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*Review*

# Stressors Inherent to Beef Cattle Management in the United States of America and the Resulting Impacts on Production Sustainability: A Review

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**Simple Summary:** Stress in beef cattle occurs throughout all management practices. The goal of a cow–calf producer is to produce one calf per cow a year; thus, stressors in these management systems can disrupt this desire. When homeostasis is disturbed, the efficiency of a beef cow decreases, which may lead to reproductive deficiencies, reduced daily intake, and a decreased body condition score. Therefore, this decline in production efficiency may cause a loss in the profitability of the operation. The goal of this review is to address the stressors inherent in beef cattle management systems to provide producers with insight into the best ways to mitigate beef cattle stress.

**Abstract:** Stressors are directly related to major events throughout the beef cattle production cycle. Understanding the impact stressors have on productive outcomes is critical for the efficient implementation of management strategies. Such stressors include environmental extremes, nutritional deprivation, and common management procedures. Environmental extremes such as thermal stress can disturb gestating cows' normal physiological responses, hindering reproductive efficiency. Thermal stress during the breeding season can affect embryo development causing a decrease in conception rates, although adjusting the scheduling of breeding activities can minimize losses. Additionally, suboptimal nutrition may negatively impact reproductive performance if management strategies including modifying seasonal grazing practices are not implemented. As gestation progresses, nutrient requirements increase; thus, without appropriate dietary management, poor calf performance, the loss of the body condition score, and reduced reproductive performance may result. While weaning is a common management procedure, this event is another major stress within the production system. Applying efficient strategies such as creep feeding or two-step weaning to mitigate weaning stress can maximize production efficiency. This review will explore in-depth the stressors associated with production events in the beef cattle industry and give insight into researched management strategies targeting these stressors that will improve the sustainability of the production system.

**Keywords:** beef cattle; deprivation; environment; nutrition; reproduction; stress

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## 1. Introduction

The factors associated with stress and productive efficiency in the beef cattle industry are well documented. Stress in cattle is defined as the adverse effect in the management system (internal) or environment (external) that elicits a biological response when there is a threat to the homeostasis of the organism, which forces change in animal behavior and physiology [1–3]. Homeostasis is the state in which an organism maintains a stable state in its environment [2]. Both these definitions have evolved to recognize that the response to stress differs among individuals and that physiological stress responses change over time [4].

The challenge for beef cattle producers is to accurately assess individual animal stress responses and determine whether homeostasis has been disturbed. There are three main ways to measure stress, behavioral indicators (such as temperament, pen score, and feed intake), animal-based indicators (including heart rate, morbidity, and mortality), and biomarkers (such as cortisol and prolactin) [5]. A delay in detecting and/or addressing stress can lead to prolonged and/or repeated stress within the animal. This can impact animal wellbeing as well as the economic sustainability of the operation [5].

Throughout a beef animal's life, stress can arise physically or physiologically through weather, the nutritional regimen, routine management, and handling or social interactions. When stress occurs, the animal will respond by activating the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic nervous system [5–7]. This activation results in a cascade of physiological responses designed to re-establish homeostasis including an increased heart rate, respiration rate, carbohydrate metabolism, and stimulation of the immune system [8–10]. There are two classifications of stress, acute and chronic stress. Acute stress is considered a physiological response that lasts from a few minutes to a few days and elicits the flight or fight response [11], whereas chronic stress is long-term or repeated and may be a sign of distress leading to health and reproductive disorders [5].

