Impact of Nutrition, Behavior and Other Stressors on Embryonic Loss and Fertility

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Introduction

Reproduction efficiency of the herd is optimal when replacement heifers attain puberty as yearlings and calve at 2 years of age, and cows are able to become pregnant early during the annual breeding season (Bagley, 1993). Nutrition is the environmental factor that most influences reproductive efficiency of cattle (Bagley, 1993; Diskin et al., 2003); therefore, beef females should be managed for optimal nutritional status. Moreover, under and over nutrition are perceived by the organism as an insult to its homeostasis, which is the classical definition of stress (Moberg, 2000). In turn, stress also directly impairs reproductive efficiency in cattle, with stressors originated from environmental sources (i.e. dietary change, shipping) as well as the individual animal (i.e. excitable temperament).

Stress from Change in Diet

Grazing skills and dietary habits are learned early in life (Provenza and Balph, 1988). This learning resulted in the development of motor skills necessary to harvest and ingest forages (Provenza and Balph, 1987), and allowed animals to increase their consumption of forage (Lyford, 1988). These skills learned between weaning and breeding have been reported to carry through to the next grazing season (Olson et al., 1992). Furthermore, the willingness to try novel food declines with age (Provenza and Balph, 1988). Young livestock ingest small amounts of novel food and gradually increase the amount ingested if no adverse effects occur (Chapple and Lynch, 1986). Therefore, when introduced to novel food/environment livestock may spend more time and energy foraging (Osuji, 1974), but ingest less food (Arnold and Maller, 1977; Hodgson and Jamieson, 1981; Curll and Davidson, 1983). Thus when heifers grazed forage from weaning to breeding rather than being placed in drylots, they appeared to retain better grazing skills and increased average daily gains into the subsequent summer (Olson et al., 1992; Perry et al., 2013). Similar to the losses in weight that occurred (Figure 1) when heifers that were developed in a feedlot from weaning until the next spring were moved from a feedlot to grass (Perry et al., 2013); a decrease in feed intake from 120% of maintenance to 40% of maintenance resulted in a loss of 56.3 lbs over 2 weeks (4.03 lbs/day, Mackey et al., 1999). However, heifers that were developed from weaning until the next spring on range with supplementation showed no weight loss the following spring (Perry et al., 2013). Furthermore, heifers that were kept in a drylot until artificial insemination (AI; n = 214) had decreased (P = 0.04) pregnancy rates compared to heifers that had previous grazing experience (n = 207; 59.4% vs. 49.1%; Table 1). Therefore, post-insemination nutrition and dietary modifications may have a tremendous influence on embryonic survival due to the stress associated with such changes.

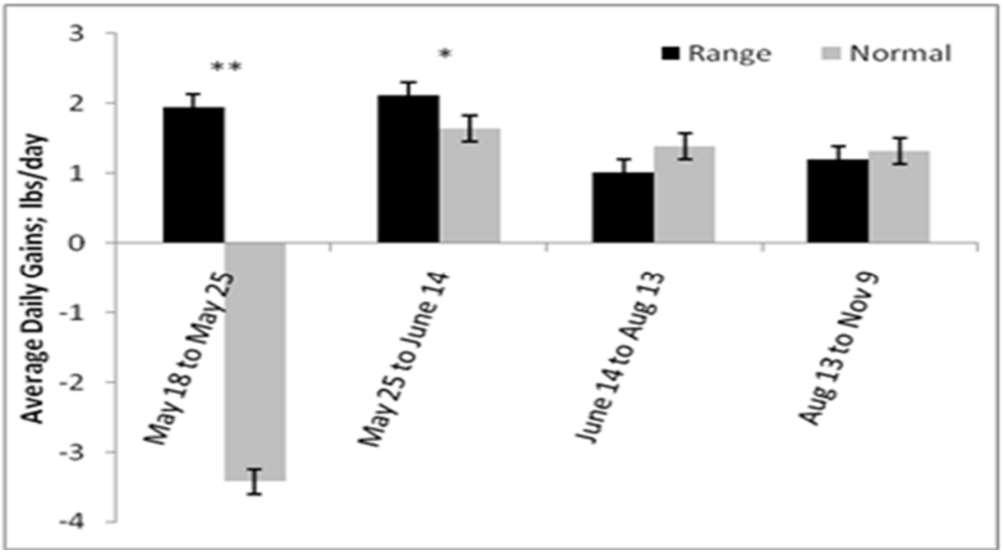

Figure 1. Average daily gain (lbs/day) of heifers weaned and developed on range (Range) compared to heifers weaned and developed in a drylot (Normal). All heifers were moved to the same pasture on May 18th (*P = 0.06; **P < 0.05)

Table 1. Reproductive performance of heifers that were weaned and developed on range (Range) compared to heifers weaned and developed in a drylot (Lot) (all heifers were moved to grass following AI on the first day of the breeding season).

