Seasonal and Environmental Effects on Energy Requirements and Performance of High-Producing Cattle

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Introduction

Seasonal effects on performance by beef and dairy cattle are well documented. These changes likely reflect climatic, photoperiod, animal, and management differences among seasons (Galyean and Hubbert, 1995). Nutrient requirements are typically estimated based on the assumption that animals are fed under conditions with little or no environmental stress, and therefore should perform to their genetic potential. Nonetheless, environment can play a significant role in animal performance, and adverse environmental conditions may not allow an animal to reach its full potential. Decreased productivity can result from changes in climatic factors such as precipitation and associated problems like muddy pen conditions, humidity, wind, and temperature; and in many cases, these factors interact to create an even greater level of stress for animals.

In this brief review, we will consider effects of season and associated environmental effects on production by beef and dairy cattle. Our focus will typically be on changes in feed intake and energy requirements, as these two factors seem most affected by season/environment and are the driving forces in cattle production.

Seasonal Effects on Intake, Performance, and Energy Requirements

Photoperiod Effects

The NRC (1987) suggested that photoperiod might be a potentially important factor influencing feed intake by beef cattle. In wild and/or recently domesticated ruminants like red deer, important effects of photoperiod on intake and metabolism have been reported (Barry et al., 1991). For example, voluntary intake by red deer was considerably greater during the summer than winter, but sheep showed little seasonal variation in voluntary dry matter intake (**DMI**), and goats showed an intermediate response (Domingue et al., 1991). Seasonal responses in feed intake noted in red deer and other wild ruminants seem to be controlled by changes in day length, and are entrained to photoperiod by changes in the hormone melatonin (Barry et al., 1991). Barry et al. (1991) suggested that these annual rhythms in food intake are most likely a result of an increase in metabolic demand associated with hormonal changes that occur with altered photoperiod. Blaxter and Boyne (1982) reported cycles in the rate of metabolic heat production that coincided with natural seasonal changes in sheep fed near-maintenance.

Effects of photoperiod on growth, intake, and hormone secretion by domesticated ruminants were reviewed by Tucker et al. (1984), who reported that increased daily exposure to light increased feed intake by sheep and cattle with ad libitum access to feed. Tucker et al. (1984) suggested that effects on feed intake were likely secondary to effects on growth; however, growth responses to extended photoperiod have not been consistent. Voluntary DMI by Danish Black and White bulls increased 0.32 % for each 1-h increase in day length (Ingvarsten et al., 1992), and these authors found a range in the literature they reviewed of -0.6 to 1.5 % change in DMI per hour change in day length. Ingvartsen et al. (1992) suggested that voluntary intake would be expected to be 1.5 to 2 % greater in long-day months and 1.5 to 2 % less in short-day months.

Miller et al. (1999) reported that in cows that were 70 d in milk at the beginning of the winter solstice, long daily photoperiod (18 h of light and 6 h of darkness) increased fat-corrected milk yield by 6.9 %. Photoperiod increased DMI by 3.5 (without bovine somatotropin) to 8.9 % (with bovine somatotropin). Moreover, long daily photoperiod was additive to treatment with bovine somatotropin. Energy balance was not affected by photoperiod in this study, and long daily photoperiod did not significantly affect serum insulin-like growth factor (**IGF-I**) or prolactin concentrations.

Dahl et al. (2000) summarized ten studies in which photoperiod was altered with lactating dairy cattle and noted that long-day photoperiod (e.g., increased from less than 12 h to between 16 to 18 h) increased milk yield by approximately 2 kg/cow daily.

Milk fat was generally not changed by photoperiod. Some studies showed increases in DMI, whereas others showed no change. Dahl et al. (2000) suggested, however, that DMI has generally increased in longer-term studies, as would be expected, to meet the demand for increased milk production. Although the exact mechanism responsible for the effects of photoperiod on production is unknown, Dahl et al. (2000) indicated that increases in circulating concentrations of IGF-I are likely involved.

