# Influence of weaning strategy on behavior, humoral indicators of stress, growth, and carcass characteristics

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**ABSTRACT:** Weaning is one of the most stressful events a calf experiences in our current beef production system. Its effects may include reduced feed intake, increased activity, slower growth, and increased susceptibility to disease. This study was designed to evaluate weaning after a 7-d placement of nose flaps at 7 mo (**N**, *n* = 40) and delaying weaning by 49 d relative to 7-mo weaning (**D**, *n* = 39) as alternatives to the industry standard; abrupt weaning at 7 mo of age (**A**, *n* = 39). The 4-yr trial utilized Angus and Angus X Senepol steer calves. Calves were randomly assigned to weaning strategy after being stratified by dam parity (heifer/cow), hair coat phenotype (normal/slick), and body weight. Behavioral observations were made on five steers per strategy group per year over the weeks surrounding weaning. Activity levels were determined by accelerometers worn on neck collars. Blood samples were obtained from the observed cattle during the last 2 yr to determine haptoglobin and cortisol concentration. Once weaned, the steers were followed through finishing and carcass characteristics obtained at harvest. Twelve of 38 steers in the N group had sores in their nostrils from the nose flaps when the flaps were removed at weaning of A/N (237 ± 3 d of age). The A and D calves were more active than N calves in the first 2 to 3 d after weaning but settled down to similar activity levels to N by the day 4. The A and D groups were more vocal than N during the same time frame. Cortisol and haptoglobin remained within normal reference ranges. Average daily body weight gain (**ADG**) was greater for D than A, who in turn had greater ADG than N during the first 42 d after A and N calves were weaned (0.69, 0.54, and 0.37 kg/d for D, A, and N, respectively; *P* < 0.01). All treatment groups graded Low Choice at harvest and exhibited similar efficiency of gain during growth and finishing (*P* > 0.2). Based on ADG during the 42 d after weaning, we recommend delaying weaning when available pasture and cow body condition support this strategy. When conditions do not permit delayed weaning, abrupt weaning may be the next viable option based on animal welfare concerns and increased handling to place and remove the flaps. Nose flaps reduced vocalization at weaning but resulted in less postweaning ADG. Based on our data, we suggest that abrupt weaning under the conditions of this study, is less stressful than we perceive it to be, based on calf behavior.

**Key words:** activity, behavior, carcass characteristics, hormones, weaning strategy



Transl. Anim. Sci. 2021.5:1-16
doi: 10.1093/tas/txaa231

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Received June 23, 2020.
Accepted December 18, 2020.

## INTRODUCTION

In current U.S. beef production systems, weaning (the separation of a calf from its dam) is perhaps the most stressful experience a calf will face. According to USDA-NAHMS (2010), 49.8% of calves are removed from the presence of their dams abruptly and relocated away from their farms of origin. Rarely is this traumatic event an isolated source of stress, since weaning is also often used as a convenient time to vaccinate, deworm, dehorn, and/ or castrate. Because all these routine husbandry practices can be stressful, their combination into a single event can have deleterious effects on calves' wellbeing (Weary et al., 2008).

The behavioral response to weaning in calves is multi-faceted. Feed intake is often reduced as a result of several factors, including more time spent walking/seeking, exposure to novel feeds, and changes in social structure in the herd (Veissier and Neindre, 1989; Price et al., 2003). Reduction in feed intake leads to weight loss or slower body weight gain (Price et al., 2003). Weaning may result in depression and/or aggression (Veissier and Neindre, 1989). In addition to behavioral changes, stress at weaning has been shown to alter the concentrations of a variety of humoral compounds as the weaned animal copes with the stressor (Arthington et al., 2005). Among these are cortisol and haptoglobin.

The stress caused by weaning can increase the susceptibility of calves to disease, especially bovine respiratory disease (Yates, 1982), which is extremely costly to the beef industry in the United States. According to USDA-NASS, about 2 million head of cattle are placed in feedlots each month (USDA-NASS, 2018). An estimated 16.2% of these are treated for respiratory disease after their arrival (USDA–APHIS, 2013) at a direct cost of $23.60 per head or about $91.7 million per year. This does not account for production losses or mortality; however, it demonstrates the impact stress-related disease has on the industry.

Strategies purported to reduce stress at weaning, such as nose flaps designed to prevent suckling while allowing physical contact with the dam (Figure 1) and delaying weaning to more closely adhere to a natural weaning time, are available; however, there has been little research to quantify the impact of these strategies on animal behavior, humoral response, and performance beyond the preconditioning phase, including impacts on carcass merit. Hypothesizing these strategies could result in measurable reductions in stress-related behaviors and increases in performance, the goals of this study were, therefore, to 1) characterize calf behavior in the weeks surrounding weaning; 2) assess calf activity levels with the use of accelerometers during the same time period; 3) monitor changes in haptoglobin and cortisol levels during weaning; 4) quantify growth efficiency during preconditioning; and 5) document any impacts of weaning strategy on feedlot performance and carcass merit.

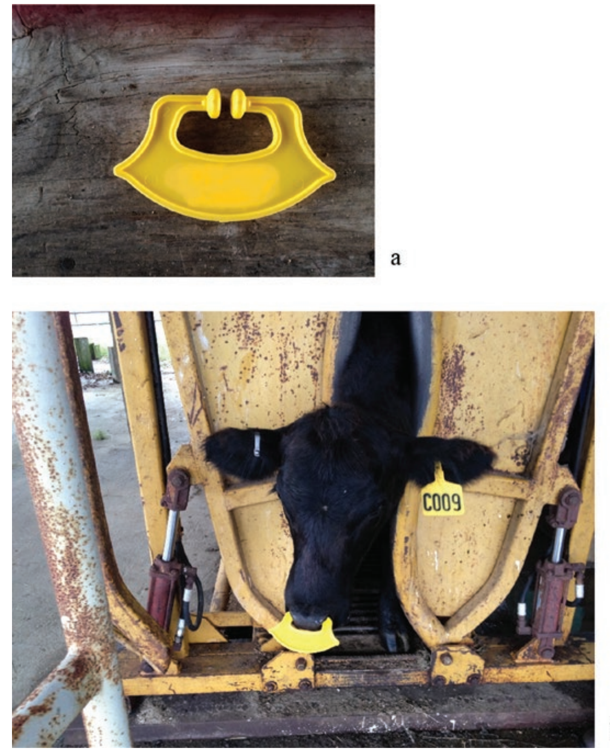



**Figure 1.** Nose flap before (a) and after (b) insertion into the nose of a calf to prevent suckling.

## MATERIALS AND METHODS

The 4-yr trial (2013–2016) was conducted at Cherry Research Farm (**CRF**; Goldsboro, NC) and Butner Beef Cattle Field Laboratory (**BBCFL**; Butner, NC) with approval from the Institutional Animal Care and Use Committee at North Carolina State University (protocols #13-081-A, #13-124-A, and #16–152).