As for the cause of stress within a beef cattle production system, the primary stressors are environmental extremes such as thermal stress (heat, cold, wind, rain, and ice), nutritional stress (undernutrition and nutritional imbalance), and stressors associated with common management procedures (transportation and weaning) [5]. Environmental extremes associated with thermal stress are common in regions with high and low ambient temperatures and may lead to hypo- and hyperthermia, which may have lasting impacts on cattle productivity. Another stressor is nutritional stress, and while this stress may be avoided by simply choosing the right calving season or breeding season for the climate, the stress of poor nutritional management can occur during any period of the beef production cycle. Management stress, on the other hand, commonly occurs in cow–calf operations during weaning, although this type of stress can be frequently observed during transportation and feedlot entry. This paper will discuss these stressors experienced by beef cattle during their productive lives and how they can affect the economic sustainability of an operation. Using published research related to beef cattle production, this review will provide insight into stressors inherent to beef cattle production, the resulting potential impacts of stressors, and management strategies for stress mitigation. The following stressors will be addressed within this review utilizing the undermentioned order: (1) environmental extremes, (2) nutrient deprivation, and (3) management procedures. The proceeding three sections will detail each stressor and the respective impacts on the production system along with common mitigation practices associated with the stressor.

## 2. Environmental Extremes

During times of climatic extremes, the normal maintenance requirements of the cow are disturbed, thus affecting feed intake, the rate of gain, mortality, and fertility [12]. Extreme effective ambient temperatures can directly and indirectly affect productive parameters [13]. More specifically, when extreme increases or decreases in environmental temperature occur, normal maintenance requirements are disrupted, and energy is redirected from growth and development or healthy weight gain and reproduction to re-establishing homeostasis [14–16]. Environmental conditions such as drought, extreme weather, heat stress, and ambient temperatures create additional stress on both the cow and calf [13]. Thus, in extreme-weathered regions, producers will avoid these high-risked conditions to protect against potential losses [17]. This mitigation strategy, however, is limited as more than 40% of beef cows and 50% of the United States' cow–calf producers are located in tropical/subtropical climates of the south and southeast [18,19], where production must adapt to a warming climate. As such, due to the prevalence of beef cattle production systems commonly located within these regions encountering thermal stress, this review will primarily focus on the impacts of increased heat load in beef cattle on productive parameters.

### *2.1. Heat Stress*

The normal regulation of body temperature in cattle may be disrupted in hot, humid environments [20]; thus, the adoption of certain behavioral mechanisms to decrease animal exposure to heat is vital for maintaining productive efficiency [21]. When normal physiological responses are disturbed in these extreme environments, heat stress occurs forcing the cattle to become hyperthermic, and the heat exchange of metabolic functions including growth, maintenance, and lactation is reduced [22]. During times of heat stress, cattle will hyperventilate causing respiratory alkalosis. An extreme event causing abnormally hot and humid weather lasting at least one day, called a heat wave, has been a reoccurring phenomenon in regions around the United States [23,24]. In 1999, north-central Nebraska experienced a heat wave which killed 5000 head of cattle on feed [25]. Further, cattle entering the feedlot are the most vulnerable to heat stress reducing feed intake, thus affecting efficiency and growth [26].

The breeding season is another period of the beef production cycle which may be negatively impacted by thermal stress; thus, adequate planning is crucial to enhance the conception rates and reproductive efficiency of the herd [27]. Elevated temperatures and humidity result in a state of heat stress in the cow, during which the redistribution of blood flow occurs. More specifically, blood flow to internal organs, such as the uterus, is reduced, whereas blood flow to the skin and extremities is elevated. The result is an increase in uterine temperature and reduction in the perfusion of hormones to uterine tissues [28–30]. Additionally, the resulting endocrine disruption of processes controlling gonadal development and function [31] may delay the development of ovarian follicles, increase fetal and embryo loss, and reduce the ovulation rate [3,32]. Ultimately, these endocrine changes may reduce the degree of dominance of the selected follicle, thus altering the ovulatory mechanism and reducing oocyte quality [17,33]. The potential for embryonic loss is increased when the cow conceives in a time of heat stress due to disruption in the physiological regulation of oviductal and uterine function [34], which are critical for reproductive success. The root of this embryonic loss is a decrease in the synthesis of specific proteins by the embryo, causing heat shock from prolonged exposure to elevated temperatures [35–37]. In some cases, the embryo is able to adjust to the maternal environment either by self-adjustment or by acting on the dam, but this is dependent on the timing of the heat stress on the mother [34]. However, when heat stress is induced later in embryonic development, during the preimplantation period, embryo survival is increased [22,35]. These results can be attributed to the acquisition of resistance to maternal heat stress by the embryo during the four- to eight-cell stage of development called the morula stage [35,38]. Within the heat stress transcription factor system, a cellular response occurs to minimize the effects of heat stress [39,40]. Heat stress factor 1 binds to the promoter of the heat shock protein (HSP) gene, which rapidly increases expression in heat-stressed cells inducing protective mechanisms [40,41]. More specifically, the production of HSP70 increases as gestation progresses, which serves to stabilize protein structure and thereby inhibit the translation of factors inducing apoptosis [42,43]. As reported by Silva et al. [40], as maternal heat stress continues into the later stages of embryo development, the ability of resistance to elevated temperatures becomes more apparent in the embryo, indicating adaptability.