Seasonal Changes in Feed Intake and Performance

Although controlled research with artificially altered day length has clearly demonstrated production responses in lactating dairy cows, in practice, effects of photoperiod are very difficult to separate from seasonal changes in temperature, humidity, precipitation, and so on. Considerable information is available with both beef and dairy cattle regarding seasonal effects on feed intake and performance. Hicks et al. (1990) used DMI data by yearling beef steers at a commercial feedlot to assess seasonal patterns. Dry matter intake and average daily gain (**ADG**), respectively, for the feeding period averaged 9.35 and 1.44 kg/d for steers started on feed from July 31 to October 29, compared with 9.23 and 1.38 kg/d for steers started on feed from January 29 to April 30, 9.23 and 1.34 kg/d for steers started on feed from May 1 to July 30, and 9.15 and 1.35 kg/d for steers started on feed from October 30 to January 28. Despite differences in DMI among seasons, the pattern of change in intake over time during the feeding period (138-d average) was similar among seasons. Correlations of weather data with DMI were generally low, but effects of heat and cold stress were noted. Schake (1996) summarized 15 yr of data from commercial feedlots and noted significant year, gender, and year x season interactions for ADG and feed:gain (**F:G**) ratio. Cattle fed from January to June had consistently lower ADG and required more feed per unit gain than those fed from July to December.

Birkelo et al. (1991) evaluated the maintenance requirements of Hereford steers at high and low planes of nutrition over five consecutive seasons (summer, fall, winter, spring, summer). A higher plane of nutrition (2.27 vs. 1.2 times maintenance) increased fasting heat production and metabolizable energy (**ME**) required for maintenance; however, within plane of nutrition, season had limited effects on fasting heat production and ME requirements for maintenance. Although ADG was decreased during winter compared with other seasons, the authors suggested that this effect was likely a function of acute cold stress rather than a chronic increase in metabolic rate.

Galyean and Hubbert (1995) analyzed two data sets, each from a single feedlot in different geographical locations – Arizona (collected over a 13-yr period) and Kansas (collected over a 4-yr period). Type of cattle (e.g., Brahman crossbreds for Arizona vs. British and British x Continental crossbreds for Kansas) and initial body weight (**BW**; 168.4 kg for Arizona vs. 345.2 kg for Kansas) and thereby length of feeding period (281.3 vs. 125.1 d for Arizona vs. Kansas) varied considerably between the two data sets. To determine the influence of season and year on the relationship between DMI and initial BW, data were analyzed for each data set using stepwise regression procedures. Similar to Hicks et al. (1990), months of the year in which cattle were started on feed were classified by season. Effects of season varied between the two data sets (Table 1). In the Arizona data, the intercept was less for cattle started on feed during the spring and summer months than for those started on feed during the winter and fall months. The slope of the regression of DMI on initial BW was greater for cattle started on feed during the winter and spring months than during summer and fall months (Table 1). With the Kansas data, intercepts differed among the four seasons, with the greatest intercept for cattle started on feed in the spring months, followed by summer and fall; cattle started on feed during the winter months had the lowest intercept. The slope differed only for cattle started on feed during the spring (lower than for other seasons). Year effects were significant in many cases, particularly for the Arizona data set, but variable. Galyean and Hubbert (1995) suggested that if seasonal effects are primarily a function of climatic events (temperature and precipitation), greater intakes might be expected with cattle started on feed during the winter and spring months in Arizona compared with those started on feed during the summer and fall months (likely hotter and wetter time periods, respectively). In addition, they suggested that cattle started on feed during the winter in Kansas might be expected to have lower DMI because of the potential for severe winter weather. Alternatively, if changes in photoperiod are the primary driver of seasonal effects on intake, cattle started on feed during the winter and spring months in Arizona would spend the bulk of their 9- to 10-month feeding period during a time of long day length, and thereby might be expected to have greater DMI. Likewise, for cattle in Kansas started on feed during the spring and summer months, most of their

4- to 5-month feeding period would occur while day length was increasing.

