Simulated preslaughter holding and isolation effects on stress responses and live weight shrinkage in meat goats

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ABSTRACT: The objective of this experiment was to determine the effects of preslaughter isolation and feed withdrawal duration on physiological responses and shrinkage in goats. A total of 84 Spanish does (36 mo of age, average weight 35 kg) were individually weighed and scored for excitability before two replicate (day) trials. The does were feed-deprived (FD) or fed (F) in holding pens (treatment, TRT) for either 0, 7, 14, or 21 h (TIME). At the end of the holding periods, FD and F does were blood-sampled (n = 6 does/treatment/time/replicate) and weighed again to assess physiological responses and shrinkage, respectively. Individual does from each pen were blood-sampled again after imposing one of three handling post-treatments: a 15-min isolation with no visual contact with other does (I); a 15-min isolation with visual contact (IV); or no isolation (C, control). Plasma cortisol concentrations were higher at 0 h than at other holding time periods (P < 0.01). Plasma triiodothyronine, thyroxine, and leptin concentrations, and differential leukocyte counts were not influenced by any of the factors. The rate of decline in glucose concentrations over TIME was greater in FD than in F group (TRT × TIME, P < 0.05). The overall plasma creatine kinase activity peaked at 7 h before reaching a lower level at 14- and 21-h holding (P < 0.05). Plasma urea nitrogen concentrations were higher at 0- and 21-h than at 7- and 14-h holding (P < 0.01). Plasma nonesterified FA concentrations in the FD group remained at an elevated level during holding, but in the F group the levels decreased at 7 h and remained at that level (TRT × TIME, P < 0.01). Excitability scores did not have any effect on the variables measured. Shrinkage increased with longer holding time, but more prominently in the FD group (TRT × TIME, P < 0.01). Plasma cortisol concentrations were greater in I and IV groups than in the C group (P < 0.01). The novelty of environment during preslaughter holding, and social isolation may be more potent stressors than feed deprivation in goats, although shrinkage may increase with increasing feed-withdrawal times.

Key Words: Goats, Isolation, Preslaughter Holding, Stress

Introduction

Overnight holding of animals at the slaughter facility, a common commercial practice, helps livestock recover from transportation stress prior to slaughter (Kannan et al., 2000). Preslaughter fasting also helps reduce carcass contamination with gut contents during slaughter (Gregory, 1998). However, prolonged feed deprivation, social disruption, and the novelty of environment that accompany preslaughter holding may increase stress responses and metabolic changes. Preslaughter stress in goats can greatly affect muscle metabolism and may negatively impact meat-quality characteristics (Kannan et al., 2001).

While well-designed slaughter plants can facilitate easy movement of livestock in holding pens (Grandin, 1990), any delays in procedures involving social isolation of animals can increase stress responses. Prolonged delays during movement of livestock from holding pens to restraining pens should be avoided to reduce animal stress (Cockram and Corley, 1991).

Goat meat (chevon) is a major source of animal protein throughout the world, particularly in Asia and Africa. In the United States, the importance of goats as meat animals has increased in recent years, as evidenced by increased importation of goat carcasses (Glimp, 1995; Pinkerton, 1995). Meat goats are frequently transported long distances to slaughter facilities that accommodate goats, but were designed for other species.
Specific data regarding physiological responses to different stress factors during preslaughter holding of goats will help in designing facilities and in determining management practices that are ideal for meat goats. The objectives of this experiment were 1) to determine the stress responses and live weight losses due to simulated preslaughter holding of goats for different durations and 2) to determine the stress responses to social isolation with and without visual contact with other goats.

Materials and Methods

Animals

The protocols for this study were approved by the Animal Care and Use Committee at Fort Valley State University (Fort Valley, GA). Spanish does (n = 84; 36 mo of age, average weight 35 kg) were used for this experiment. The study was completed in two trials (Replicate), with 42 does being used on each day. The replicate trials were conducted 2 d apart during August 2000. Spanish does are horned and are generally raised for meat production. The goats were not dehorned in the present study and were raised primarily on free-range pasture with a grain supplement. Care was taken to avoid including any animals showing estrous behavioral signs in the study.