Additionally, the species of cattle, *B. indicus* or *B. taurus*, can influence cattle resistance to elevated temperatures. In a recent study, *B. indicus* embryos were less affected by heat stress compared to their *B. taurus* counterparts which had lower rates of embryonic development and reduced embryo quality [40]. It could be that *B. indicus* cattle, such as Nellore, are more adapted to environments with elevated temperatures. More specifically, reports by Hernández-Cerón et al. [44] and Paula-Lopes et al. [45] reported that Brahman embryos were more resistant to heat stress compared to Angus, as demonstrated by reduced embryonic loss. Elevated HSP gene expression is less common in *B. taurus* cattle as they perform better in cooler climates, compared to their *B. indicus* counterparts, which perform better in warmer climates [46]. Incorporating *B. indicus* genetics into a herd located in a hot, humid climate can increase herd productivity. This species of cattle has reduced metabolic rates, thus decreasing the amount of heat produced [47]. Inter- and intramuscular fat deposits insulate the animal causing the heat produced from metabolic processes to dissipate [19]. Additionally, *B. indicus* cattle have smoother hair coats that are lighter in color preventing heat absorption and reflecting solar radiation [47]. Although there has been some evidence showing that some *B. taurus* cattle varieties, such as Senepol and Romosinuano, display the genes for embryo resistance to heat stress, it is not as common compared to *B. indicus* cattle [40].

### *2.2. Climate*

Climate change is considered a long-term change in natural events causing variation [48]. The health of rangeland ecosystems has been greatly affected by climate change in the United States through the increased incidence of drought, decreased aquifer levels, and the overgrowth of invasive plant species [48,49]. Rangelands consist of diverse species of shrubs, forbs, and grasses used for many different services for cattle production [49]. Weather extremes such as heat waves and heavy precipitation have significantly increased east of the Mississippi River [48,50,51]. These weather extremes can decrease productivity and cause economic loss in the beef cattle industry.

In the U.S., when drought occurs, producers using a late-spring calving season have less time to react due to the presence of late-term cows and infant calves [17]. Some drought management strategies include early weaning, a modified stocking rate, creep feeding, supplementation, and culling [52,53]. Choosing calving seasons around extreme weather such as freezing rain, flooding, or blizzards is important as it can affect calving, breeding, and the nurturing of young calves [17]. For example, in a study conducted in the northern Great Plains, Kruse et al. [54] reported a 2% increase in calf morbidity during late-winter calving compared to early- or late-spring demonstrating the value of selecting the right calving season specific to regional environmental factors.

