away from feed bunks, waterers, pen dividers, and resting areas. Space allocations are related directly to slope. In temperate Midwestern climates, the following relationships have been found to be workable (MWPS, 1987): 2% slope or less: 37 to 74 m^2 (400 to 800 ft^2) per animal; 2 to 4% slope: 23 to 37 m^2 (250 to 400 ft^2); and 4% or greater slope: 14 to 23 m^2 (150 to 250 ft^2). Space allocations can be less in drier regions of the country. In the Southwest, at 0% slope, typical allocations are 14 to 23 m^2 (150 to 250 ft^2) per animal. In other regions, space allocations may need to be increased above Midwestern norms in consideration of such factors as soil type and rainfall distribution.

The area requirements for cattle are greatly influenced by group size. One animal housed separately in a pen requires the greatest amount of floor area on a per-animal basis. As group size increases, the amount of area required per individual decreases. When an animal is housed individually, the minimum pen width and length should be at least equal to the length of the animal from nose tip to tail head when the animal is standing in a normal erect posture.

Acceptable indoor pen floor surfaces for beef cattle include unfinished concrete, grooved concrete, concrete slats, expanded metal, plastic-covered metal flooring, and rubberized mat. The floor surface in stanchions and metabolism stalls may be concrete, expanded metal, wood, rubberized mat, or a combination of materials that provides support for the animals' bodies; does not damage hooves, feet, legs, and tails; and can be cleaned.

STANDARD AGRICULTURAL PRACTICES

For beef cattle, management procedures may be performed by properly trained, nonprofessional personnel. These include, but are not limited to, vaccinating, dehorning and castrating young cattle, horn-tipping, ear-tagging, branding, weighing, implanting, use of hydraulic and manual chutes for restraint, roping, hoof-trimming, routine calving assistance, ultrasound pregnancy checking, feeding, and watering.

Other husbandry and health practices used in beef cattle research and teaching that similarly may be performed by properly trained, nonprofessional personnel, but that require special technical training and advanced skill levels, include artificial insemination, electroejaculation, pregnancy palpation, embryo flushing and transfer, nonroutine calving assistance and dystocia treatment, emergency cesarean section, retained placenta treatment, and dehorning and castration of older cattle.

One of the main animal husbandry concerns is that of pain and distress, especially pain inflicted from standard husbandry procedures. Dehorning, castration, and branding are husbandry procedures that can cause pain and discomfort; nevertheless, these procedures are justified as a management tool to minimize injuries or other problems associated with confining horned cattle and commingling bulls. Additional guidelines outlining veterinary oversight of these practices, other animal health issues, and related institutional policies are covered in Chapters 1 and 2.

Dystocia Management

Matings should be planned to lessen the genetic probability of dystocia. When dystocia does occur, proper care and assistance at calving can decrease injury or death of both calves and heifers/cows.

Parturition without complication is common in beef cows. Therefore, before administering assistance to a cow experiencing difficulty with calving, personnel should be familiar with the stages associated with approaching parturition and the signs of normal delivery. As a general rule, females should be examined within 30 to 60 min following presentation of feet, nose, or fetal membranes if delivery of the calf does not appear imminent. However, heifers or cows exhibiting signs of a malpresentation, oversized fetus, fetal anomaly, or other obvious complication must be assisted immediately.

Facilities should be provided that are designed for restraint of cows and heifers experiencing dystocia. Because many animals, especially heifers, lie down during the obstetrical procedure, sufficient space should be provided to permit adequate freedom of movement. It is important that the obstetrical restraint facility be fitted with side gates, both of which are hinged at the head end, so that the animal can become fully recumbent and the obstetrical procedure can be performed with safety and efficiency.