Holding Treatments

On each day of the experiment, the animals were removed from pasture and were confined in a smaller enclosure 1 h before blood sampling. Grain supplement and water were provided in this enclosure. All 42 animals were blood-sampled (Pre-trial) in the morning (0800 h). At 1000 h, 12 does were randomly chosen (21-h holding group), loaded onto a livestock trailer, and taken to the holding pens (2 × 3 m). The holding pens were located less than 1 km from the Pre-trial holding area, and the transportation did not exceed 5 min. Immediately after unloading, individual animals were weighed and scored for excitability. Six of the does were allotted to a randomly chosen pen with no feed, but with ad libitum access to water (feed-deprived, FD), while the remaining six does were allotted to another pen with ad libitum access to feed (concentrate) and water (Fed, F). The F groups were maintained as controls to estimate stress responses due to feed withdrawal component alone during holding. Another group of does were similarly treated at 1600 h and were designated as the 14-h holding group. At 2400 h, another group of 12 does were similarly transported, weighed, and penned (7-h holding group). The floor space allowed for the penned goats was 1 m² per animal. The recommended floor-space requirement for sheep in commercial holding pens is 0.5 m² (Grandin, 1990). At 0800 h the following day, the remaining 6 does were transported, weighed, and blood-sampled immediately (0-h holding group). These goats were the controls for holding time effect and were randomly assigned to FD and F (n = 3) groups. Blood samples were also collected from FD and F (treatment, TRT) animals held for different durations (TIME). Each animal was weighed again after holding to calculate shrinkage loss. Baseline values were assessed using Pre-trial samples from 12 animals chosen randomly.

Excitability Scores

Excitability scores were recorded when the animals were weighed the first time, before being assigned to pens for holding. The excitability ratings were conducted only once under the assumption that temperaments of individual goats do not change over time. Grandin (1993) reported that temperament scores were stable over time in cattle. Individual animal weights were recorded using a weigh chute (with electronic scale) that does not squeeze, but is narrow enough to minimize animal movement. Excitability scores were recorded using a four-point system based on the behavior of each animal, similar to the method used by Voisin et al. (1997). A score of 1 to 4 was given to each animal by a single observer, with a higher score representing a more excitable animal. A score of 1 was given if the animal was calm with little movement; a score of 2 if the animal shook the weigh chute occasionally; a score of 3 if the animal continuously moved and shook the weighing device; and a score of 4 was given if the animal struggled violently while being weighed. The observer also handled each animal by securing its horns just before weighing, thus also obtaining a closer assessment of the animal’s temperament.

Isolation Post-treatments

After the holding time part of the experiment, individual goats were subjected to one of three post-treatments (PTRT): (i) 15 min in an isolation box with no visual contact with other goats (I); (ii) 15 min in an isolation box, but with maintained visual contact with other does (IV); and (iii) no isolation PTRT (control, C). Isolation boxes, each measuring 120 × 43 × 90 cm (length × width × height), were placed in a pen (3 × 4 m) adjacent to the holding pens. This pen contained several goats (0-h holding) for IV animals to maintain visual contact. The PTRT I box was covered on all sides except the top, but PTRT IV box was covered only on the two sides. The front and rear panels of the IV box had vertical windows allowing the animal to maintain visual contact with other goats. After the 15-min isolation treatments, the I and IV animals were blood sampled to assess stress levels. The C animals were blood-sampled immediately after leading the goat to the isolation pens.

Behavioral Observations

Video cameras were used to monitor primarily the agonistic activities of animals held for 21 h (FD and F).
Behavioral observations were made during alternating 2-h periods, with 2 h of recording and 2 h of pause, for a total period of 10-h holding. Frequency of agonistic encounters in both F and FD pens was noted during each 2-h observation period. Frequencies of standing, walking, lying, and drinking behaviors were also noted every 5 min during each 2-h observation period. Agonistic activities were recorded when physical contacts were made (hits) or attempted (threats) with head or horn(s) of initiator of the behavior. Standing, walking, lying, and drinking behaviors were mutually exclusive. In the F group, when the animals showed feeding behavior, only agonistic encounters were recorded. Therefore, feeding behavior mutually excluded any of the other behaviors.