Globally, the increase in carbon dioxide ($CO_2$) in the atmosphere has been affecting forage availability and quality [55,56]. Grasses are categorized into warm-season (C4) and cool-season (C3) [57]. While both these grass types are nutritionally different, increased $CO_2$ levels affect both plants. With the combination of warming and elevated $CO_2$ levels, Augustine et al. [58] reported that forage production, on average, increased 38% with both C3 and C4 grasses. These authors evaluated grasses present in a northern mixed grass prairie in Wyoming, USA, which consisted primarily of the C3 grasses Western Wheat Grass (*P. smithii*) and needle-and-thread grass (*H. comata*) and C4 grass Blue grama (*B. gracilis*) [58]. While the productivity of these grasses is important, looking at the nutritional value of forage is crucial for optimal beef cattle efficiency. Accordingly, Augustine et al. [58] reported cattle grazing on the previously C3 and C4 grass species experienced a reduction in weight gain due to the decrease in total digestible nutrients. Corroborating these results, Barbehenn et al. [59] reported a decline in the protein levels of six different C3 grass species when exposed to increased $CO_2$ levels compared to six C4 species found in the same region. Conversely, McGranahan and Yurkonis [56] documented an increase in forage quality and protein levels when elevated $CO_2$ was present. Management strategies such as protein supplementation and modifying the seasonality of grazing can be implemented for the maximum efficiency and productivity of an operation [58]. Collectively, these results demonstrate the need for research investigating the impact of climate on forage quantity and quality and subsequent impacts on animal productivity.

## 3. Nutrient Deprivation

Nutrients consumed by the cow are considered the "fire of life" for reproduction and all other biological functions [60]. Nutrition influences reproduction in beef cattle [61]; thus, the body condition score (BCS), an indirect measurement of body nutritional status, influences overall productivity and reproductive performance [62]. During breeding season and before parturition, the BCS is an important factor positively impacting pregnancy rates in beef cattle [63]; thus, providing adequate nutrient intake is crucial for reproductive efficiency. Within the cow–calf production cycle, nutrient requirements change based on the physiological status of the animal and should be monitored and matched to the environment [62]. During important production cycles such as calving and breeding, successful producers will choose a season that is the least stressful and when supplemental feed resources and grazing opportunities are abundant [64].

### *3.1. Reproductive Performance*

Many husbandry practices and environmental variables/conditions such as nutritional status and feed intake can greatly affect productivity [65–68]. Ultimately, the reproductive system is mediated by metabolic hormones and energy metabolites and body temperature, thus affecting oocyte quality, uterine health, ovarian function, and the development compacity of the conceptus [69]. Adequate nutrient intake is important before and after calving as this impacts the calving-to-conception interval of the cow [65]. The acquirement of an adequate pulse frequency (4-5 pulses/10-h period) of luteinizing hormone (LH)/gonadotropin hormone-releasing hormone (GnRH) allows for the resumption of cyclicity about 60 days after calving [68], whereas the BCS at calving impacts LH pulse frequency [70]. According to Rutter and Randel, 1984 [66], there has been a general agreement that a postpartum cow with a good BCS score will return to estrus earlier, whereas obese cows with a high BCS may experience suboptimal reproductive performance. A low BCS is a reliable indicator of poor nutrient intake, which may prolong the length of the postpartum interval and return to estrus [65,67], negatively impacting the productive efficiency and economic sustainability of the operation [66]. In a report by Richards et al. [71], it was documented that the resumption of estrous cyclicity was delayed, and a greater percentage of cows conceived later in the breeding season when cows had an inadequate BCS (<4; scale from 1–10) at calving. Reproductive performance such as postpartum rebreeding is negatively affected by undernutrition due to low-quality feed or a feed shortage; thus, adequate BCSs are important throughout a beef cow's production cycles.

Choosing a breeding season that matches high forage quality with production requirements is important for not only the cow but also the calf. Environmental factors including annual rainfall and weather extremes vary among regions, thus preventing a universal breeding season [17]. For instance, in the western United States, forage quality and availability are determined by general topography, the geographic area, elevation, and amount of precipitation [72]. Additionally, the opportunity to achieve greater efficiency from the forage available is through a short breeding season [72]. An ongoing University of Nebraska study reported a decrease in pregnancy rates when cattle are bred to calve during May, which was attributed to the low forage availability and quality and the time of breeding in late summer [73]. As such, undernutrition is considered a main deficiency that influences reproduction in cattle [74,75]. Conversely, others have reported that early-summer calving resulted in adequate forage availability due to the higher crude protein concentrations that met nutritional requirements for the female with minimal supplementation [76,77]. During times of drought, the potential for aflatoxins is increased due to the growth of some species of mold [78–80]. This poisonous by-product can lower reproductive efficiency through abnormal estrous cycles and abortions, a reduced growth rate, and decreased feed efficiency [80]. The quality of the forage determines cattle forage intake, forage protein content, and mineral content, so when only low-quality forage is available, supplementation is often required [61,81–83].