In dystocia cases where fetal presentation appears to be compromised or there appears to be a disparity between the size of the fetus and the diameter of the birth canal, assistance of the delivery by personnel appropriately trained in the judicious use of a fetal extractor may be attempted. In general, if more than slight traction is required on the fetal extractor, the procedure should be stopped and a veterinarian called immediately to perform a caesarean section or fetotomy. Use of excessive force can damage the calf and/or dam and lead to suffering and/or death. Strict sanitation should be used with all obstetrical procedures.

Vaccinations and Drug Administration

Vaccinations are a key component to any herd health program. Care should be taken to ensure the proper use, handling, and storage of vaccines and approved or investigational drugs. The preferred site of injection is the neck for either intramuscular or subcutaneous injections; however, for investigational drugs used in research, alternate sites of administration may be required or preferred as dictated by the research protocol. Investigators and animal care staff should utilize best management practices associated with the use of syringes and handling needles. Use and regular replacement of disposable syringes and needles is highly recommended to avoid excessive trauma and disease transmission.

Castration

Castration of male beef cattle is performed to reduce aggressiveness, prevent physical danger to other animals in the herd and to handlers, enhance reproductive control, manage genetic selection, and satisfy consumer preferences regarding taste and tenderness of meat. Accordingly, castration of young bulls is a necessary management practice in beef production.

Several methods for castrating cattle are acceptable, including surgical removal of the testicles using a knife or scalpel to open the scrotum and cutting or crushing the spermatic cords with an emasculatome or emasculator. Bloodless procedures utilizing specialized rubber rings or surgical tubing bands (applied with specially designed instruments) are available to create devitalization and eventual sloughing of the tissues below the ring or band. High-tension banding systems may be used with appropriate veterinary supervision and/or training in those situations where surgical castration may predispose to postsurgical complications or when surgical castration is not appropriate because of its effect on research protocol. The castration method used should take into account the animal's age and weight, the skill level of the technician, environmental conditions, and facilities available as well as human and animal safety. Whatever the method of castration, the procedures should be conducted by, or under the supervision of, a qualified, experienced person and carried out according to castration equipment manufacturer recommendations and accepted husbandry practices (Battaglia and Mayrose, 1981; Ensminger, 1983).

Surgical castration is normally a short-term event with short-term duration of pain-associated responses. Bloodless castration has been associated with lower short-term pain indicators but longer chronic pain indicators (Moloney et al., 1995; Thuer et al., 2007). Bloodless castration should be used when surgical castration may predispose to postsurgical complications or when surgical castration is not appropriate because of its effect on the research protocol. Castration is least stressful when performed at or shortly after birth, but lower stress is reported if performed before 2 or 3 months of age or before animals reach a body weight of 230 kg (Farm Animal Welfare Council, 1981). It is strongly recommended that calves be castrated at the earliest age possible.

It may be desirable to inject local anesthetic in the scrotum of calves heavier than 230 kg when surgical methods of castration are used or when the spermatic cords are crushed. Topical local anesthetics may also be used on open wounds. Improved animal performance, as one potential indicator of improved animal welfare, has not been observed in animals locally anesthetized at the time of castration (Ting et al., 2003; Wildman et al., 2006; Rust et al., 2007). It should be recognized that the effect of anesthetic agents is short-lived. Nevertheless, procedures should be implemented to minimize pain and discomfort, especially in older cattle. Castration of older, heavier bulls should be performed only by skilled individuals. When it is necessary to castrate these heavier bulls, techniques and procedures to control bleeding must also be used. No advantage to use of anesthesia is apparent when bloodless castration is practiced (Chase et al., 1995).

The possibility of infection should be given additional consideration after castration. Equipment should be sterilized, and facilities should be clean and sanitized. Infection following castration can be minimized by keeping the animals in a clean area and away from excessive mud or contaminants following the procedure until the wound is healed. If tetanus is a common disease associated with the premises, or if a bloodless castration method is utilized, the herd health veterinarian should schedule a prophylactic tetanus immunization program.

Dehorning

Horns on cattle can cause bruises and other injury to other animals, especially during transport and handling. Horns on adult cattle also can be a hazard to humans. Hornless cattle require less space in the feedlot and at the feed bunk. Polled breeds should be used whenever possible.