Although it is intriguing to speculate about the causes for seasonal differences in feed intake performance, data like those analyzed by Hicks et al. (1990) and Galyean and Hubbert (1995) must be interpreted with caution because source and background of cattle, feed ingredient supplies, and management factors also change with seasons. The potential role of these changes is discussed briefly in the next section.

Seasonal Changes in Cattle, Feed Supplies, and Management

From the perspective of the beef cattle industry, seasonal changes bring changes in source and background of cattle. Availability of cattle for placement in feedlots or grazing typically coincides with weaning on fall- and spring-calving operations. Nutritional background of cattle can have significant effects on feedlot performance. Choat et al. (2003) compared feedlot performance by British crossbred steers that had previously grazed winter wheat pasture or native range before placement in a feedlot for finishing. Gain during grazing was greater for wheat pasture steers, but ADG and gain efficiency in the feedlot were greater for steers that had previously grazed native range, presumably reflecting their lighter initial BW. Hersom et al. (2004a) did not observe differences in feedlot ADG and gain efficiency between British crossbred steers that previously grazed wheat pasture at high or low ADG or native range at a low ADG. Nonetheless, during the finishing period, heat production by native range steers was greater than by high-ADG wheat steers, suggesting that nutritional restriction during grazing increased maintenance energy requirements, presumably because of increased visceral organ mass per unit BW (Hersom et al., 2004b). Less genetic diversity, coupled with a more constant nutritional background, probably decreases effects of seasonal variation associated with source and background in dairy cattle.

Feed commodity supplies change with time, which likely plays a role in seasonal changes in feed intake and performance by both high-producing beef and dairy cattle. Desiccation (or hydration), insect damage, and physical breakdown can occur when grains are stored, potentially resulting in variations in nutrient supply and effectiveness of processing across seasons. Depending on storage conditions, harvested forages and silages are particularly susceptible to nutrient losses over time. Local growing conditions (e.g., drought, precipitation, soil nutrient deficiencies) also could affect nutrient supply as commodities from different geographical locations are received at various times of the year. The quantitative contribution of feed supply factors to variation in performance of feedlot beef and dairy cattle is not well established, but these factors should be considered as potential contributors to seasonal variation in performance.

Table 1. Effect of season in which cattle were started on feed on the regression of DMI on initial BW with data from commercial feedlots in two locations (adapted from Galyean and Hubbert, 1995).

Feedlot location	Season[a]	Intercept[b]	Slope	R^2	$S_{y.x}$
Arizona	Winter	4.5375	0.0095	0.7021[c]	0.1872[c]
	Spring	4.2361	0.0116		
	Summer	4.4754	0.0082		
	Fall	4.5375	0.0082		
Kansas	Winter	4.1120	0.0150	0.4965	0.5814
	Spring	5.7389	0.0108		
	Summer	4.5762	0.0150		
	Fall	4.4176	0.0150		

[a]Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November.
[b]Significant intercept adjustments for several years, on the order of 1.25 to 6.4%, were detected, and values are reported in the original publication.
[c]The R^2 and $S_{y.x}$ value are for the overall series of equations that describe the effects of season and year adjustments.

Management often changes with season, which might contribute to differences in performance across time. For feedlot beef cattle, growth-promoting implant programs might be changed to reflect different weight classes, types, and backgrounds of cattle that are received at various times during the year. Newly weaned, stressed cattle are more likely to succumb to respiratory disease, so management at beef feedlots (e.g., frequency of observation and cattle-to-human contact) might change seasonally as employees focus efforts on cattle with an increased risk of morbidity. Schake (1996) noted marked seasonal trends in total payroll expenses and contract labor expenses at feedlots; thus, employee turnover issues might contribute to seasonal differences. Seasons characterized by increased precipitation, with associated muddy pen conditions, necessitate management changes such as increased frequency of pen cleaning. Increased frequency of pen cleaning could, in turn, alter the extent to which cattle are *disturbed* (e.g., moved in and out of pens) and thereby alter feed intake and performance.

