Nutritional and Management Considerations to Minimize Stress and Optimize Production Efficiency in Cow-Calf Systems

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Introduction

Stress response is defined as the reaction(s) of an animal to internal and external factors that influence its homeostasis and wellbeing (Moberg, 2000), whereas animals unable to cope with these factors are classified as stressed (Dobson and Smith, 2000). Within beef production systems, cattle are inevitably exposed to stress during their productive lives (Carroll and Forsberg, 2007), including psychologic, physiologic, and physical stressors associated with routine management practices (Cooke, 2017). In cow-calf systems, stressors may emerge from housing management, dietary and environmental changes, inadequate or excessive nutrition, disease, and cattle disposition. Hence, management to prevent and/or alleviate stressors is critical for optimal productive efficiency in cow-calf and beef production enterprises.

Although the physiologic consequences of stress are still not fully elucidated (Pacak and Palkovits, 2001), it has been demonstrated that stressors impact the immune system, as well as different responses within the body, mainly via the hypothalamicpituitary-adrenal (HPA) axis (Elenkov, et al., 2000). Elevated cortisol is one of the main outcomes of the HPA reaction, independently if the stressor is from psychological, physiological, or physical nature (Cooke, 2017). This is the reason to why cortisol is generally considered the paramount to the neuroendocrine stress response (Sapolsky et al., 2000), and a major link between stress and productive functions (Cooke, 2017). Despite playing crucial roles in several body functions, cortisol degrades muscle and adipose tissues to increase the availability of energy to the animal. Cortisol has also been shown to impair physiological reactions associated with reproduction (Dobson et al., 2001). Supporting the negative impacts of stress + HPA axis in beef production systems, our group demonstrated a negative relationship between plasma cortisol concentrations and reproductive performance in beef females (Figure 1; Cooke, 2014, Cooke et al., 2017; Cooke et al., 2018).

Stocking Density

High stocking density is perceived as a major stressor by livestock (Grandin, 2014). However, stocking density has been overlooked by US cow-calf producers due to the extensive nature of these operations (Asem-Hiablie et al., 2016). Yet, there are

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specific segments within cow-calf production where cattle are exposed to intensive management and housing, particularly replacement heifers. In typical US spring-calving herds (\geq 70% of the nation's cow-calf operations; NASS, 2016), replacement heifers are weaned in the fall (~7 months of age) and exposed to their first breeding season the following spring (~15 months of age). During late fall and winter, heifers may be reared in drylot systems to ensure adequate feeding for growth (Olson et al., 1992; NASS, 2016) without specific considerations for stocking density. Moreover, intensifying cow-calf production by placing beef females in drylots during most or all of the year has been gaining attention (Lardy et al., 2017), as availability of grazing areas becomes limited by environmental challenges (e.g. drought), conversion to crop grounds, and use for non-agricultural purposes (e.g. accommodate urban expansion).

Despite the increasing number of beef females reared in drylots within the US cowcalf industry, our research group (Schubach et al., 2017) was the first to investigate and portray the potential adversities resultant from this management scheme to heifer welfare and reproductive development. We compared growth, physical activity, stress-related and physiological responses, and puberty attainment in beef heifers reared on high (14 m²/heifer, drylot; HIDENS) or low (25,000 m²/heifer, paddocks; LOWDENS) stocking densities from weaning until their first breeding season. The HIDENS was designed within the recommended stocking density for growing cattle reared in drylots (FASS, 2010). Heifers from both treatments received similar dietary regimens given that paddocks had no forage available for grazing, and a variety of stress-related, physical activity, and developmental responses were evaluated.

Physical activity: Heifers from HIDENS took fewer steps/week compared with LOWDENS (Table 1), given the larger area that LOWDENS heifers had available for movement. Hence, high stocking density reduced the opportunity for heifers to exercise.