### *Animal Husbandry Birth Through Preconditioning, Including Treatment Assignment*

Calves were born in winter to early spring (December–March), castrated at birth, and reared on pasture at CRF at their dams' side for an average of 237 ± 3 d. They received minimal concentrate prior to weaning and had free-choice access to a complete mineral supplement (supplied 16% Ca, 1.9% P, 11.4% Mg, 0.1% K, 1,002 ppm Cu, 35 ppm

Se, and 113,500 USP IU vitamin A; Renaissance Nutrition, Inc., Roaring Springs, PA) and water. Steer body weight (**BW**) was recorded and steers were vaccinated according to normal farm protocol (2 mL/steer SC, Vision 7 Somnus with SPUR®, Merck Animal Health, Omaha, NE; 5 mL/head SC, Bovi-Shield Gold®, Zoetis, Inc., Parsippany, NJ) and dewormed (5 mg/kg body weight fendbendazole, Safeguard, Merck animal Health, Omaha, NE) 28 d prior to weaning (see Figure 2 for a time line of the trial). Thirty steers per year in years-1 to -3 and 28 steers in year-4 were selected and stratified by hair coat phenotype (assessed at birth to be slick or normal), dam parity (first calf heifer or cow), and BW (mean = 254 ± 6.7 kg). They were randomly assigned to one of three weaning strategy groups. Strategies were traditional, abrupt weaning (**A**, *n* = 39); weaning after placement of a nose flap for 7 d (**N**, *n* = 40); or weaning delayed by 49 d from the date A and N were weaned (**D**, *n* = 39). Treatments A and N ran concurrently.

The steers and their dams were maintained as a single herd until 14 d prior to weaning. At this time, because there were only 10 accelerometers available and to create greater uniformity among the steers used to determine activity levels and behavior, the heaviest five calves from mature cows in each treatment group, balanced for hair coat phenotype, were selected for behavior observation (**OBS**) and activity level determination. Using similarly sized steers also protected the smaller steers from potential, postweaning aggression by larger steers while they would be housed, postweaning, in a corral. All three groups of steers had BW recorded 14 d before weaning of A and N. This was considered the actual start of the experiment and the day when steers designated for A and N OBS (*n* = 5 per treatment) received accelerometers (Actical®, Philips Respironics, Bend, OR), attached via neck collars, as they passed through the handling facility. The OBS steers were sorted out of the main herd and put in a 3.4 ha pasture with their dams, separated from the remainder of the herd to facilitate observation. The D steers, including D OBS, and their dams were maintained with the main herd until 7 d prior to their weaning day. Forage in both pastures was similar and consisted primarily of bermudagrass (*Cynodon dactilon* (L.) Pers.), crabgrass (*Digitaria siderograpta* Chiov.), and dallisgrass (*Paspalum dilatatum* Poir.). Mixed grass hay or small grain baleage was offered to both animal groups when pasture became limiting.

After 7 d, both OBS and non-OBS steers from all three treatment groups had BW recorded (A and N 7 d preweaning), nose flaps were placed in N steers (both OBS and non-OBS), and steers and dams were returned to their respective pastures.

At the end of another 7 d, all steers (OBS and non-OBS, all treatments) had BW recorded, nose flaps were removed from N, and A and N calves were placed into corrals (A/N OBS steers, alone, in a small corral [14.6 × 17.7 m] and A/N non-OBS steers in a large corral [18.9 × 67.1 m] with weaned heifers). Weaning was delayed by 8 d for A and N in yr 4 as the result of flooding from Hurricane Matthew. Some non-OBS N steers lost their nose flaps prematurely each year (2, 1, 2, and 7 for 2013, 2014, 2015, and 2016; respectively). All OBS steers kept their nose flaps for the duration of the observation period.

Weaned calves had ad libitum access to hay, water, and trace mineralized salt. Grain (80.2% ground corn, 17.3% soybean meal, and 2.5% limestone; as fed) was offered each morning at

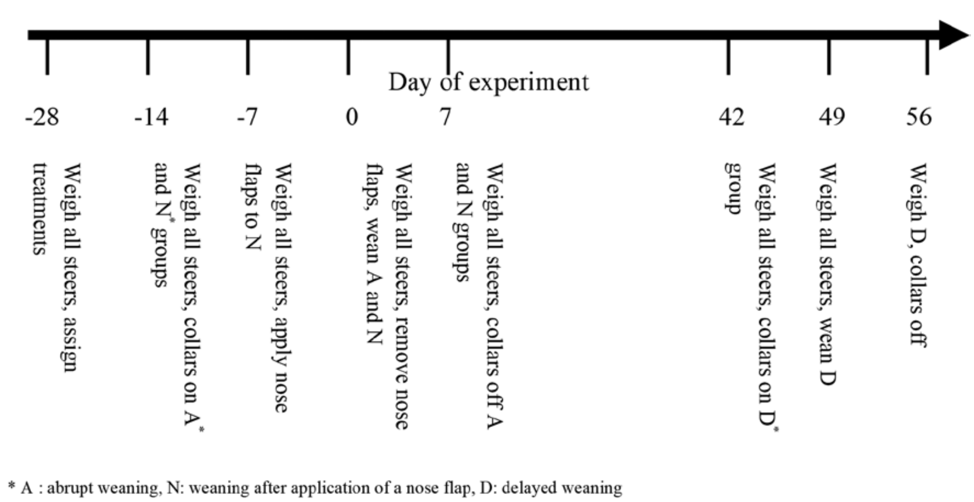



**Figure 2.** Time line of the experiment for each year.

approximately 0750 h, increasing from 1.4 to 2.3 kg per head per day over the 3 d immediately after weaning. Grain offered was held at 2.3 kg per animal throughout the remainder of the preconditioning period. Weaned, OBS steers remained in the smaller corral for 7 d, after which the accelerometers were removed and they were then turned in with the larger group of weaned cattle. All weaned cattle had BW recorded 7 d after weaning.

Dams of the A and N cattle were sent to a pasture out of sight of their offspring to accomplish weaning of A and N treatment groups. The D steers and their dams were placed in a separate pasture to await delayed weaning. Dam body condition for all three treatment groups was assessed on a scale of 1–9 (1 being emaciated and 9, obese) at weaning of A and N in 2013–2015. Flooding prevented safe assessment in 2016.

At 42 d after the weaning of A and N groups, steers in all three treatment groups had BW recorded, D OBS received accelerometers (7 d preweaning), and were returned to pasture for preweaning observation. All 10 D steers (OBS and non-OBS) were housed together to facilitate care, both on pasture, before weaning, and in the smaller corral, after weaning. The delay period between weaning of A and N and weaning of D remained consistent to protocol (49 d) in 2016. Delayed weaning and recording of weaning BW for D took place 7 d after the placement of the collars (49 d after weaning of A and N) and final BW for D steers in this phase of the experiment were collected 7 d after weaning, when accelerometers were removed.

Following the weaning of D steers, the weaned cattle were preconditioned for 45 ± 7 d at CRF prior to being shipped to BBCFL for growing and finishing. During the preconditioning period, calves were housed on pasture, received 2.3 kg grain mix (80.2% ground corn, 17.3% soybean meal, and 2.5% limestone; as fed) per head per day and had access to ad libitum hay, trace mineralized salt, and water.

### *Accelerometry and Behavior Observations*

Behavioral observations began the day after application of the accelerometers (13 d before weaning for A and N, 6 d before weaning for D). The observations made during the first observation period served as a baseline week since none of the steers were subjected to treatment. Observations were collected over 10-min intervals for 1 h, three times per day at approximately 0730, 1130, and 1530 h. A single person made observations to minimize disturbance to the cattle and to reduce variation created by multiple observers. Observations were made on four consecutive days (Tuesday through Friday). The observer watched for predesignated behaviors that were considered key indicators of stress or absence thereof. Categories were grazing, eating hay, standing still or walking slowly, suckling or attempting to suckle, ruminating, lying down, and other behaviors (included drinking, grooming, eating minerals, scratching, playing, aggression, etc.). Individual vocalizations were counted. Observations of each individual steer were made at least three times during each 10-min interval and an effort was made to make the observations without disturbing the animals.