	Range	Lot
Number of heifers	207	214
Puberty status, (%)[a]	89/91 (93.6%)	90/92 (97.3%)
Synchronized conception rate, (%)[b]	122/207 (59)[y]	105/214 (49)[z]

[a] Percentage of heifers that had reached puberty before the start of the breeding season
[b] Percentage of heifers pregnant during the 10 d synchronization period
[yz]Means within a row having different superscripts tended to differ (P = 0.04)

Shipping Stress and Embryonic Mortality

Knowing that nutritional changes around the time of AI can have tremendous effects on embryo survival, a common question regards the best time to move heifers. With the knowledge of the critical time points in embryonic development, it is possible to understand how stress from shipping could also result in increased embryonic mortality in cows (Table 2). When animals are loaded on a trailer and hauled to a new location, they become stressed and release hormones related to stress. These hormones lead to a release of different hormones that change the uterine environment in which the embryo is developing. During blastocyst formation, hatching, maternal recognition of pregnancy, and attachment to the uterus, the embryo is vulnerable to these changes. The most critical time points are between days 5 and 42 after insemination. Before day 5, the embryo is in the oviduct and is not subject to changes in the uterine environment. Therefore, stress does not influence embryo survivability at this time. The greater the length of time after day 42, the less severe the influence of shipping stress on embryonic loss appears to be. When the embryo is completely attached to the uterus, the embryo is supported by the dam and appears to be less easily affected by environmental changes. On the other hand, in between these time points (5 – 42 days), the embryo is at greatest risk. Shipping during this time can cause detrimental changes to the uterine environment and may result in embryonic mortality. Administration of the prostaglandin inhibitor flunixin meglumine to cows and heifers 10 to 13 days after AI (when they were transported) reduced pregnancy losses about 9% (Merrill et al., 2007). However, administration of flunixin meglumine 10 to 15 d after breeding did not increase pregnancy establishment in cows. In another study, handling heifers to administer flunixin meglumine (compared to leaving them in the pasture) reduced pregnancy rates by 6% (Geary et al., 2010). Taken together, these studies provide evidence that some heifers are more susceptible to the stress of handling.

Table 2. Effect of time of transport after insemination on pregnancy rates

	Days after insemination that transportation occurred			
	1 to 4	8 to 12	29 to 33	45 to 60*
Synchronized pregnancy rate	74%	62%	65%	
% pregnancy loss compared to transportation on days 1 to 4		12%	9%	6%*
Breeding season pregnancy rate	95%	94%	94%	

*Loss in heifers compared to percentage pregnant prior to transportation (pregnancy determined by transrectal ultrasonography). Data adapted from (Harrington et al., 1995).

Temperament and Reproduction in Beef Females

For over a century, the word temperament has been used to define the fear-related behavioral responses of cattle when exposed to human handling (Fordyce et al., 1988). As cattle temperament worsens, their response to human contact or any other handling procedure becomes more excitable. Within the beef cattle industry, producers select cattle for temperament primarily for safety reasons. However, recent studies demonstrate that cattle temperament may also have productive and economic implications to beef operations

Is Excitable Temperament a Stress Response?

Stress response is defined as the reaction of cattle to internal and external factors that affect their well-being, and animals that are unable to cope with these factors are classified as stressed. Examples are extreme temperatures, diseases, and injuries. Based on this concept, the agitated and/or aggressive responses expressed by cattle with excitable temperament when exposed to human handling can be attributed to their fear and consequent inability to cope with this situation; therefore, classified as a stress response. In addition to altered behavior, temperamental cattle may also experience changes in their body physiology, and the hormones produced during this fear-related stress reaction influence several aspects, such as growth, health, and reproduction.

One of the main hormones produced during a stress response is cortisol. Several studies reported that blood cortisol concentrations are greater in temperamental cattle compared to calm cattle (Table 3). This outcome validates that excitable temperament can be classified as a stress response, and is one of the reasons why cortisol is commonly considered paramount to the behavioral stress response.