Blood Sampling

Blood samples were collected by venipuncture into evacuated vacuum tubes containing 81 μL of 15% EDTA solution by trained personnel. All efforts were made not to agitate the animals during blood sampling, and the samples were drawn as quickly as possible after catching. The blood tubes were kept on ice until separation of plasma. After smears were prepared on microscope slides for differential leukocyte counts, the blood tubes were centrifuged at 1,000 × g for 30 min, the separated plasma was placed into screw-cap vials, and stored at −40°C until analysis.

Radioimmunoassays

Plasma cortisol, triiodothyronine (T₃), thyroxine (T₄), and leptin concentrations were measured using RIA. Plasma cortisol concentrations were analyzed using Coat-A-Count (Diagnostic Products Corporation) RIA kit as described by Kannan et al. (2000). The sensitivity of the assay was 2.0 ng/mL. Within- and between-assay coefficients of variation were 4.8 and 6.4%, respectively. Plasma T₃ and T₄ concentrations were also determined using Coat-A-Count (Diagnostic Products Corporation) RIA kits. The sensitivity of the T₃ assay was 0.07 ng/mL and within- and between-assay CV were 5.9 and 6.3%. The sensitivity of the T₄ assay was 2.5 ng/mL. The within- and between-assay coefficients of variation were 3.3 and 8.1%, respectively. Plasma leptin concentrations were analyzed using a Multi-Species Leptin RIA kit (Linco Research, St. Louis, MO). The assay was validated for parallelism and recovery for goats in our laboratories as described by Kannan et al. (2000). The sensitivity of the leptin assay was 1.0 ng/mL and within- and between-assay CV were 3.6 and 8.7%, respectively.

Blood Metabolites

Plasma glucose, creatine kinase, and urea nitrogen (PUN) concentrations were analyzed using commercially available diagnostic kits (Sigma Diagnostics, St. Louis, MO). Glucose concentrations were enzymatically determined using the Trinder reagent procedure (Procedure No. 315) at 505 nm. Creatine kinase (CK) activity was colorimetrically determined using Procedure No. 520 at 520 nm. Quantitative determination of PUN was made using the Urease/Berthelot procedure (Procedure No. 640) at 570 nm. Plasma nonesterified fatty acid (NEFA) levels were analyzed using the Acetyl-CoA Synthetase/Acetyl-CoA Oxidase method (NEFA C, Code No. 994-75409 E; Wako Chemicals, Richmond, VA) at 550 nm. For all blood metabolite assays, absorbance values were determined using a Shimadzu (Model UV-2401 PC) UV-VIS Recording Spectrophotometer (Shimadzu Scientific Instruments, Inc., Columbia, MD).

Differential Leukocyte Counts

Two blood smears were made from each sample on microscope slides. The blood smears were dried at room temperature and stained with Wright’s Giemsa (Bayer Corp., Diagnostic Division, Elkhart, IN) using an automatic slide stainer (Hema-TekTM 2000 Model 4488; Miles Inc. Diagnostic Division, Elkhart, IN). Different types of leukocytes (neutrophils, lymphocytes, eosinophils, and monocyes) were identified under the microscope, using a 100/1.25 oil-immersion objective, and counted (100 cells per slide) using the straight-edge method described by Schalm et al. (1971).

Statistical Analysis

The data on holding time effects were analyzed as Split-Unit designs, and the data on isolation PTRT effects were analyzed as Split-Split-Unit designs using General Linear Models procedure in SAS (SAS Institute Inc., Cary, NC). Plasma cortisol, T₃, T₄, glucose, CK, PUN, and NEFA data were analyzed with respective Pre-trial concentrations as covariates. Whenever necessary, the data were transformed into a logarithmic scale to meet the assumptions of ANOVA. However, the means were transformed back to the original scale and presented. When significant by ANOVA, the means were separated by Least Significant Difference test (LSD). Excitability score was introduced as an independent variable into the model, but was subsequently removed since it did not affect any of the dependent variables. Frequencies of each behavior recorded by video cameras were summed for each 2-h observation period, and the data from the two replicate trials were averaged. No mean comparison statistic was used for behavior data since the information was collected only on two 21-h holding pens per treatment.