Physiological responses. Cortisol concentration in hair from the tail switch is a validated biomarker of chronic stress in cattle (Burnett et al., 2014; Moya et al., 2015), given that cortisol is gradually accumulated in the emerging tail hair and its concentration represents long-term adrenocortical activity (Moya et al., 2013). Accordingly, cortisol concentration in hair from the tail switch were greater in HIDENS compared with LOWDENS heifers during the majority of the experimental period (Figure 2), corroborating that high stocking density chronically stimulated heifer adrenocortical activity. Mean expression of heat shock protein (HSP) 70 and HSP72 mRNA in whole blood during the experiment were greater in LOWDENS vs. HIDENS heifers (Table 1). Although HSP mRNA expression can also be used as diagnostic marker of stress, exercise upregulates and increases circulating concentrations of these HSP (Milne and Noble, 2002). Exercise activates the HSP response via several mechanisms including increased muscle temperature, exercise-related production of reactive oxygen species, and muscle ATP depletion (Noble et al., 2008). Hence, treatment effects detected for whole blood mRNA expression of HSP70 and HSP72 were also associated with the increased physical activity of LOWDENS heifers throughout the experiment, including prior to and during handling for sampling.

Growth responses: Elevated physical activity increases maintenance requirements in cattle (NRC, 2000). According to physical activity and space available to LOWDENS, their maintenance energy requirements were estimated to be 15% greater compared with that of HIDENS heifers (NRC, 2000). However, LOWDENS and HIDENS heifers had similar body weight (BW) gain during the experiment (Table 1), despite receiving the same diets and calculated differences in nutritional needs. Alternatively, the chronic stress experienced by HIDENS heifers likely increased their basal metabolism and maintenance requirements to the same level that physical activity increased these parameters in LOWDENS heifers.

Reproductive development: Puberty attainment was delayed in HIDENS compared with LOWDENS heifers (Table 1; Figure 3). Within heifers that reached puberty during the experiment, HIDENS were heavier and older at puberty compared with LOWDENS heifers (Table 1). Although age at puberty in cattle is highly determined by BW and growth rate (Schillo et al., 1992), high stocking density hindered puberty attainment despite similar growth between HIDENS and LOWDENS heifers. It is also important to note that heifers from both treatments achieved the recommended BW for puberty attainment during the experimental period (60-65% of mature BW; Patterson et al., 2000).

Results from Schubach et al. (2017) were novel and indicate that rearing heifers in drylots with a high stocking density is detrimental to welfare aspects including physical activity and chronic stress, resulting in delayed puberty despite adequate age and body development. Puberty attainment defines reproductive development, and regulates lifetime reproductive efficiency of beef females (Schillo et al., 1992). In turn, physical activity modulates circulating concentrations of endogenous opioids (Harber and Sutton, 1984), which impact secretion of gonadotropins required for a successful ovulation and puberty achievement in cattle (Mahmoud et al., 1989). Chronic stress and resultant increase in adrenocortical activity also impair gonadotrophin synthesis and reduce the sensitivity of the brain to estrogen (Dobson and Smith, 2000). Therefore, Schubach et al. (2017) exposed the need for research to investigate management and stocking density guidelines for beef heifers reared in drylots, which will contribute to enhancing welfare conditions and overall efficiency in US cow-calf systems.

Stress from Change in Environment and Diet

Grazing and dietary habits are learned early in life, resulting in motor skills necessary to harvest and ingest forages (Provenza and Balph, 1987). Moreover, such skills learned between weaning and breeding have been reported to carry through to the next grazing season (Olson et al., 1992). Young ruminants consume small amounts of novel food and gradually increase the amount ingested if no adverse effects occur (Chapple and Lynch, 1986). Hence, replacement heifers often spend more time and energy foraging while ingesting less food when introduced to novel environments and feed sources (Osuji, 1974; Curll and Davidson, 1983). Accordingly, heifers that grazed forage from weaning to breeding rather than being placed in drylots retained better grazing skills and had increased average daily gains into the subsequent grazing season (Olson et al., 1992).