The second observation period for A and N began 6 d before weaning, and was as described previously, lasting 4 d. During this period, A steers had accelerometers, only, and N steers had both accelerometers and nose flaps, allowing us to watch for behavior changes in both groups caused by the placement of the nose flaps relative to base week. This period was not present during the observation of D, since no animals wore nose flaps.

The final observation period for all treatment groups began the day after weaning day. It also proceeded as described earlier with the exception that new behavior categories were tracked. Categories after weaning included eating hay, eating concentrate, standing still or walking slowly, pacing, lying down, rumination, and all other behaviors. Again, individual vocalizations were counted. Concentrate was offered after 20 min of observation had been completed (at approximately 0750 h). Observations were made for four consecutive days as previously described.

After all observations had been completed, individual steer behavioral observations were tallied by category within 10-min periods and then totaled for each day of observation by animal. The total number of observations was calculated for each steer by totaling all observed behaviors for each day. Rumination was considered a simultaneous behavior and not tallied in the total. (e.g., A calf noted as standing or lying could also be ruminating. Only the standing or lying was tallied in the hourly total). The "other behaviors" category was also not included in the tally because many were very short duration and were for observation purposes, only. Percentage of total observations for individual categories, including rumination, was then calculated (e.g., Observations tallied as "standing" in day/total observations in day × 100 = % standing).

Accelerometers were preprogrammed to begin measuring activity at 0800 h on the day they were placed on the steers (at least 1 h prior to the placement of the first collar in its host animal). The accelerometers were programmed to collect data once per minute (the longest interval available) to ensure battery life throughout the collection period. None of the collars/accelerometers became displaced prior to the end of the data collection period. Once removed from the calves 7 d after weaning, accelerometry data were downloaded using associated software (Actical 3.10; Respironics, Inc., Murrysville, PA). One device malfunctioned in year-2 and its data was not included in the analysis. Animal activity output was expressed as "relative activity units" (**RAU**). Relative activity data was totaled for each day of observation.

### *Blood Collection for Humoral Analysis*

Addition of new faculty between years 2 and 3 facilitated the analysis of blood for cortisol and haptoglobin. As a result, during year-3 and -4, blood samples were collected via jugular venipuncture using 3.8 cm × 18-gauge needles into 10 mL Vacutainer® tubes (Beckton Dickinson, Franklin Lakes, NJ) containing Lithium Heparin. Two tubes per steer were collected on day –14, –7, –5, 0, +2, and +7 relative to weaning for A and N and at day –7, 0, +2, and +7 for D. Blood tubes were immediately placed on ice and stored until processing. Plasma was separated by centrifugation at 2.316 × *g* for 30 min. Plasma was pipetted into plastic storage vials, frozen, and stored at –10°C. Once all samples for the year had been collected, they were shipped on dry ice to the University of Florida, Range Cattle Research and Education Center, Ona, for determination of plasma cortisol and haptoglobin according to procedures described in Moriel et al. (2016). Intra- and inter-assay CV for haptoglobin (respectively) were 2.17 and 3.43% in year 3 and 3.18 and 4.38% in year 4. Cortisol was determined as a single assay with intra-assay CV of 5.30 and 4.98% in years 3 and 4, respectively.

### *Husbandry at the Growing/Finishing Facility*

Steer BW was recorded upon arrival at BBCFL. Steers were quarantined on pasture for 28 d and adapted to a corn silage-based, growing total mixed ration (**TMR**, see Table 1 for ingredient composition and Table 2 for nutrient content). Following quarantine, steer BW was again recorded and the steers stratified by hair coat phenotype, weaning treatment, and BW for assignment to 3 pens (2.7 × 9.4 m). Pens were equipped with Calan gate feeders (American Calan, Northwood, NH) which allowed only one steer access and so permitted determination of individual feed intake. Steers received the growing TMR ad libitum and had access to free-choice water. Daily feed was weighed into each steer's feeder in the morning and residual feed assessed visually at the next morning's feeding. Feed offered was adjusted up or down to achieve maximum residuals of approximately 5% of feed offered. Residual feed was removed and weight recorded at 2-week intervals unless excessive residual was present, risking spoilage and contamination of the fresh feed. In this case, residual was removed more frequently and feed offered adjusted downward.

Once the steers had learned how to operate the gates, steer BW was recorded on two consecutive days to obtain start weight for the growing phase. Steer BW was recorded every 28 d until day 84, when 2-d consecutive BW was recorded in preparation for the transition to the finishing phase. To accomplish transition without digestive upset,

**Table 1.** Diet composition of feedlot total mixed rations (TMR) with standard deviations (SD) fed to steers weaned at 237 d age either abruptly or after 7 d nose flap placement or after a 49 d delay at 286 d or age

| Component, % of DM (unless otherwise indicated) | Growing TMR | Finishing TMR |
|---|---|---|
| | Basal concentrate mixtures | |
| Corn | 34.2 | 81.2 |
| Soybean meal | 60.4 | 13.0 |
| Limestone | 3.6 | 1.6 |
| TM salt | 1.3 | 0.3 |
| Rumensin 90, kg/tonne | 0.5 | 0.2 |
| Vitamin A, D, E; kg/tonne | 1.4 | 0.4 |
| | Total mixed rations (SD) | |
| Corn silage, % as fed | 86.6 (3.47) | 13.4 (0.32) |
| Basal concentrate, % as fed | 33.5 (3.47) | 66.5 (0.32) |

**Table 2.** Nutrient composition of feedlot total mixed rations (TMR) with standard deviations (SD) fed to steers weaned at 237 d age either abruptly or after 7 d nose flap placement or after a 49 d delay at 286 d or age

| Component, % of DM (unless otherwise indicated) | Growing TMR (SD) | Finishing TMR (SD) |
|---|---|---|
| Dry matter, % | 39.4 (4.17) | 71.2 (3.19) |
| Crude protein | 12.5 (2.48) | 12.5 (1.19) |
| ADF | 19.3 (3.01) | 8.1 (0.68) |
| NDF | 31.4 (4.09) | 16.5 (1.46) |
| Ash | 4.7 (1.25) | 3.4 (0.95) |
| Ca | 0.5 (0.16) | 0.3 (0.05) |
| P | 0.3 (0.05) | 0.3 (0.01) |
| Mg | 0.2 (0.04) | 0.2 (0.01) |
| K | 1.1 (0.22) | 0.7 (0.03) |
| Na | 0.1 (0.08) | 0.1 (0.05) |
| Fe (ppm) | 259 (76.7) | 178 (35.7) |
| Mn (ppm) | 52 (5.8) | 29 (4.2) |
| Zn (ppm) | 66 (24.3) | 53 (24.3) |
| Cu (ppm) | 26 (11.4) | 16.7 (3.2) |
| TDN | 74.6 (2.44) | 82.8 (1.12) |
| NE lact | 0.78 (0.03) | 0.87 (0.01) |

TMR was shifted over 10 d to the finishing formulation (Tables 1 and 2), after which the cattle received the finishing diet ad libitum until the majority of the group had deposited at least 1.25 cm of backfat. Steer BW was recorded on day 140 and day 141 and as they were loaded for shipping to Cargill Meat Solutions (Wyalusing, PA) for harvest 8.5 ± 6.8 d later. Shipping weights were used to determine dressing percentage and adjusted end weights.