Thus, although it is tempting to attribute seasonal effects on cattle production entirely to changes in photoperiod or climatic variables, it is probable that other factors like feed supplies and management contribute to seasonal effects. Delineating the factors that contribute to seasonal changes in feed intake and performance by high-producing beef and dairy cattle seems a worthwhile, although complex, research goal.

Effects of Rain, Snow, and Mud on Intake, Performance, and Energy Requirements

Several specific environmental factors are known to have important effects on feed intake and/or energy requirements. Because the effects of cold and heat stress are well documented, and many excellent review articles are available on these topics (e.g., NRC, 1981; Minton, 1987; Young, 1987; West, 2003), our discussion will focus on effects of precipitation and mud on production by beef and dairy cattle.

For beef cattle, a rain event has been reported to temporarily decrease intake by 10 to 30 % (NRC, 1981). Similarly, Morrison et al. (1970) reported that ADG decreased by 14.7 % and feed required per unit of gain increased by 17.1 % when cattle were exposed to 10 min/h of artificial rain. Decreasing rain exposure to 2.25 min/h decreased ADG by 5.63 % and increased F:G by 5.42 %. In a study evaluating the effects of weather on milk production and rectal temperature of Holstein cows, Kabuga and Sarpong (1991) reported that rain did not influence milk yield or milk fat yield; however, rectal temperature was significantly decreased by rain in cows fed higher concentrate diets. Although it is evident that rain events may at least temporarily impair cattle performance, muddy facilities caused by rain or snow events are likely cause for greater concern.

Figure 1 (NRC, 1981) shows the effect of various environmental factors on feed intake by cattle. Animals exposed to adverse conditions, such as deep mud, storms, and rain would be expected to have substantially decreased intake. Moreover, NRC (1981) reported that mild mud (10 to 20 cm deep) decreased intake by 5 to 15 %, whereas severe mud (30 to 60 cm deep) decreased intake by 15 to 30 %. Effects of mud are expected to be further magnified when access to feed is limited or suitable bedding is not available (NRC, 1981). Trials conducted in California studied the effects of mud, wind, and rain on feedlot performance (Morrison et al., 1970). Based on data collected over three years, it was evident that mud seriously decreased animal performance for periods of time during the winter and spring. Average daily gain was decreased by 23.9, 31.1, and 35.5 % for the years 1967, 1969, and 1970; respectively, when muddy conditions were imposed on feedlot steers. Likewise, F:G was increased 20.5, 26.7, and 30.1 % during each of the three years. In Holstein steers, Rayburn and Fox (1990) reported that mud 4, 8, and 12 cm deep decreased DMI by 15.0, 22.5, and 30.0 %; decreased ADG by 21.2, 32.2, and 43.8 %; and increased F:G by 7.8, 14.1, and 23.9 %; respectively, compared with pens that did not have mud. DeRouchey et al. (2005) reported that NE_m requirements of cattle fed in outside lots with frequent deep mud are 30 % greater than requirements of cattle fed in facilities with no mud, shade, good ventilation, and no chill stress. A summary of data showed that different depths of mud could create up to a 35 % decrease in ADG vs. no mud (DeRouchey et al., 2005). Thus, muddy pen conditions can be extremely detrimental to performance by beef cattle, and management factors designed to alleviate or lessen the effects of mud should be considered.