Results

Liveweight shrinkage increased steadily over time in the FD group, reaching 7% after 21-h holding. In the F group, shrinkage did not change up to 14-h holding, but reached 6% after 21-h holding, attributing to a TRT
The differential leukocyte counts and neutrophil to lymphocyte ratio were not influenced by TRT or TIME (Table 1).

### Table 1. Effects of holding time on differential leukocyte counts (mean ± SEM) in Spanish does held with or without feed in pens (Treatment, TRT) for different durations

<table>
<thead>
<tr>
<th>Holding time (TIME)</th>
<th>Neutrophils</th>
<th>Lymphocytes</th>
<th>Monocytes</th>
<th>Eosinophils</th>
<th>N:L</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.6 ± 4.22</td>
<td>46.8 ± 4.30</td>
<td>1.0 ± 0.61</td>
<td>7.6 ± 2.29</td>
<td>1.0 ± 0.28</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>60.8 ± 2.72</td>
<td>32.7 ± 2.78</td>
<td>0.8 ± 0.40</td>
<td>5.7 ± 1.50</td>
<td>2.1 ± 0.18</td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>54.4 ± 2.72</td>
<td>39.8 ± 2.78</td>
<td>1.1 ± 0.39</td>
<td>4.7 ± 1.50</td>
<td>1.6 ± 0.18</td>
<td>12</td>
</tr>
<tr>
<td>21</td>
<td>52.5 ± 2.72</td>
<td>40.8 ± 2.78</td>
<td>1.3 ± 0.39</td>
<td>5.5 ± 1.50</td>
<td>1.4 ± 0.18</td>
<td>12</td>
</tr>
<tr>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.5 ± 3.85</td>
<td>41.3 ± 3.93</td>
<td>2.0 ± 0.56</td>
<td>4.2 ± 2.10</td>
<td>1.4 ± 0.26</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>52.3 ± 2.85</td>
<td>42.1 ± 2.90</td>
<td>1.0 ± 0.42</td>
<td>4.6 ± 1.57</td>
<td>1.4 ± 0.19</td>
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<tr>
<td>14</td>
<td>51.6 ± 2.72</td>
<td>42.1 ± 2.78</td>
<td>1.9 ± 0.39</td>
<td>4.4 ± 1.50</td>
<td>1.4 ± 0.18</td>
<td>12</td>
</tr>
<tr>
<td>21</td>
<td>53.8 ± 2.72</td>
<td>41.6 ± 2.78</td>
<td>0.8 ± 0.40</td>
<td>3.9 ± 1.50</td>
<td>1.3 ± 0.18</td>
<td>12</td>
</tr>
<tr>
<td>Baseline</td>
<td>50.5 ± 2.63</td>
<td>38.2 ± 3.51</td>
<td>6.9 ± 2.24</td>
<td>1.2 ± 0.42</td>
<td>1.5 ± 0.17</td>
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</tr>
</tbody>
</table>

*P*-values by ANOVA

<table>
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<tr>
<th>TRT</th>
<th>0.81</th>
<th>0.44</th>
<th>0.22</th>
<th>0.32</th>
<th>0.32</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME</td>
<td>0.15</td>
<td>0.26</td>
<td>0.40</td>
<td>0.89</td>
<td>0.12</td>
</tr>
<tr>
<td>TRT × TIME</td>
<td>0.09</td>
<td>0.18</td>
<td>0.35</td>
<td>0.86</td>
<td>0.11</td>
</tr>
</tbody>
</table>

<sup>a</sup>Sampled without holding time, immediately after taking animals to the holding pens.

Plasma cortisol concentrations were higher at 0 h than at other time periods studied (*P* < 0.01, Figure 2). Feed deprivation during holding did not have a significant effect on plasma cortisol concentrations. Plasma T<sub>3</sub> and T<sub>4</sub> concentrations were not influenced by any of the factors studied. The average T<sub>3</sub> concentrations were

Figure 1. Effect of holding Treatment (Feed deprived, Fed) and Time (7, 14, 21 h) on liveweight shrinkage in Spanish does showing Treatment × Time interaction.