Samples of TMR and feed ingredients were collected twice each week and stored at –10°C until after the cattle had been harvested. Samples of feed refusals were taken each time refusals were removed from feeders. They were also stored at –10°C. All samples were composited into monthly samples and dry matter (**DM**) content determined (Shreve et al., 2006; NFTA method 2.2.2.5). Daily feed dry matter intake (**DDMI**) was calculated from total feed DM offered and total refusal DM removed: (Feed DM offered–Refused DM)/number of days.

### *Carcass Measurements*

Hot carcass weights were recorded at harvest and dressing percentage calculated. Trained graders from USDA assigned quality and preliminary yield grades to the carcasses based on visual appraisal. After carcasses had chilled for at least 24 h, measurements of back fat (**FAT**); kidney, pelvic, and heart fat (**KPH**); and rib eye area (**REA**, between the 12th and 13th rib) were made. Marbling scores were assigned and final yield grades (**YG**) calculated [YG = PYG + (required REA – actual REA) * 0.3 + (% KPH – 3.5) * 0.2].

### *Statistical Analysis*

Design for this experiment was a randomized, complete block replicated over 4 yr. Data were analyzed using Proc Mixed of SAS (SAS v. 9.4; SAS, Inc.; Cary, NC). For all models, year was the random term and where appropriate, calf was used as a repeated measure. Class variables included year, dam parity, hair coat phenotype, whether the steer was OBS or not, status of the nose flap at removal (missing or present), OBS period, day of OBS, and treatment group. Steers from N whose flaps were lost prior to weaning were not included in the analysis. One OBS steer lost its flap prior to scheduled removal date; however, not during observation, so his data was included. Two calves had inexplicably high (10 times higher than average) haptoglobin levels at one collection day each (one at weaning in year 3 and the other 2 d after weaning in year 4). These data points fell outside the 99th percentile as determined by Proc Univariate of SAS, so they were not included in the analysis. Any main effect which returned a *P*-value greater than 0.2 was eliminated from the model as was interactions that returned *P* > 0.2. Final models included treatment, hair coat phenotype, OBS period, day of OBS, and the interaction of period and day, where it was significant.

Significance was defined as $P \leq 0.05$ and a trend was defined as $0.05 < P \leq 0.10$. While hair coat phenotype did return significant differences for some parameters, there were no significant interactions between hair coat phenotype and weaning strategy. Differences for hair coat phenotype will not be discussed in this paper.

## RESULTS AND DISCUSSION

### *Birth Through Preconditioning*

***Cow body condition.*** Cow body condition scores at the weaning of A and N were 5.5, 5.4, and 5.9 (SEM = 0.16) for 2013, 2014, and 2015; respectively, well within the 5.0–7.0 range recommended for breeding beef cattle (Eversole et al., 2005). Adequate condition at this stage indicated that no harm would come to the cows by allowing steers in the D group to continue to suckle beyond the traditional weaning date used for A and N. Cows who reared A calves had lower BCS than cows who reared N calves (5.4 and 5.8, respectively; SEM = 0.11, $P = 0.01$) and cows who reared D calves were intermediary (BCS = 5.6). There is no clear explanation for these findings. Since all the cows remained within the recommended range and differences were small, however, the differences are not likely of any biological significance.

***Steer growth.*** Steers were 209 ± 3 d of age at treatment assignment and did not differ by treatment ($P = 0.72$). Observed calves were older than those not observed (212 vs. 206 d, $P < 0.01$). Since the heaviest calves were selected for observation, it is logical that they were also the older animals. The difference, while statistically significant, was small and would not have impacted the outcome of the trial.

Body weight among treatment groups did not differ at the trial's initiation (Table 3) and the treatment groups remained similar in BW through preconditioning and at shipment to the finishing facility. We also found few differences in ADG by the steers. We had hypothesized that N calves, deprived of suckling, would gain less BW than A calves that had accessed to milk as a supplement to pasture and hay. Boland et al. (2008) and Enríquez et al. (2010) reported significantly greater ADG by control calves, destined for abrupt weaning, than by calves wearing nose flaps in the period prior to weaning. Haley et al. (2005) reported greater gain in control calves than calves wearing nose flaps in one trial, but not in another, similar to our findings. There was no delayed weaning treatment group in any of these trials. There is no clear explanation for variation in the ADG results in these experiments. It is possible that day-to-day variation in BW negated small treatment differences. Possible contributing factors to the differences in results between experiments are management differences such as penning cattle as compared to leaving them on pasture or moving them from one location to another at the onset of the trial.

During the 7 d following weaning of the A and N groups, the D steers gained more than their weaned peers (Table 3, $P < 0.01$) while A and N gained at similar rates. This is not surprising since the D steers were able to supplement forage with milk and they remained with their dams. Boland et al. (2008) and Enríquez et al. (2010) reported greater ADG for abruptly weaned cattle as compared to those that had worn nose flaps. Haley et al.

**Table 3.** Growth parameters among steer calves weaned abruptly (A, 237 d age), after 7 d nose flap (N, 237 d age) application, or after a time delay of 49 d (D, 286 d age) from birth until shipment to a finishing facility with standard errors (SEM)

| Parameter | A | N | D | SEM |
|---|---|---|---|---|
| BW* 14 d before weaning A and N, kg | 260.4 | 263.8 | 263.2 | 5.5 |
| BW 7 d before weaning A and N, kg | 266.6 | 268.4 | 262.7 | 5.3 |
| BW at weaning A and N, kg | 275.7 | 278.1 | 273.3 | 4.7 |
| BW 7 d after weaning A and N, kg | 280.1 | 279.8 | 286.4 | 5.0 |
| BW 42 d after weaning A and N, kg | 302.5 | 285.2 | 293.1 | 4.8 |
| BW at shipment to finishing facility, kg | 321.4 | 317.3 | 314.1 | 4.8 |
| ADG*: birth to weaning of A and N, kg/d | 1.01 | 1.02 | 1.00 | 0.02 |
| ADG: 7 d preweaning of A and N, kg/d | 1.33 | 1.13 | 1.71 | 0.59 |
| ADG: 7 d postweaning of A and N, kg/d | 0.61[a] | 0.31[a] | 1.86[b] | 0.26 |
| ADG: 42 d after weaning A and N, kg/d | 0.54[b] | 0.37[a] | 0.69[c] | 0.04 |

[a,b,c] Values without common superscripts differ ($P \leq 0.05$).

* BW: body weight; ADG: average daily gain.

(2005) reported inconsistent results after weaning and suggested plain of nutrition being better in 1 yr than the others which could have caused the difference in results.

At 42 d after weaning A and N, BW of all three treatment groups remained similar; however, ADG varied (Table 3, $P < 0.01$). The D group gained faster than A, which gained faster than N. Haley et al. (2005) reported that in the period of 7–21 d postweaning, calves that had worn nose flaps and abruptly weaned cattle gained similarly. Enríquez et al. (2010) reported similar gains for abruptly weaned and calves that had worn nose flaps over the 44-d postweaning period. Management differences could possibly explain the difference between our results and those reported elsewhere. The calves in both other trials mentioned were pastured and received no supplementation while the weaned calves in our trial were housed in a drylot where they received hay and concentrate. While our calves had been exposed to the hay previously, they had not been completely reliant on it and their experience with supplemental concentrate was minimal. Additionally, 12 of 38 steers that had worn nose flaps had bloody sores inside their nostrils. It is possible that soreness reduced feed intake. Incidence of nasal sores from the use of nose flaps has not been described in the literature so its frequency is unknown.