Disbudding and dehorning of cattle in the United States is not currently regulated. The Canadian Veterinary Medical Association recommends that disbudding be performed within the first week of life (CVMA, 1996). In the United Kingdom, disbudding with a hot iron is preferred to dehorning and it is advised that this should be performed before cattle reach the age of 2 mo. In Australia, dehorning without local anesthesia or analgesia is restricted to animals less than 6 mo old (La

Fontaine, 2002). Calves suffer less pain and stress, have less risk of infection, and have better growth rates when dehorning is performed at a very young age (Newman, 2007). Stafford and Mellor (2005) found that the use of local anesthetics virtually eliminated the escape behavior of calves associated with the dehorning process and that a 2-h delay was observed in the cortisol response to horn amputation. Whenever possible, the use of a local anesthetic is encouraged when dehorning. Additional information on dehorning can be found in AVMA (2008) guidelines on castration and dehorning, and in Chapter 10: Sheep and Goats.

When horned breeds of cattle are selected, dehorning (removal of horns) should be performed under the supervision of experienced persons using proper techniques (Ensminger, 1970; Battaglia and Mayrose, 1981). The horn buds should be removed at birth or within the first month after birth by several means, including hot cauterizing irons, cauterizing chemicals, a sharp knife, or commercially available mechanical devices. It is strongly recommended that calves be dehorned at the earliest age possible.

When it is necessary to remove horns from older cattle, methods that minimize pain and bleeding and prevent infection should be employed. Dehorning should be performed by a person knowledgeable and experienced in the appropriate procedures. Appropriate restraint and local anesthesia to control pain should be used when cattle older than 1 mo of age (>50 kg) are dehorned. Cattle should be monitored for hemorrhage and infection following dehorning. Adult cattle should be dehorned if aggressive behavior is displayed toward herd mates or humans. Dehorning may temporarily depress the growth of cattle (Loxton et al., 1982).

In the event that bunk and pen space are ample (e.g., 2 times recommended space requirements), then tipping the horn (removing the tip only) may be considered as an alternative to minimize potential bruising or injury of pen mates. However, Ramsay et al. (1976) reported that, after transport, carcass bruises were as common among tipped cattle as among horned ones.

Identification Methods

Proper animal identification is essential to research, facilitates record keeping, and aids in the routine observation and repeat identification of cattle. Methods of identification include skin color markings, ear tagging, tattooing, hot branding, freeze branding, and electronic identification. Ear tags are best used in conjunction with a more permanent form of identification such as a tattoo or brand, as ear tags are sometimes lost. Hot branding the hide is utilized as a means of identification; however, loss in hide value and studies indicating that freeze branding is less painful than hot branding (Lay et al., 1992; Schwartzkopf-Genswein et al., 1997) have begun to minimize the use of hot branding. Alternatives to hot branding should be considered. However, skin and hair color in addition to a limited access to liquid nitrogen or dry ice in extensive range operations may affect the ability to achieve a quality freeze brand. At some locations, branding is required by law. Both hot branding and freeze branding should be performed by trained personnel to minimize skin contact with the branding device to only that required to achieve a useful brand. Advent of a national animal identification system (NAIS) in the form of visual (flap tags) or radio frequency identification (RFID) ear tags serve as an additional means of identification. As this system will become standard for all cattle as part of a national program, managers of beef cattle as part of resident herds used in research should comply with the established guidelines.

Implanting

Implanting of cattle is a management practice for the administration of growth promotants and potentially as a means of delivery of investigational compounds used in research. For proper absorption and maximum response, implants should be placed correctly and in the correct location. Traditionally, implants are placed beneath the skin on the back side of the middle third of the ear; however, alternate implantation sites may be required as designated by the research protocol. Proper disinfection of the implant site is required to prevent infection. Care should be taken not to injure major blood vessels or the cartilage of the ear when implanting in the ear location. Utilization of best management practices associated with the use of the implant device and correct needle-handling procedures are required by suitably trained personnel.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of beef cattle environments.