Following this rationale, Perry et al. (2013) compared BW change and pregnancy rates to artificial insemination (AI) in replacement beef heifers that were weaned into drylots and moved to pastures after breeding, compared with cohorts that were maintained on pasture since breeding. These authors reported less BW gain after AI in heifers originated from drylots, as well as reduced pregnancy rates to AI compared with those with previous grazing experience (Table 2). Hence, the stressors elicited by change in environment, associated with inadequate forage intake, contributed to decreased reproductive efficiency in drylot heifers moved to pastures upon AI (Perry et al., 2013).

Excitable Temperament Also Is a Stressor

As mentioned above, stress response is defined as the reaction of an animal to internal and external factors that influence its homeostasis, and cattle unable to cope with these factors are classified as stressed (Dobson and Smith, 2000; Moberg, 2000). Based on this concept, the fearful and/or aggressive responses expressed by excitable cattle during human handling can be attributed to their inability to cope with this situation; therefore, classified as a stress response. Accordingly, excitable cattle typically experience changes in their neuroendocrine system and HPA axis that culminates with increased synthesis of cortisol. Several research studies reported that cattle with excitable temperaments have greater circulating cortisol concentrations during handling compared to cohorts with adequate temperament (Cooke, 2014). It is worth mentioning that the aforementioned studies evaluated *B. taurus*- and *B. indicus*-influenced cattle from different ages, genders, and across intensive and extensive systems. Hence, excitable temperaments have been positively associated with neuroendocrine stress reactions independent of breed type, age category, and production system.

As an initial attempt to associate temperament and reproduction in beef females, Plasse et al. (1970) classified *B. indicus* heifers according to temperament score (1 = calm, 2 = moderate, and 3 = excitable temperament) and reproductive score (heifers with inadequate reproductive performance received the greatest scores). These authors reported that temperament score was positively correlated with reproductive scores and negatively correlated with length of estrus, and suggested that consideration of temperament in selection programs might have a positive influence on the reproductive efficiency of the cowherd. However, the practical effects of excitable temperament on reproductive function of beef females still needed further investigation. Hence, our research group recently assessed the impacts of temperament on reproductive performance of *B. taurus* and *B. indicus*-influenced cows (Cooke et al., 2009; Cooke et al., 2011; Cooke et al., 2012).

Cooke et al. (2009) evaluated temperament at the beginning of the breeding season in Braford cows exposed to a 90-d bull breeding, and Brahman x British cows assigned to fixed-time AI followed by a 90-d bull breeding. Probability of pregnancy during the breeding season was negatively associated with temperament score, independently of breed and reproductive management (Figure 4). Similarly, Cooke et al. (2011) evaluated temperament in Nelore cows assigned to a fixed-time AI protocol, and reported

that cows with excitable temperament had reduced pregnancy rates compared to cohorts with adequate temperament (Table 3). More recently, Cooke et al. (2012) evaluated temperament at the beginning of the breeding season in Angus × Hereford cows assigned to 50-d bull breeding only, or fixed-time AI followed by a 50-d bull breeding. Cows with excitable temperament had reduced pregnancy rate, calving rate, weaning rate, and kg of calf weaned/cow exposed compared to cows with adequate temperament (Table 3), indicating that excitable temperament not only impairs reproductive performance, but also overall production efficiency in cow-calf systems.

Collectively, these results demonstrated that cows with excitable temperament had reduced reproductive performance compared to cohorts with adequate temperament. Such outcomes were independent of breed type (*B. taurus* and *B. indicus*-influenced cattle), reproductive management (AI, natural breeding, or both), and perhaps nutritional status because cow BCS at the beginning of the breeding season was not affected by temperament (Cooke et al., 2009; 2011; 2012). Plasma cortisol concentrations were greater in cows with excitable temperament (Cooke et al., 2009; 2012), which indicates that their decreased pregnancy rates could be attributed to neuroendocrine stress responses stimulated by handling for estrus synchronization and AI (Dobson et al., 2001). However, the same decrease in reproductive performance was observed in excitable cows assigned to natural breeding only, with no human interaction or handling to stimulate neuroendocrine stress responses during the breeding season. Therefore, additional mechanisms associating temperament and reproduction in beef females, including post-conception effects and potential genetic and innate deficiencies within the reproductive system of excitable cows, warrant further investigation (Cooke et al., 2012).