***Humoral indicators of stress.*** Plasma cortisol and haptoglobin are low in healthy, unstressed cattle. Baseline cortisol reference concentrations for cattle reported in the literature are variable but fall within the range of 0.3 µg/dL (Hopster et al., 1999) to 5.5 µg/dL (Doornenbal et al., 1988). All cortisol concentrations in the present study were within the normal range (Table 4). Mean cortisol in D was greater ($P < 0.01$) than in A and N steers and was greatest when baseline concentration was determined, prior to weaning and observation. There is no clear explanation why this treatment group would have elevated cortisol as compared to their A and N peers. Doornenbal et al. (1988) reported that serum cortisol increased from 3.85 to 5.49 µg/dL as steers aged from 7.5 to 12.5 mo; however, there was only a 7-week age difference between the D and A/N calves so age difference may only account for a small portion of our observed treatment variation. Cortisol remained consistent within D steers over time; however, the A and N steers had variations in cortisol over the course of the experiment. Cortisol was elevated in A at nose flap insertion and in both A and N 2 d after nose flap insertion as compared to baseline levels. Since the response was seen in both groups and concentrations were back to baseline levels at weaning, increased handling or the presence of the observer may have had an influence on cortisol in these calves, which as the trial progressed, had time to adapt to both handling and the observer. The D calves were handled at the same times as the A/N calves which could explain their lack of response over the baseline week.

Haptoglobin is often undetectable in healthy cattle; however, research indicates reference

**Table 4.** Concentrations of humoral stress indicators in steers weaned abruptly (A, 237 d age), after 7-d placement of a nose flap prior to weaning (N, 237 d age), or after a delay of 49 d (D, 286 d age) with standard errors (SEM)

| Humoral factor | A | N | D | SEM |
|---|---|---|---|---|
| Cortisol, µg/dL | 1.90[a] | 1.58[a] | 2.37[b] | 0.14 |
| Baseline | 1.70[a;x] | 2.07[ab;xy] | 2.70[b] | 0.28 |
| Nose clip insertion | 2.43[yz] | 2.25[yz] | n/a | 0.21 |
| Nose clip + 2 d | 2.56[z] | 2.41[z] | n/a | 0.21 |
| Weaning day | 1.84[xy] | 1.54[xy] | 1.93 | 0.28 |
| Weaning + 2 d | 1.90[ab;xyz] | 1.30[a;x] | 2.43[b] | 0.28 |
| Weaning + 7 d | 2.17[ab;xyz] | 1.43[a;x] | 2.44[b] | 0.28 |
| Haptoglobin, mg/dL | 4.26[b] | 5.59[b] | 0.29[a] | 0.88 |
| Baseline | 8.73[b;z] | 9.21[b;z] | 3.57[a;y] | 1.73 |
| Nose clip insertion | 7.89[z] | 7.53[y,z] | n/a | 1.73 |
| Noseclip + 2 d | 5.32[y,z] | 6.61[y,z] | n/a | 1.73 |
| Weaning day | 1.80[x,y] | 1.21[x] | ND*[x,y] | 1.83 |
| Weaning + 2 d | 4.88[b;x,y] | 7.04[b;y,z] | ND[a;x] | 1.83 |
| Weaning + 7 d | 1.61[a,x] | 4.81[b;x,y] | 0.92[a;x,y] | 1.73 |

[a,b]Values without common superscripts differ between treatments within time ($P < 0.05$).

[x,y,z]Values without common superscripts differ between times within treatments ($P < 0.05$).

*ND: not detectable.

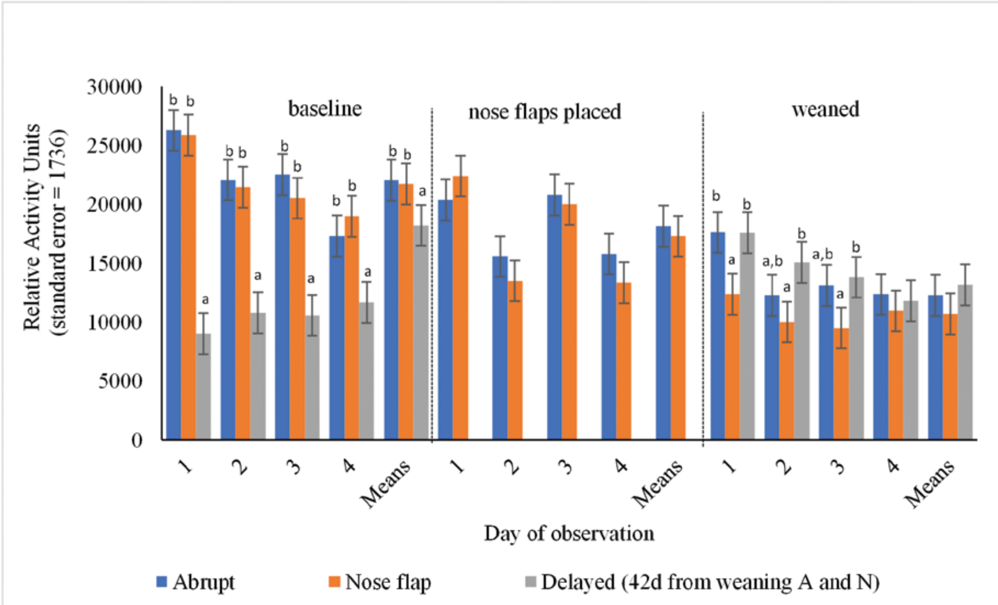
concentrations of 0–20 mg/dL (Gånheim et al., 2003; Chan et al., 2004; Seppä-Lassila et al., 2013) for healthy cattle. Haptoglobin has been shown to increase above baseline with the challenge of respiratory disease (Godson et al., 1996) with concentrations peaking (110 mg/dL) 8 d after infection. At weaning, Arthington et al. (2003 and 2005) reported peak concentrations (2.4–14.9 mg/dL) 3–4 d after weaning. While within the reference range found within the literature, they considered the increase they observed a response to the stress of weaning. Haptoglobin concentrations in our steers remained within the reference range throughout the trial (Table 4). For all treatment groups, haptoglobin concentrations tended to decline between baseline sampling and weaning. Only those in N had elevated haptoglobin at 2 d after weaning as compared to concentrations on weaning day; however, this may not have been the optimum time to detect changes in this protein and it is possible that had we been able to sample in the 3–4 d after weaning time period, elevations would have been detected.

Across all sampling times, the steers in the A and N treatment groups had greater average haptoglobin concentrations than D. The difference was driven largely by the greater concentrations found in A and N at baseline and preweaning samples since levels were similar among treatments at weaning. One possible explanation is the greater time interval from preweaning vaccinations for the D steers (70 d) as compared to A and N (14 d); however, Arthington et al. (2013) and Rodrigues et al. (2015) found haptoglobin levels returned to prevaccination levels 3–6 d after vaccination. Based on these findings, haptoglobin in our A and N calves should have been at normal levels before the trial began. There is therefore no clear explanation for the difference and the concentrations reported for A and N were still within the range for healthy cattle. Having a larger number of cattle could have possibly given us additional insight.

Haptoglobin levels responded to time within each treatment (Table 4). For A and N, levels declined from collection of baseline samples to weaning, rose slightly by 2 d after weaning, and then declined again to preweaning levels by 7 d postweaning. Thompson et al. (2011) reported elevated haptoglobin 10 d after weaning in calves that had worn nose flaps for 7 d and in control calves as well. This time frame was beyond that in our study and beyond what was described in other research, previously mentioned. Delay weaned steers' haptoglobin was undetectable by weaning and remained more consistent over the course of the experiment. Because we saw no consistent patterns of change for cortisol and haptoglobin and because of our small sample size, it is difficult to determine whether there was a humoral stress response or not.