Protein supplementation increases cattle's total daily energy intake, permitting greater forage consumption and digestibility [84]. When forage quality is low or around average, forage intake with protein supplementation increases, but energy supplementation does not. When forage quality is high, forage intake is constant with protein and energy supplementation. However, energy supplementation increases production cost, and as such, this may not be economically appropriate for all producers [82]. In a report by Cooke et al. [85], it was documented that performance and reproductive development were impacted detrimentally when cows on low-quality forage had a reduced supplementation frequency. Nevertheless, Kanuya et al. [86] lay out multiple management strategies available that include a component of strategic feeding supplementation when the forage quality is low to even out the feed supply over the year. Overall, it is important and sometimes necessary to meet a cow's high nutrient demand with supplementation during lactation and breeding when forage conditions and quality are not optimal [64,82]. These findings further reinforce supplementation when the forage quality is low for the optimal ruminal digestion of protein.

### *3.2. Gestation and Calving*

Stress during gestation impacts both offspring and cow performance. Nutrient requirements increase as gestation progresses; therefore, if nutrients are restricted during the last third of gestation, reproductive performance is often negatively affected by the decreasing weight and condition of the dam [61,81,87]. Hough et al. [61] reported that cows during the last 90 days of gestation lost 22 kg of body weight and decreased in the weight–height ratio when there was a reduction in protein and energy intake by 43%. In contrast, Izquierdo et al. [88] stated that the decrease in the frequency of protein and energy supplementation during the third trimester of gestation did not affect the reproductive performance or BCS of the cow pre- or postpartum. However, decreasing those supplementations during the third trimester did reduce preweaning growth performance. This suggests supplementation during this trimester does not improve maternal performance but is required for the optimal preweaning calf growth performance.

Calf performance is related to the maternal nutrition of the beef cow [89]. During the fetal period, the nutrient deficiency of the cow can reduce the progression of skeletal muscle development because the growth of new muscle fibers only occurs during this period [89–94]. Additionally, pre-calving nutrition influences the mammary gland and colostrum yield of the cow, thus affecting the disease susceptibility of the calf [89,95]. In a study by Corah et al. [96], 19% of calves from mature cows fed a low-energy diet were treated for scours. The level of gamma globulin in the cows' colostrum may have been altered resulting in the calves not being able to absorb enough immunoglobulin to support their immune system. Nutrient deficiencies during early pregnancy have a potential long-term effect on offspring as vital organs and tissues are being developed; therefore, later gestation deficiencies impact carcass weight and fetal growth [93,97]. Deficiencies of trace minerals during gestation can negatively impact the fetus's immunological, growth, and morphological development [81,98]; thus, the fetus relies on the maternal–fetal interface to meet trace mineral requirements [99]. Trace minerals such as Cu, Zn, I, Mn, Se, and Fe are commonly supplemented in a beef cow diet. Marques et al. [100] reported that gestating cows fed trace mineral supplementation (Co, Cu, Mn, and Zn) had less trace mineral concentrations in the liver when compared to the offspring. This suggests that trace mineral supplementation is directed towards fetal requirement over maternal requirement [81].

## 4. Management Procedures

Necessary management procedures such as routine handling and transportation in a cattle operation may induce a stress reaction in the animal and pose an economic burden to the livestock industry reflected for both the consumer and producer [101]. Normal procedures such as weaning, transportation, and commingling can increase the production and secretion of stress-related hormones. This, in turn, can adversely affect the immune function, growth, and reproduction of the cattle, particularly if the stress is chronic [101–105].