Conclusions

Stress has direct implications to beef cattle production systems, including reproductive efficiency of beef females within cow-calf operations. These impacts are mediated, at least partially, by neuroendocrine stress reactions that hinder ovulation and pregnancy success. Moreover, stressors from different natures (physical, physiological, and psychological) stimulate similar negative responses to cattle welfare and production. Many of these stressors are elicited by routine production practices including stocking density, nutrition, transport, and cattle responses to human handling. Therefore, management that prevents or mitigate these stressors are warranted for optimal production efficiency of cow-calf operations.

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Item	LOWDENS	HIDENS	P-value
Physical activity, steps/week	19,709	3,148	< 0.01
Growth parameters			
Initial weight, kg	211	212	0.82
Final weight, kg	356	358	0.84
Growth rate, kg/day	0.777	0.783	0.82
HSP mRNA expression			
HSP70, fold effect	3.72	2.39	0.09
HSP72, fold effect	3.48	2.77	0.04
Puberty attainment			
Total pubertal heifers, %	65.4	31.9	< 0.01
Age at puberty, days	331	364	0.04
BW at puberty, kg	324	372	< 0.01

Table 1. Physical and physiological responses in beef heifers reared in low stocking density (25,000 m²/heifer; LOWDENS) or high stocking density (14 m²/heifer; HIDENS)

Adapted from Schubach et al. (2017).

Table 2. Reproductive performance of heifers that were weaned and developed on pasture compared to heifers weaned and developed in a drylot. All heifers were moved to pasture following artificial insemination (AI)

Item	Pasture	Drylot	P-value
Number of heifers	207	2014	
Puberty status at AI, %	93.6	97.3	0.93
BW gain after AI, kg	0.94	0.13	< 0.01

Adapted from Perry et al. (2013).

Item	Adequate	Excitable	P-value
Bos indicus			
Pregnancy rate to AI, %	42.8	35.3	0.05
B. taurus			
Pregnancy rate (breeding season), %	94.6	88.7	0.03
Calving rate, %	91.8	85.0	0.04
Weaning rate, %	89.9	83.9	0.09
Calf weaning BW, kg	248	247	0.71
Calf BW weaned/cow exposed, kg	223	207	0.08

Table 3. Reproductive performance of beef cows according to temperament

Adapted from Cooke et al. (2014).



Figure 1. Probability of pregnancy to fixed-time artificial insemination (AI) in beef cows according serum cortisol concentrations at the time of AI. Pregnancy status was verified 30 d after AI via transrectal ultrasonography. A linear effect was detected (P < 0.01). Adapted from Cooke et al. (2017)



Figure 2. Cortisol concentrations in tail switch hair from heifers reared in low (25,000 m²/heifer; LOWDENS) or high stocking density (14 m²/heifer; HIDENS). ** P < 0.01 and * $P \le 0.05$. Adapted from Schubach et al. (2017).



Figure 3. Puberty attainment in heifers reared in low stocking density (25,000 m²/heifer; LOWDENS) or high stocking density (14 m²/heifer; HIDENS). Within days, * $P \le 0.05$ and ** $P \le 0.01$. Adapted from Schubach et al. (2017).



Figure 4. Probability of pregnancy in beef cows according temperament score (1 = calm, 5 = excitable) at the beginning of the breeding season. A linear effect was detected (P < 0.01). Adapted from Cooke et al. (2009).

SESSION NOTES