Table 3. Blood cortisol concentrations of cattle with calm or excitable temperament. [1]

Item	Adequate	Excitable
Bos indicus		
Steers	16.7	19.6
B. indicus × *B. taurus*		
Heifers	45.5	57.9
Cows	30.7	42.4
B. taurus		
Heifers	32.1	41.8
Cows	17.8	22.7

[1] Cooke et al. (2009ab), Cooke et al. (2012a), and Francisco et al. (2012a).

Assessment of Temperament in Beef Cattle

Cattle temperament can be visually evaluated by many methods, which can be categorized into non-restrained and restrained techniques (Burrow and Corbet, 2000). Within the non-restrained techniques, cattle temperament is evaluated by their fear or aggressive response to man when they are free to move within the evaluation area. Examples of these techniques are chute exit velocity and pen score. Exit velocity evaluates the speed of an individual animal immediately after it leaves the squeeze chute by measuring the time required for the animal to travel a pre-determined distance. This assessment can be expressed in actual speed measures (i.e., feet/second), or in a 1-5 scale, where 1 are the slowest and 5 are the fastest animals. The pen score evaluates the behavioral response of an individual animal when it enters a small pen and interacts with a person standing inside the pen. Typically in a 1-5 scale, the pen score increases as the animal response becomes more aggressive toward the person. The restrained techniques evaluate cattle temperament when they are physically restricted, such as in the squeeze chute. An example of the restrained techniques is the chute score, also denominated crush score. Cattle are individually restrained in the chute and scored in a 1-5 scale according to its behavior; where 1 = calm with no movement, 2 = restless movements, 3 = frequent movement with vocalization, 4 = constant movement, vocalization, shaking of the chute, and 5 = violent and continuous struggling. This measurement can be taken in cattle that are squeezed or not in the chute. However, squeezed animals may not express their real temperament. Other methods to assess cattle temperament have also been reported; however, chute score, exit velocity, and pen score have been shown to be repeatable within animals and relatively simple to carry out during handling procedures. Additionally, these techniques are typically related to each other and with blood cortisol concentrations, indicating that these 3 measurements can similarly assess cattle temperament and denote the amount of behavioral stress that the animal is experiencing. To further increase the accuracy in temperament evaluation, producers can utilize more than one technique and combine the results into an overall temperament score, which typically relates better with blood cortisol concentrations compared to individual techniques.

Table 4. Factors that affect cattle temperament. [1]

Item	Method of Assessment [2]	Mean
Sex		
Male	*Temperament Score; 1 – 5 scale*	2.7
Female		3.0
Age		
< 2 years	*Exit Velocity Score; 1 – 5 scale*	3.1
> 2 years		2.8
Horn status		
Horned	*Exit Velocity Score; 1 – 5 scale*	2.7
Polled		3.0
Breed type		
Brahman x Hereford	*Temperament Score; 1 – 5 scale*	3.6
Brahman x Angus		3.8
Angus		1.7
Simmental x Angus		1.8
Human interaction		
Frequent	*Crush Score; 1 – 7 scale*	1.5
Infrequent		2.1

[1] Adapted from Voisinet et al. (1997), Fordyce et al. (1985, 1988), and Cooke et al. (2009a).
[2] As score increases, exit velocity increases, and crush/temperament becomes more excitable.

Factors that Influence Temperament in Beef Cattle

Cattle temperament is influenced by several factors such as sex, age, and horn status (Fordyce et al., 1988; Voisinet et al., 1997). However, none of these characteristics has been shown to affect cattle temperament as much as production system and breed type (Table 4). Cattle reared in extensive systems, such as the range cow-calf operations in the western states, are expected to have more excitable temperament compared to cattle reared in intensive operations because of less frequent interaction with humans (Fordyce et al., 1985). Further, cattle with high Brahman influence have more excitable temperament compared to *B. taurus* cattle (Fordyce et al., 1988; Voisinet et al., 1997). Therefore, cattle reared on extensive production systems, particularly if they have Brahman-influence, are potentially difficult to control and handle, which can pose significant management, economic, and productivity problems.

Temperament and Reproduction in Beef Females

Excitable temperament is detrimental to the nutritional status of cattle, given that temperamental cattle have decreased feed intake compared to calm cohorts (Brown et al., 2004; Nkrumah et al., 2007). In addition, cattle with excitable temperament also have altered metabolism and partitioning of nutrients in order to sustain the behavioral stress response, which results in further decreases in nutrient availability to support body functions (Cooke et al., 2009a; Cooke et al, 2009b). Nutritional status largely determines reproductive performance in cattle; therefore, excitable temperament may indirectly impair reproduction in beef heifers and cows by decreasing nutritional balance.