***Steer relative activity and behavior.*** The accelerometer output is reported as RAU, which are an omnidirectional reflection the subject's activity and energy expenditure. Robért et al. (2009) demonstrated accelerometers can successfully be used to accurately detect such activities as lying, standing, and walking and that they are useful in monitoring circadian activity patterns of feedlot steers (Robért et al., 2011). Treatment and treatment by period and treatment by period by day interactions were detected ($P < 0.01$). Calves assigned to the D group had fewer RAU during the week for determining baseline activity levels than calves assigned to either the A or N treatments (10,545 vs. 21,969 and 22,172 RAU, respectively; $P < 0.01$). The most obvious explanation for the difference is that by the time the accelerometers were placed on the D calves (42 d after A and N were weaned), pasture was scarce and so they spent more time at a hay feeder, where they were relatively still, than did the A and N calves, which spent more time grazing and only relied on hay when pasture diminished. This assumption is supported by a decline in RAU for the A and N calves over the course of observation periods 1 (Figure 3, baseline) and 2 (nose flaps placed). Day to day variation was likely influenced by weather. All the cattle were stationary during windy periods of heavy precipitation and such weather existed more in some years than others and could have resulted in less RAU for certain days.

The greatest difference in activity levels were seen over the first 4 d after weaning. Both the A and D calves had significantly more RAU than N (Figure 3, $P = 0.03$) on day 2. On day 3 and 4, D calves continued to have more RAU than N ($P = 0.02$ and 0.06 for day 3 and 4, respectively) while A calves were intermediary in RAU and did not differ from either D or N ($P > 0.15$). By the fourth observation day after weaning, all treatment groups exhibited similar RAU. Weaned calves were housed in a corral and so had limited space for movement. Had they been weaned in a pasture setting, RAU counts and treatment differences might have been even greater; however, they probably would have followed a similar pattern over time. Price et al. (2003) reported calves weaned on pasture increased their walking by 2.5 times over calves weaned to a drylot.




[a,b] Bars without common superscripts differ ($P < 0.05$)

**Figure 3.** Relative activity of steers weaned abruptly (237 d age), after 7-d placement of a nose flap prior to weaning (237 d age), or after a delay of 49 d (286 d age).

We are not aware of other published research where 3-dimensional accelerometers were used to record activity levels specifically associated with weaning; however, Haley et al. (2005) placed pedometers, which measure 2-dimensionally, on a subset of their experimental cattle and noted that the number of steps per day did not differ between control and nose flap calves during the baseline period. Once nose flaps were placed, the nose flap cattle took about 2,000 more steps per day than the control group. They reported on the day following weaning, the abruptly weaned calves took over 17,500 steps more than the calves that had been fitted with nose flaps. Both treatment groups returned to baseline levels of steps per day by day 4 after weaning. Over the 8-d period surrounding weaning, their nose flap calves averaged 4,084 fewer steps than the controls. These results show similar activity patterns to those in our study.

The objective of placing nose flaps is to prevent suckling while allowing physical contact with the dam. During the baseline period, A calves were observed suckling and/or attempting to suckle more than either N or D calves (Table 5, $P < 0.01$). Since older calves (D) would be expected to be closer to natural weaning, the difference between A and D is not surprising; however, there seems to be no obvious explanation for the difference between A and N during the baseline week since calves were of similar age and all had similar access to suckling. This pattern continued during the week of nose flap placement, with A suckling more frequently than N attempted to suckle (7.2 vs. 4.7%, respectively; $P < 0.01$). Over this observation period, both groups suckled or attempted to suckle more frequently than during the baseline week. The observer reported several A calves nursing from N dams during the nose flap period when N calves could not access milk and N calves persistently trying to suckle. The increase in suckling and/or attempting to suckle by A calves could have been due to the opportunity to obtain milk from multiple dams but this cannot be affirmed based on study design. Suckling attempts by N calves tended to decline over the 4-d observation to 2.5% of observations (day 1 vs. day 4, $P = 0.07$). This is similar in time frame to data reported in Hötzel et al. (2012) who saw suckling attempts decline 4–5 days after nose flap placement.

Walking or pacing the fenceline is a commonly observed behavior in calves recently separated from their dams. The calves in the present study exhibited this seeking behavior although it declined in A and D over the course of the observation period (Table 5, $P = 0.07$). On the first observation day, the A steers paced more than the N steers and the D steers were intermediary, in agreement with

**Table 5.** Behavior of steers weaned abruptly (A, 237 d age), after placement of a nose flap for 7 d (N, 237 d age), or after a 49-d delay (D, 286 d age) presented by treatment least square mean (LSM) or daily observations with standard errors (SEM)

| | | | Treatment | | | |
|---|---|---|---|---|---|---|
| Behavior (units) | Observation period | LSM or day no. | A | N | D | SEM |
| Suckling or attempt (% of observations) | Baseline week | LSM | $4.8^{b,x}$ | $2.8^{a,x}$ | $2.3^{a}$ | 0.7 |
| | Nose flap in | LSM | $7.4^{b,y}$ | $4.7^{a,y}$ | N/A | 0.7 |
| | Noseflap day | 1 | $9.0^{b,y}$ | $6.0^{a,y}$ | N/A | 1.4 |
| | Noseflap day | 2 | $4.6^{x}$ | $5.4^{xy}$ | N/A | |
| | Noseflap day | 3 | $6.7^{xy}$ | $4.9^{xy}$ | N/A | |
| | Noseflap day | 4 | $9.2^{b,y}$ | $2.5^{a,x}$ | N/A | |
| Pacing (% of observations) | Postweaning | LSM | 6.6 | 3.2 | 4.1 | 1.6 |
| | Postweaning day | 1 | $18.8^{b,z}$ | $2.8^{a}$ | $11.7^{ab,y}$ | 3.5 |
| | Postweaning day | 2 | $7.2^{y}$ | 2.1 | $4.2^{xy}$ | |
| | Postweaning day | 3 | $0^{x}$ | 5.4 | $0.8^{x}$ | |
| | Postweaning day | 4 | $1.1^{x}$ | 2.4 | $0^{x}$ | |
| Vocalizations (count per hour) | Baseline week | LSM | $3.3^{x}$ | $2.0^{x}$ | $1.0^{x}$ | 1.5 |
| | Nose flap in | LSM | $2.9^{x}$ | $3.5^{x}$ | N/A | 1.3 |
| | Postweaning | LSM | $20.6^{c,y}$ | $7.3^{a,y}$ | $14.4^{b,y}$ | 1.5 |
| | Postweaning day | 1 | $46.5^{c,y}$ | $12.8^{a,y}$ | $39.3^{b,y}$ | 3.0 |
| | Postweaning day | 2 | $26.8^{c,y}$ | $6.8^{a,x}$ | $13.9^{b,y}$ | |
| | Postweaning day | 3 | $6.1^{x}$ | $5.5^{x}$ | $3.4^{x}$ | |
| | Postweaning day | 4 | $3.1^{x}$ | $4.1^{x}$ | $0.9^{x}$ | |
| Eating forage (% of observations) | Baseline week | LSM | $45.0^{y}$ | $45.0^{y}$ | $46.3^{y}$ | 2.1 |
| | Nose flap in | LSM | $44.0^{y}$ | $46.0^{y}$ | N/A | 2.1 |
| | Postweaning | LSM | $13.1^{a,x}$ | $22.3^{b,x}$ | $25.9^{b,x}$ | 2.1 |
| | Postweaning day | 1 | $8.7^{a,x}$ | $23.8^{b}$ | $31.4^{b}$ | 4.1 |
| | Postweaning day | 2 | $12.8^{x}$ | 21.1 | 23.2 | |
| | Postweaning day | 3 | $20.1^{y}$ | 25.5 | 28.7 | |
| | Postweaning day | 4 | $10.9^{x}$ | 18.6 | 20.1 | |
| Lying down (% of observations) | Baseline week | LSM | $22.6^{b,x}$ | $21.8^{b,xy}$ | $14.3^{a}$ | 2.2 |
| | Nose flap in | LSM | $25.2^{x,y}$ | $20.6^{x}$ | N/A | 2.2 |
| | Postweaning | LSM | $30.9^{b,y}$ | $30.1^{b,y}$ | $14.9^{a}$ | 2.2 |

$^{a,b}$Values without common superscripts differ between treatments within period ($P < 0.05$).