HANDLING AND TRANSPORT

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of beef cattle.

SPECIAL CONSIDERATIONS

Intensive Laboratory Facilities

Some research and teaching situations require that beef cattle be housed under intensive laboratory conditions. Cattle may be kept in metabolism stalls, stanchions, respiration chambers, or environmental chambers. Housing cattle in such facilities should be avoided unless required by the experimental protocol (e.g., complete urine or fecal collection, frequent sampling, or environmental control) and then should be for the minimum amount of time necessary to accomplish the teaching or research objective. Cattle that are held or penned temporarily in crowded areas, frequently disturbed, or come into close contact with humans, or exposed to unfamiliar conditions or laboratory/teaching settings should have calm dispositions and be adapted to frequent contact with animal care personnel and to those conditions that could result in the animal having an adverse reaction. In some cases, it may be advantageous to train such animals to a halter. Time spent preparing cattle for use in a laboratory improves the quality of research and the safety of both the animals and the humans. Cattle should not be housed in isolation unless approved by the Animal Care and Use Committee for specific experimental requirements. Whenever possible, cattle should be able to maintain visual contact with others.

Unless the experimental protocol has special requirements for lighting, all animal rooms should be designed to minimize variation in light intensity. During light periods, the minimum light intensity for intensively housed cattle is 70 lx (Manser, 1994). If possible, a diurnal light-dark cycle should be used and a standard daily schedule established (Wiepkema, 1985).

Excreta should be removed from enclosed laboratories at least once daily. Pens or stalls should be washed thoroughly at the beginning of every trial. If excreta or other foreign materials such as wasted feed cannot be adequately removed through daily cleaning, additional washing may be needed during a trial. The method of collection of feces and urine from cattle in metabolism stalls, stanchions, and chambers depends on the design and construction of the unit. Additional management may be needed to keep animals clean when they are housed in stalls or stanchions. Cattle may need to be washed and curried regularly to maintain cleanliness and to avoid fly infestations. Pens, stalls, and stanchions should be large enough to allow cattle to stand up or lie down without difficulty and should be long enough to allow cattle to maintain a normal standing position.

Because of the operating costs associated with single-pass ventilation systems in controlled environmental facilities, partial recirculation (up to 80%) of exhaust air from animal rooms is common and acceptable in many studies. In facilities designed to recirculate even a small part of the exhausted air, treatment is necessary to remove odorous compounds, gases, and particulate matter.

Cattle maintained in some laboratory environments have their activity restricted more than cattle in production settings. The length of time that cattle may remain in stanchions, metabolism stalls, or environmental chambers before removal to a pen or outside lot for additional exercise should be no longer than that necessary for conducting the study. Opportunities for regular exercise should be considered if they do not disrupt the experimental protocol; care must be taken in moving animals from the laboratory to the outside environment for exercise when a large temperature differential exists. If cattle are to be housed in such laboratory environments for more than 3 wk then particular attention should be given to alertness of the animal; appetite; fecal and urinary outputs; and condition of the feet, legs, and hock joints. Rubber mats or suitable alternatives should be used to increase the comfort of cattle maintained for lengthy periods on hard surfaces.

Care of Genetically Engineered and Cloned Beef Cattle and Use of Beef Cattle in Biomedical Research