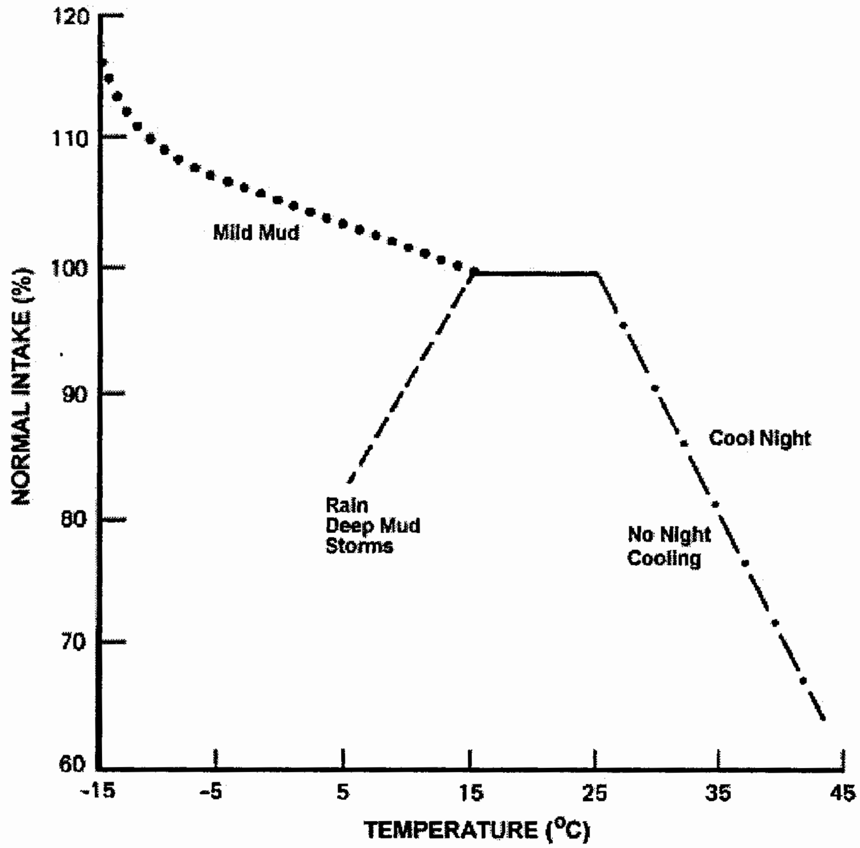

Figure 1. Environmental effects on dry matter intake (adapted from NRC, 1987).

Mud is a serious concern for dairy cattle production. Cattle of dairy breeds (Holstein) typically have less hair, external fat, and a thinner hide than beef cattle; and therefore may be less adaptable to environmental stresses like mud, wind, rain, and snow (Chester-Jones and DiCostanzo, 1996). Fox and Tylutki (1998) evaluated and revised the Cornell Net Carbohydrate and Protein System to account for effects of the environment. They suggested that for every 2.54 cm of mud, DMI by dairy cattle decreased 2.5 %. As depth of mud increased from 0 to 12 cm, DMI, ADG, and feed efficiency of Holstein cattle decreased (Rayburn and Fox, 1990). Because of the effect of prepartum intake on subsequent lactation performance (Brouk et al., 2001), it should be noted that dry cows housed in muddy conditions may be at the greatest risk for decreased performance; however, significant production losses also occur in lactating cows.

Management Options

Although our discussion has focused on seasonal and climatic factors that can alter performance by cattle, it should be recognized that physical factors associated with confinement facilities may influence performance as much as, or more than, climatic factors. Milk yield explained 45 % of the variability in DMI by cows; whereas climate accounted for 10 %, and feed and management accounted for 22 % of the variability in DMI (Brouk et al., 2001; Figure 2). Thus, to produce milk at the highest level, cows must maximize their DMI. With this in mind, it is imperative to apply good management practices to provide adequate comfort for cattle in confinement settings.

Bedding

Providing bedding for animals is one of the quickest ways to mitigate cold stress. As would be expected from climatic differences, bedding is used more often by producers in the Cornbelt than in the Southern and High Plains regions. With beef cattle, providing approximately 1 kg/d of straw per animal as bedding increased ADG by approximately 7 % and improved F:G by more than 6 % (Mader, 2003).