$^{x,y,z}$Values without common superscripts differ between periods or days within treatment ($P < 0.05$).

pedometer measurements by Haley et al. (2005). Pacing declined for A and D over the first 2 days after weaning. On day 3 after weaning, pacing activity was similar across treatments ($P = 0.17$). The observed pacing helps explain the pattern of the RAU. We detected no overall treatment differences for pacing behavior.

Vocalization in cattle is also often associated with seeking behavior when herd members are separated from one another and with stressors, such as hunger (Weary et al., 2008). Prior to weaning, vocalization counts were similar among treatment groups and low (Table 5; $P > 0.15$). Vocalizations were attributed, by the observer, to movement of feed or animals within sight of preweaning pastures. Following weaning, vocalization counts increased dramatically. All three treatment groups had greater vocalization counts on the first day of observation after weaning than they had prior to weaning (Table 5, $P = 0.02$). Nose flaps reduced vocalizations compared to both A and D ($P < 0.01$). All the calves had returned to preweaning levels of vocalization by the third day of observation, with N calves achieving preweaning levels a day earlier than A or D, suggesting they may have dealt with weaning anxiety more quickly. Haley et al. (2005) also reported greater vocalization counts on the second and third days after weaning from abruptly weaned calves as compared to calves weaned following placement of a nose flap. Vocalization counts for the control calves were similar in magnitude to those in our study. Price et al. (2003) used fenceline weaning instead of placing nose flaps. With this alternate, 2-step weaning process, vocalizations were also reduced as compared to abrupt weaning. Again, counts per animal per hour were similar in magnitude to those in this study.

Cattle in the A and N treatment groups spent more time grazing during the baseline week than those in D (33, 27, and 2% of observations, respectively; $P < 0.01$). As mentioned earlier, this is likely due to changes in pasture forage availability than to applied treatments. Conversely, D cattle spent more time eating hay during the baseline week than A or N (44, 12, and 18% of observations, respectively; $P < 0.01$). When grazing and hay observations were combined into "eating forage," treatment differences before weaning disappeared and all the cattle spent about 45% of their time eating forage (Table 5). This is similar in magnitude to behavior reported by Price et al. (2003) prior to weaning.

Following weaning, the calves' only forage source was hay. All treatment groups spent less time eating forage postweaning than preweaning (Table 5; 18% vs. 45%, respectively; $P < 0.01$). Calves in the A group tended to spend less time eating forage than either N or D (13% vs. 22 and 26%, respectively; $P = 0.06$); however, the majority of this difference was the result of the earliest part of the observation period, since by the third day of observation after weaning, there were no significant differences (Table 5). Haley et al. (2005) also reported less time spent eating among abruptly weaned calves as compared to calves weaned after nose flap placement. Boland et al. (2008) reported that calves with nose flaps in place spent less time eating (grazing) than either control or calves separated from their dams by a fenceline prior to remote separation from the dams. Following remote separation of the dams, Boland et al. (2008) reported that there was no further reduction in eating time among calves that had worn nose flaps, while abruptly weaned controls and fenceline calves experienced reductions in eating to levels below those of calves that had worn nose flaps, although the fenceline group spent more time eating than the control group. Price et al. (2003) also found that fenceline separation prior to weaning reduced the decline in eating time after remote separation. The results of Boland et al. (2008) suggest that two-stage weaning with a fenceline separation may be a better alternative than nose flaps, since it reduced the decline in time spent eating.

Upon weaning, it is common for producers to offer concentrate to calves to replace the nutrition that had previously come from milk. We initially offered 1.4 kg per steer per d of a corn-based concentrate and increased this to 2.3 kg per steer per d over 3 d. There were no treatment differences in concentrate consumption and all calves readily accepted it ($P > 0.36$). Time spent eating concentrate was determined by pecking order within each group rather than by treatment. Concentrate was cleaned up within 30 min.

Calves from all three-treatment groups spent similar amounts of time lying down prior to weaning (Table 5, $P > 0.61$). During the observation period after weaning, the D calves spent less time lying down than either A or N calves, with the exception of the fourth day after weaning, when all spent similar amounts of time lying down. We had anticipated that A calves would spend less time lying down than N calves, after weaning, and that D and N calves would follow similar patterns for lying down. One possible explanation for what we observed is that the N calves, who paced less than A and seemed more at ease in the absence of their dams, may have been prone to lying down and that their behavior influenced their A peers, since all were housed together. These two treatment groups ran concurrently and had been housed together to facilitate observation by a single observer from the initiation of the trial and so they remained together after weaning. Delayed wean calves were housed in absence of other weaning strategy groups. Haley et al. (2005) reported that abruptly weaned calves spent less time lying down than those weaned with nose flaps, in contrast to our observations. Their cattle were maintained on pasture rather than being housed in a corral and this difference may have influenced behavior.

We postulated that another possible influence on lying down could have been environmental temperature. The Thermal Heat Index (THI) developed by Thom in 1959 is the basis for the Livestock Weather Safety Index (WSI; LCI, 1970) which divides heat stress risks into classes. Based on the WSI, THI between 23 and 26°C can reduce productivity and THI between 26 and 29°C can pose danger to animal wellbeing. Hahn (1999) states that ambient temperatures above 15°C can induce nominal performance losses in feeder calves gaining 0.8 kg/d. Dry bulb temperatures during the 1130 and 1530 h observation sessions after weaning were 22.3 and 23.7°C for the A and N calves, respectively, and 13.1 and 14.3°C for the D calves ($P < 0.01$). The A and N calves were also subjected to heat indices of 25.5°C or greater on 3 of 4 observation days at both the mid-day and afternoon periods in each year of the trial. The D calves, on the other hand, had less than 1 instance per year of heat index exceeding 25°C after weaning. Elevated temperatures and HI during the postweaning period for A and N may have caused these steers to rest more in shaded areas of the corral and to lie down in these areas where the soil may have been cooler. The D steers would not have experienced the same need to cool themselves. Mattachini et al. (2011) reported a negative correlation between lying behavior in lactating dairy cows and temperature-humidity index and Heinicke et al. (2019) reported increased activity with decreased lying time. Cattle in these trials had access to shaded, free-stall housing; however, so observed behaviors may not be comparable to those of cattle provided with minimal shade. A clear explanation for our observations is not apparent.