Relative size, cost of maintaining beef cattle, and the use of alternate animal models in biomedical research have largely minimized the use of beef cattle in this regard. Nevertheless, beef cattle have played a role in understanding such maladies as lysosomal storage diseases (e.g., mannosidosis) and hemochromatosis (iron overload), among others, which have similarities to diseases, often genetically based, found in humans; therefore beef cattle may serve as highly valuable biomedical models in some cases. In addition, the potential use of cattle (albeit more often dairy cattle than beef cattle) as bioreactors for the production of human gene products or pharmaceuticals ("pharming") in milk, blood, urine, or tissues may further extend the use of beef cattle for biomedical applications. Standards for the care and welfare of beef cattle used in biomedical research should be the same as that applied to all beef cattle. However, institutional or biomedical funding agencies may require more specific disease entry testing requirements for cattle used in biomedical research, in addition to having more stringent procedures with respect to adherence to alternate oversight committee guidelines for reporting, housing, observation and care procedures (e.g., federal assurance statement guidelines, institutional biohazard committees, lab animal vs. production animal designations that may dictate care practices) than might be utilized or generally accepted under typical agricultural research and production systems.

In some cases, in which in vitro reproductive technologies are used for the production of beef cattle in research (genetically engineered, cloned, or otherwise), maturation, fertilization, manipulation, and/or culture, differences can exist in fetal morphology, physiology, and in the expression of developmentally important genes (Farin et al., 2004) that may require alteration in management strategy (e.g., increased frequency of observation at calving). For example, cattle produced in this manner may exhibit "large calf syndrome" and therefore may require extra assistance at calving (see Dystocia Management section).

The animal biotechnology sector continues to grow, with significant advancements being made that may directly (genetic engineering) and indirectly (e.g., vaccine development) affect beef cattle research (Jain, 2008), and it is important to recognize that alterations through the genetic engineering of beef cattle may similarly require alterations in beef cattle care practices. With respect to genetic engineering, unanticipated results from genetic modifications have been observed in several genetically engineered species (e.g., consequences to genetic engineering for double muscling in beef cattle: Rollin, 1996) that require diligence on the part of the researcher and animal care staff in assessing animal welfare (Rollin, 1996). However, the general standards of care associated with genetically engineered and cloned beef cattle should be the same as that applied to all beef cattle unless the specific genetic modification requires an alteration in management within the research environment to specifically facilitate animal welfare. Additional considerations regarding the use of genetically engineered animals are outlined in Chapters 1 and 2.

EUTHANASIA

According to the USDA and Food Safety and Inspection Service (FSIS) *Humane Slaughter of Livestock* regulations (USDA-FSIS, 2003), floors of livestock pens, ramps, and driveways of harvest facilities shall be constructed and maintained so as to provide good footing for livestock (CFR, 2006). Animals shall have access to water in all holding pens and, if held longer than 24 h, access to feed. Also, for animals held overnight there shall be sufficient room in the holding pens for the animals to lie down (CFR, 2006).

The AVMA *Guidelines on Euthanasia* (AVMA, 2007; current guidelines at http://www.avma.org/) lists several methods of euthanasia that are appropriate for ruminants. Intravenous administration of barbiturates, potassium chloride used in conjunction with general anesthesia, and penetrating captive bolt are acceptable means of euthanasia in all cases. Other conditionally acceptable methods include intravenous administration of chloral hydrate (following sedation), gunshot to the head, and electrocution. In all cases, euthanasia should only be performed by trained individuals.

Agents that result in tissue residues cannot be used for the euthanasia of ruminants intended for human or animal food, unless those agents are approved by the Food and Drug Administration. Carbon dioxide is the only chemical currently used in euthanasia of food animals (primarily swine) that does not lead to tissue residues. Use of carbon dioxide is generally not recommended for euthanasia of larger animals. The carcasses of animals euthanized by barbiturates may contain potentially harmful residues, and such carcasses should be disposed of in a manner that prevents them from being consumed by humans or animals.

Dying, diseased, and disabled livestock shall be provided with a covered pen sufficient to protect them from adverse climatic conditions (CFR, 2006). Incurably ill or injured animals in chronic pain or distress should be humanely euthanized as soon as they are diagnosed as such and according to AVMA (1993) recommended procedures. Their disposal should be accomplished promptly by a commercial rendering service or other means (e.g., burial, composting, or incineration) according to applicable ordinances and regulations.

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