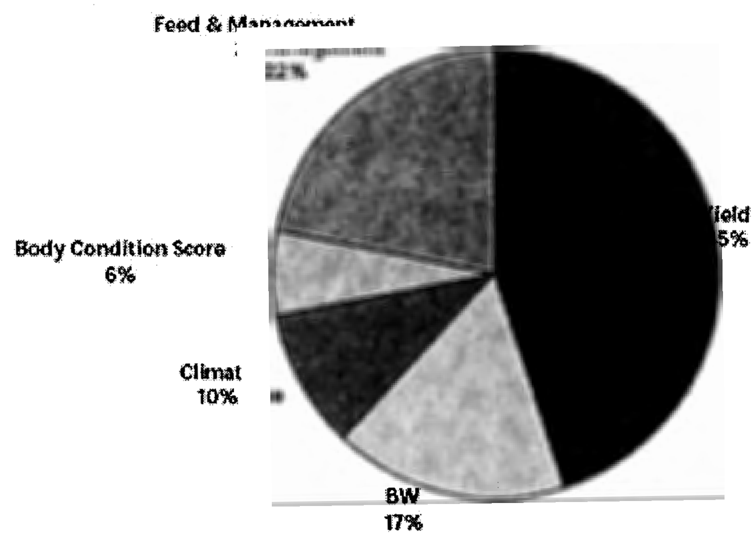

Figure 2. Variability explained by factors that affect DMI in lactating dairy cows (adapted from Brouk et al., 2001).

Based on research results, the estimated net return per animal averaged $60 to $80 more for bedded vs. unbedded cattle (Mader, 2006). Nonetheless, using bedding increases waste products in the pens, and when the bedding selection is a fibrous feed source, cattle will sometimes consume the bedding instead of their diet; which could potentially lead to decreased ME intake and performance. Although use of bedding for an entire feedlot may not be practical, providing bedding in certain pens (e.g., pens housing morbid animals or animals requiring special care and attention) may be beneficial.

For dairy cattle, selection of bedding is often related to animal comfort. Selecting the proper bedding for maximal animal comfort often entails the use of bedding materials that conform to an animal's shape and that are easily compressed. In many areas, sand is a commonly used bedding material, especially in free-stall dairy facilities (Brouk et al., 2001). Sand provides a comfortable cushion that conforms to the body of the animal. Likewise, several commercial free-stall surface materials are available, which have been reported to result in a percentage of occupancy ranging from 50 to under 20 % (Brouk et al., 2001). This range in occupancy suggests the need for care in selection of bedding materials that maximize utilization.

Six stall base types were tested to determine occupancy and percentage of lying time in dairy cows (Wagner-Storch et al., 2003). The base types included two mattresses, a waterbed, a rubber mat, concrete, and sand. Cows spent more time in mattress-based stalls, but spent the greatest percentage of time lying in sand-based stalls when stocking density was high. In contrast, cows in low-stocking density groups spent the most time and a greater percentage of time lying on mattress surfaces; but in the low-stocking density group, sand bedding was not a treatment. Based on the results of Wagner-Storch et al. (2003), mattresses and sand were superior to other bedding sources. Increased occupancy length should be indicative of greater comfort, and thereby may have implications for cattle performance. Nonetheless, overall ADG and DMI by female dairy calves did not differ between bedding treatments of granite fines, sand, rice hulls, long wheat straw, and wood shavings (Panivivat et al., 2004). It should be noted, however, that more antibiotic treatments were given for scours when granite fines and sand were used as bedding. Thus, choice of bedding materials might be affected by management concerns (e.g., morbidity) related to the age or class of the animal in question.