Also, the hormones produced during a stress response, particularly cortisol, directly disrupt the physiological mechanisms that regulate reproduction in beef females, such as ovulation, conception, and establishment of pregnancy. As an example, cows with calm temperament have reduced cortisol and greater blood concentrations of luteinizing hormone, the hormone required for puberty establishment and ovulation, compared to temperamental cows. Accordingly, it was recently demonstrated that beef heifers with calm temperament reached puberty sooner than temperamental cohorts (Table 5). Brahman-influenced cows with excitable temperament had decreased chances of becoming pregnant during the breeding season compared to calm cohorts. Similar relationships were detected when blood cortisol concentrations were evaluated against puberty or pregnancy instead of temperament in those heifers and cows (Table 5). In addition, Angus × Hereford cows with excitable temperament had reduced pregnancy rate, calving rate, weaning rate, and lbs of calf weaned/cow exposed compared to cows with adequate temperament (Table 6), indicating that excitable temperament not only impairs reproductive performance, but also overall production efficiency in cow-calf systems. Therefore, management strategies that improve the overall temperament of the herd are imperative for optimal productivity of cow-calf operations (Plasse et al., 1970; Cooke et al. 2009a).

Table 5. Post-weaning temperament scores (1 = calm; 5 = excitable temperament) and blood cortisol concentrations of replacement heifers that attained or not puberty by 12 months of age. [1]

Item	Non-pubertal	Pubertal
Temperament score	2.7	2.3
Cortisol, ng/mL	50.0	39.7

[1] Adapted from Cooke et al. (2009b).

Table 6. Reproductive performance of Angus x Hereford beef cows according to temperament. [1]

Item	Adequate	Excitable
Pregnancy rate, %	94.6	88.7
Calving rate, %	91.8	85.0
Weaning rate, %	89.9	83.9
Calf weaning BW, lbs	545	543
Lbs of calf weaned/cow exposed to breeding	490	455

[2] Adapted from Cooke et al. (2012).

Improving Temperament of Beef Cattle

One alternative to improve temperament and consequently benefit reproduction in beef females is to adapt them to human handling. Early studies reported that cattle accustomed to human handling had calmer temperament, reduced blood cortisol concentrations, and increased LH concentrations compared to non-acclimated cattle (Crookshank et al., 1979; Echternkamp, 1984;

Fordyce et al., 1985). Further, replacement heifers exposed to an acclimation process to human handling for 4 weeks after weaning had improved temperament, reduced cortisol, and reached puberty and became pregnant earlier compared to non-acclimated cohorts (Table 7). However, no beneficial effects on temperament and reproduction were detected when mature cows were exposed to acclimation to human handling (Cooke et al., 2009a). Therefore, adapting beef females to human interaction early in their productive lives may be an alternative to improve their temperament and consequently hasten their reproductive development. Further, including temperament in culling/selection criteria might be the most appropriate alternative to improve the overall temperament and consequent reproductive performance of the adult herd.

Table 7. Effects of acclimation to human handling on temperament, cortisol, and reproduction of replacement heifers. [1,2]

Item	Acclimated	Non-acclimated
Brahman-influenced heifers		
Chute score, 1 – 5 scale	1.4	1.9
Cortisol, ng/mL	37.8	50.5
% of pubertal heifers by 12 months of age	65.	39
% of pregnant heifers 30 days into breeding season	50	32
Angus x Hereford heifers		
Exit velocity, feet/s	7.0	8.6
Cortisol, ng/mL	26.1	32.8
% of pubertal heifers by 12 months of age	59.6	37.8

[1] Acclimated heifers were exposed to a handling process 3 times weekly for 4 weeks after weaning. Control heifers remained undisturbed on pasture.
[2] Adapted from Cooke et al. (2009b) and Cooke et al. (2012).

Conclusions

Exposing beef females to stressful situations during and after breeding has detrimental effects on their reproductive performance. Abrupt changes in diet around the time of AI has negative impacts on pregnancy success. Shipping heifers and cows beginning 8 days after AI also leads to increased pregnancy loss. Excitable temperament, a fear-related behavioral response, has detrimental effects on reproductive function of beef heifers and cows. Hence, producers should adopt management strategies to prevent such stressors and optimize reproductive efficiency in beef operations.

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