Observed rumination frequency was similar ($P$ = 0.37) across treatments prior to and during nose flap placement. Calves were ruminating at about 15% (SEM = 3.4%) of observations. Following weaning, all treatment groups seemed to ruminate more with some days having observation frequencies of approximately 20%; however, there were no overall treatment differences in rumination behavior with frequency means of 19.0, 17.8, and 14.4% for A, N, and D, respectively, after weaning. Enriquez et al. (2010) reported treatment x day interactions for rumination where rumination increased for control calves on day 2 following weaning before returning to preweaning levels on day 4. Fenceline weaned calves had greater rumination frequency on the day after weaning and returned to preweaning frequency on day 4 after weaning.

### *Growing and Finishing*

Following their quarantine, the steers began the growing phase of the trial and BW of the three treatment groups was similar (Table 6, $P$ = 0.21). Weights of the three treatment groups remained similar through shipment to the harvest facility ($P$ = 0.36) as did ADG ($P$ = 0.78). Daily DMI was also not affected by weaning strategy ($P$ = 0.91). As a result, there were no differences in feed efficiency between the three treatment groups ($P$ = 0.65). With the exception of studies with early weaning, we are not aware of other studies that have followed groups of calves of similar age weaned by different weaning strategies through harvest. Thompson et al. (2011) took ultrasound carcass measurements; however, they do not report feedlot gain or feed consumption. Our data suggest that weaning strategy did not impact growth beyond the backgrounding period (42 d after weaning A and N) when calves are of similar age.

### *Carcass Characteristics*

Weaning strategy had minimal impact on carcass characteristics (Table 7). Carcass weight, back fat thickness, and KPH fat percentage were not different among treatments. The D steers had slightly smaller ribeye area than A steers ($P$ = 0.04) with N steers being intermediary for this characteristic. All three-treatment groups had ribeye area that was similar to current industry average of 89.7 $cm^2$ and fell within the optimal range for the food service sector for cooking time and tenderness (77.4–96.6 $cm^2$) reported by Dunn et al. (2000). These results are in agreement with those of Myers et al. (1999)

**Table 6.** Growth and finishing characteristics of steers weaned abruptly (A, 237 d age), after 7-d placement of a nose flap prior to weaning (N, 237 d age), or after a delay of 49 d (D, 286 d age) with standard errors (SEM)

| Parameter (units) | A (SEM) | N (SEM) | D (SEM) |
|---|---|---|---|
| BW* at start growing phase, kg | 353 (4.2) | 349 (5.1) | 343 (3.9) |
| BW at end growing phase, kg | 505 (5.4) | 507 (9.4) | 494 (5.0) |
| BW at end finishing phase, kg | 610 (7.2) | 594 (7.0) | 601 (8.9) |
| BW at harvest, kg | 629 (7.4) | 622 (9.3) | 615 (7.3) |
| ADG* growing phase, kg/d | 1.8 (0.05) | 1.8 (0.08) | 1.8 (0.04) |
| ADG finishing phase, kg/d | 1.4 (0.05) | 1.5 (0.09) | 1.4 (0.05) |
| ADG overall, kg/d | 1.6 (0.03) | 1.6 (0.04) | 1.6 (0.03) |
| DMI* growing phase, kg/d | 10.7 (0.18) | 10.5 (0.23) | 10.5 (0.17) |
| DMI finishing phase, kg/d | 10.4 (0.29) | 10.7 (0.33) | 10.5 (0.28) |
| DMI overall, kg/d | 10.5 (0.18) | 10.6 (0.23) | 10.5 (0.18) |
| Gain:feed, growing phase | 0.17 (0.003) | 0.17 (0.006) | 0.17 (0.003) |
| Gain:feed, finishing phase | 0.14 (0.004) | 0.14 (0.006) | 0.14 (0.003) |
| Gain:feed, overall | 0.15 (0.002) | 0.16 (0.003) | 0.16 (0.002) |

*BW: body weight; ADG: average daily gain; DMI: dry matter intake.

**Table 7.** Carcass characteristics of steers weaned abruptly (A, 237 d age), after 7-d placement of a nose flap prior to weaning (N, 237 d age), or after a delay of 49 d (D, 286 d age) with standard errors (SEM)

| Parameter | A (SEM) | N (SEM) | D (SEM) |
|---|---|---|---|
| Dressing percentage, % | 60.0 (0.30) | 60.1 (0.37) | 60.5 (0.29) |
| Adjusted end weight, kg* | 636.6 (8.3) | 626.8 (10.3) | 618.8 (8.1) |
| Back fat, cm | 1.37 (0.03) | 1.58 (0.04) | 1.49 (0.03) |
| Kidney, pelvic, heart fat, % | 2.03 (0.09) | 2.06 (0.13) | 2.08 (0.09) |
| Ribeye area, $cm^2$ | 92.7 (1.42)[b] | 90.2 (1.88)[a,b] | 87.0 (1.40)[a] |
| Yield grade | 2.90 (0.09)[a] | 3.19 (0.12)[a,b] | 3.22 (0.09)[b] |
| Marbling score† | 5.44 (0.17) | 5.55 (0.23) | 5.83 (0.17) |
| Quality grade‡ | 17.00 (0.21) | 16.91 (0.27) | 17.31 (0.20) |

[a,b] Values without common superscripts differ ($P < 0.05$).

*Adjusted end weight = hot carcass weight/mean dressing percentage.

†Marbling score: 5 = small amount, 6 = modest amount.

‡Quality score 16 = select, 17 = low choice, 18 = average choice.

and Meyer et al. (2005) who showed that early weaned calves that had been exposed to concentrate feeding for longer periods of time had an advantage at harvest over steers weaned at an older age. This principle could also apply to the comparison of normal-aged and delay weaned cattle. Thompson et al. (2011) reported no difference between A and N steers in REA, backfat thickness, or marbling score their study. Delayed weaned steers had poorer yield grade than A ($P = 0.02$) in the present study, due to their smaller REA; however, based on current grid marketing standards, no Yield Grade discounts across treatments would be expected. The steers received an average quality grade of Low Choice.

## IMPLICATIONS

Results of this study imply that when steers are followed to harvest, weaning strategy has little impact on the efficiency of production or on end product quality. The presence of nasal lesions in 12 of 38 steers which received nose flaps suggests further research into the animal welfare implications of this strategy may be warranted. This study also suggests that the producer who sells his/her cattle after a brief preconditioning period should consider the weaning strategy chosen. Our data indicates that if cows are in good body condition and there is adequate pasture forage available, delaying weaning would enhance ADG and allow the sale of heavier calves, increasing profitability. Humoral data collected in this trial were not consistent with data presented in the literature. Had our sample size been larger, we may have seen clearer humoral effects; however, since all the steers remained within published reference ranges, it may be that weaning, especially when it is accomplished in the absence of other stressors such as co-mingling and transport, is not as stressful as people perceive it to be based on animal behavior, particularly when the cattle are being managed in a rotational grazing system where they receive human contact multiple times per week.

## ACKNOWLEDGMENTS

The author wishes to acknowledge Mark Clements and all the staff at Cherry Research Farm (Goldsboro, NC) and at Butner Beef Cattle Field Laboratory (Bahama, NC) for their assistance with this project. Without their continued support and hard work, completion of this study would not have been possible. We are grateful for consistent funding from the North Carolina Cattle Industry Assessment for the duration of the project. Lastly, we are also grateful to Dr Philipe Moriel (Range Cattle Research and Education Center, University of Florida, Ona, FL) for his assistance with analysis of blood samples for hormones.

*Conflict of interest statement.* None declared.

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