Pen Cleaning

As noted previously, controlling mud in cattle facilities is imperative to maximize performance potential of both beef and dairy cattle. One of the most obvious ways to avoid problems caused by mud is to keep it from accumulating in pens. Grandin (1999) described current management practices that the Australian feedlot industry has implemented to deal with mud. To maintain smooth, sloped, water-repellent surfaces, pen surfaces are groomed every 8 wk with a box scraper equipped with a laser-leveling device. Typically, these areas in Australia receive more than 50 cm of rain yearly, so frequency of cleaning should be adjusted accordingly based on annual precipitation. The purpose of using a laser is to produce a smooth pen surface with a 3 % slope grade (optimal grade to allow for proper drainage) from the feed bunk toward the cattle alley. In addition, a compacted layer of manure is left to repel water, and special care is taken to maintain the integrity of this manure layer.

Instead of using a box scraper to clean pens, front-end loaders are commonly used in the U.S. Nonetheless, using a front-end loader to clean pens makes it more difficult to maintain a smooth pen surface and could potentially cause damage to the protective seal under the pen's surface. Because front-end loaders are efficient at removing large amounts of manure from pen surfaces per unit time, it might be beneficial to use a combination of a front-end loader for major manure removal and a scraper for final cleaning and grading. Aside from scraping pen surfaces, other management tools are available to maintain clean pens. Using concrete or products such as fly ash, which set-up similar to concrete (VanDevender and Pennington, 2004), minimizes deep mud and also allows for a solid area for bedding cattle. Potential effects on feet and leg problems in cattle need to be considered, however, when very hard surfaces are used.

Shelters

Morrison et al. (1970) provided feedlot cattle with 3.67 m x 7.32 m shelters on all but the south side of the pen to protect the animals from wind. When feedlot performance was compared to that by cattle with no shelter and subjected to artificial wind produced by fans, no improvements in ADG or F:G were noted for cattle with shelter. In fact, the ADG was slightly greater and F:G was slightly improved for cattle housed without wind protection on three sides of their pen. Mader et al. (1997) evaluated performance of cattle fed in outside lots provided either overhead shelter, a tree shelterbelt, or neither shelter nor windbreak. For yearling beef cattle, providing shelter or wind protection did not improve performance in the winter, and in the summer, providing shelter or wind protection actually decreased ADG. In a subsequent study, performance by heavier steers fed for 2 to 3 mo was significantly impaired when wind protection was not provided. The weather during this subsequent study was much more severe than in previous studies. Thus, the severity of winter conditions affects the outcome associated with providing shelter to cattle, so under moderate conditions, improvements may not be realized. Likewise, any benefit of feeding cattle in sheltered or protected areas in the winter may be offset by decreased performance in the summer.

Despite potentially negative effects of shelter from wind, providing shade to animals during the summer may be beneficial; however, the benefits of shade diminish as cattle become acclimated or when hot weather subsides, often resulting in compensation by unshaded cattle (Mader, 2003). Results from a feedlot trial conducted in Lubbock, TX (Mitlöhner et al., 2001) showed significant increases in final BW, DMI, and ADG by beef heifers provided shade during the summer compared with unshaded heifers. These results suggested that whether compensation can offset negative effects of heat stress on beef cattle performance depends on the time during the feeding period when the heat stress occurs and the overall length of the heat stress period.

Summary and Conclusions

Intake, energy requirements, and performance by beef and dairy cattle vary with season of the year. Effects of season are attributable, in part, to changes in photoperiod, climate, and associated factors like rain, snow, and mud. Nonetheless, other factors contribute to seasonal changes in performance, including changes in feed resources and management. Producers have several options at their disposal to manage cattle to avoid detrimental effects of climatic factors, but effects of many of these options (e.g., pen cleaning, provision of bedding or shelter) on performance have not been studied extensively. A proactive, but realistic, approach based on cost-benefit analysis should be used when implementing management techniques designed to mitigate seasonal decreases in performance by high-producing cattle.

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