### 4.1. Transportation

Transportation is a necessary part of beef cattle production as it is linked to significant bovine life events such as weaning, sorting, slaughter, and processing [106–108]. However, this management practice elicits a stress response in the beef animal, which may negatively impact productive outcomes including reproductive performance and health status. Even pre- and post-transportation management such as social regrouping, noise, vibration, and crowding may elicit a stress response. Long-distance transportation is particularly detrimental to cattle's productive outcomes as it results in prolonged feed and water deprivation, causing slow recovery upon arrival [3]. A report by Marques et al. [109] compared the effects on 24-h road transportation to 24-h food and water deprivation and found that the major factor in performance loss is food deprivation during transportation. Nonetheless, performance loss during transportation can further be exacerbated due to tissue damage, discomfort, and added stress associated with the truck environment and truck-associated parameters. In addition, if cattle are shipped for long distances without food, water, or rest, an unavoidable loss of body weight, called shrink, occurs. Overall, shrink is a measure of performance, but it can also dictate the health status of the animal. The duration of the journey has a greater impact on the cow than the distance [3]. Consequently, as the duration of the journey increases, so does the mortality rate of beef cows due to factors associated with transportation. This should be a consideration for producers in planning transporting events within cattle management.

Additionally, it is important to consider the age of the cow when determining the management of transporting-related stress and its effect on immunosuppression as younger cows are more affected than older cows. Furthermore, once the cow has arrived at the destination, the cow's behavior is altered, and metabolic changes occur as the cow tries to adjust to its new environment [106]. Some of these metabolic changes include altered metabolism, immune competence, and failure in reproduction [3]. The close management of nutrition before and after transportation can play a vital role in how animals will respond to transportation stress [108]. In fact, the supplementation of zinc has been shown to improve animal welfare in response to transportation by increasing dry matter intake and reducing muscle fatigue post-transit [110]. Along with age and nutritional considerations, there are additional factors a producer should consider when transporting cattle to minimize stress such as driver training, routes of travel, truck design, and cattle behavior [107,111]. Furthermore, preweaning or preconditioning calves before transportation improves overall calf performance and decreases the incidence of bovine respiratory disease (BRD) [112,113]. Overall, while research on beef cattle and welfare during transportation in the U.S. is limited, previous work suggests the value of management strategies that minimize transportation stress and the potential for future research to explore this topic in order to manage stress more effectively within the production system.

### 4.2. Weaning

In modern cattle production systems, weaning entails the separation of calves from their dams, thus allowing the dam to improve in body condition and prepare for the next lactation [114]. There are multiple husbandry factors that occur during weaning, which may include mixing with unfamiliar cattle, novel diets and environments, frequent handling involving contact with humans, transportation, and marketing [115]. In addition, the calf undergoes sudden change during the weaning process associated with socialization as there is a loss of social contact with the dam and the milk she provides. Consequently, weaning results in behavioral and physiological alterations in the calves [114]. Therefore, the calf's immune system is altered resulting in an increase susceptibility to BRD along with an overall disruption in the homeostasis of the internal functions of the calf [115,116]. This occurs because of the number of psychological and physical stressors the animal endures during this time frame, and thus, considerations of these events associated with weaning are necessary for the proper growth and development of the calf.

Among the many behavioral changes, the most characteristic indicator of weaning stress is the change in the vocalization and activity of the calf [105]. An increase in high-frequency vocalization has been observed to provoke maternal care, reuniting with the dam, and hunger [114,117]. This is a sign of frustration from being able to receive food and care. This, however, can be detrimental to the calf as increased vocalization is energy-costly and increases the risk of attracting predators [114]. Additionally, immediately after weaning, calves have been known to increase the frequency in other stress responses associated with locomotive behaviors including walking and pacing. The number of hours a calf will spend standing compared to resting is substantially higher, which disrupts the feeding behaviors including the grazing time and consumption of solids reducing rumination time. The age at weaning can also affect production factors such as feed intake, growth, and the overall stress response [118]. In a study by Arthington et al. [119], early-weaned calves (89 days of age) had a similar feed intake as the normal-weaned calves (300 days of age) during a 28-day receiving period, but early-weaned calves gained twice the body weight than normal-weaned. Additionally, during the growing period, the dry matter intake did not differ between the two groups, but early-weaned calves were still more efficient with average daily gain compared to the normal-weaned calves. Overall, Arthington et al. [119] reported that early-weaned calves were more tolerant to stressors throughout the production periods than their normal-weaned counterparts. During weaning, according to O'Loughlin et al. [115], a percentage of the caloric nutrient intake will be used for stabilizing physiological processes associated with the immune response, depriving nutrients from processes such as growth and muscle deposition. As such, the earlier the weaning process occurs, the quicker the animal can recover from the experience to allow for proper development. For example, O'Loughlin et al. [115] examined leukocytes (neutrophils, lymphocytes, eosinophils, and monocytes) in circulation and the correlation with weaning stress. These authors reported an increase in the neutrophil count 3 days after weaning, whereas calves housed with their mother exhibited a delay in increased neutrophils [115]. Consistent with these findings, other studies have reported significant increases in circulating neutrophils following weaning [120–123]. Collectively, these results demonstrate that neutrophils are a viable biomarker to detect weaning stress and that physical separation and weaning from the dam is the most stressful to the calf. Furthermore, O'Loughlin et al. [115] report on day 14 an increase in the concentrations of plasma chemokine (CXCL8), which is an inflammatory mediator. Throughout the study, calves did not display any clinical infections or respiratory diseases, but this could be associated with husbandry management procedures performed during the study. Therefore, studies like this suggest neutrophils and plasma CXCL8 are robust biomarker indicators of weaning stress, giving light to production events that can bring about stress.

There are many different weaning methods used across beef cattle operations all with the same goal of reducing the negative consequences of weaning. The most common method of weaning is abrupt separation which has been reported to have a negative effect on cattle welfare [112,113,124]. One method used is to enable calves to cope with the changes in diet by using a practice called creep feeding [114]. Creep feeding allows the calf to have access to high-quality feed before weaning, which stimulates the calf to eat solid food and reduces its social and nutritional dependence on the dam. Studies found that calves conditioned on creep feed ate longer and had reduced behavioral stress after weaning [114,125]. Another method utilized for reducing weaning stress is mimicking the natural weaning process [114]. This can be conducted through a method that separates the cow and calf through fence-line weaning, which allows for partial physical contact without suckling [126,127]. It was found that fence-line-weaned calves had a higher daily weight gain [113], decreased vocalization, increased time eating, and less time walking during the final separation [125]. Two-step weaning or nose-flaps is a device worn by the calf for 14 days and acts as a physical barrier to nursing [127]. This two-stage method has been reported to decrease vocalization and reduce the time spent walking compared to abrupt weaning [124]. Lower-stress weaning methods may require more land, labor, and costs, thus the evaluation of these management practices needs to be addressed [127]. Understanding the physiological mechanisms associated with weaning and the resulting behaviors, beef cattle producers can adapt to reduce the weaning stress that might hinder production.

## 5. Conclusions

Once the stressors of a production system are understood, producers can find management strategies to help mitigate these stress effects. If stress during certain management strategies is not addressed, the mortality and morbidity of the herd will increase resulting in a decrease in the profitability of the production system. Overall, if decreasing the incidence of disease, implementing the optimum feeding programs, and minimizing the stress of an animal are accomplished, then reproductive efficiency will be optimized, increasing profits for the producer. Therefore, the minimization of stress is necessary for successful production management. As reported by the reviewed literature, this can be accomplished by implementing specific control strategies associated with addressing stress related to environmental extremes, nutrition, and common management procedures. This can include adaptations to the schedule associated with breeding practices, seasonal grazing, and transportation along with changes in diet and weaning practices. Minimized stress through these control strategies can result in the maximum profitability of the herd. As a producer, being able to identify indicators of stress during each stage of production and effectively addressing these stressors once they are identified ensure the effective economic sustainability of the farm and overall herd health.

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