Figure 2. Effect of holding Treatment (Feed deprived, Fed) and Time (0, 7, 14, 21 h) on plasma cortisol concentration (ng/mL) in Spanish does.
Preslaughter holding and isolation stress

Figure 3. Effect of holding Treatment (Feed deprived, Fed) and Time (0, 7, 14, 21 h) on plasma glucose concentration (mg/dL) in Spanish does showing Treatment × Time interaction.

1.6 ± 0.18, 1.8 ± 0.16, 1.7 ± 0.15, and 1.6 ± 0.15 ng/mL at 0-, 7-, 14-, and 21-h holding, respectively. Plasma T₄ concentrations were 79.2 ± 4.15, 84.3 ± 3.17, 85.1 ± 3.12, and 85.5 ± 3.13 ng/mL, respectively, at 0, 7, 14, and 21 h. Plasma leptin concentrations were not influenced by TRT × TIME or TRT, but tended to be influenced by TIME (P < 0.08). Leptin concentrations were 12.1 ± 1.82, 7.9 ± 1.29, 6.5 ± 1.28, and 9.5 ± 1.29 ng/mL at 0-, 7-, 14-, and 21-h holding, respectively.

There was a significant TRT × TIME interaction effect (P < 0.05, Figure 3) on glucose concentrations. The average plasma CK activities were higher when measured at 7-h holding than at 14 or 21 h, and enzyme activities were intermediate at 0 h (P < 0.05, Figure 4). The mean PUN concentrations were higher at 0- and 21-h than at 7- and 14-h holding (P < 0.01, Figure 5). There was a significant TRT × TIME interaction effect (P < 0.01) on plasma NEFA concentrations (Figure 6). The NEFA concentrations in the FD group remained at an elevated level at all time periods, except at 14 h, but in the F group the levels decreased at 7 h and remained at that level throughout the time periods tested.

The frequencies of agonistic encounters in the FD group were higher than in F group. Agonistic encounters were also higher during the first and third observation periods (1- to 2-h and 9- to 10-h holding) than during the second period (5- to 6-h holding). The FD goats also spent more time standing than F animals, since feeding behavior mutually excluded standing behavior in the F group. Walking, lying, and drinking

Figure 4. Effect of holding Treatment (Feed deprived, Fed) and Time (0, 7, 14, 21 h) on plasma creatine kinase (CK) activity (IU) in Spanish does.

Figure 5. Effect of holding Treatment (Feed deprived, Fed) and Time (0, 7, 14, 21 h) on plasma urea nitrogen (PUN) concentration (mg/dL) in Spanish does.
Figure 6. Effect of holding Treatment (Feed deprived, Fed) and Time (0, 7, 14, 21 h) on plasma nonesterified fatty acid (NEFA) concentration (ng/mL) in Spanish does showing Treatment × Time interaction. Behaviors were not influenced by any of the factors. Goats very rarely drank water during holding.

Isolation PTRT had a significant effect on plasma cortisol concentrations (Figure 7A). Cortisol concentrations were lower in C animals than in I or IV groups (P < 0.01). Although the cortisol concentrations were higher in I than in IV group, the difference was not significant. Similar trends were noticed in plasma glucose (Figure 7B) and NEFA (Figure 7C) concentrations, but the PTRT effect was not significant. In the goats not subjected to holding (0-h holding), however, plasma cortisol concentrations were higher in I (>20 ng/mL) than in IV or C group (Figure 8A). Similar trends were noticed in the plasma glucose (Figure 8B) and NEFA (Figure 8C) concentrations. Excitability scores did not influence any of the responses after holding or after holding plus isolation.

Discussion

Feed deprivation of meat animals prior to slaughter makes the evisceration process easier during slaughter and reduces chances of gastrointestinal wall rupture, thus preventing contamination of carcasses (Gregory, 1998). The chances of cross contamination of animals during transportation and holding are less due to reduced passage of intestinal contents. However, withdrawal of feed also results in the reduction of live and carcass weights, which are of economic importance in meat animals. Liveweight loss prior to slaughter may be of particular importance in small ruminants since the gastrointestinal tract comprises a greater proportion of live weight than in cattle or swine (Romans et al., 1994). A 24-h feed deprivation in sheep causes a loss of about 7% BW that can be attributed to reduction in gut contents (Kirton et al., 1971; Chilliard et al., 1995).

The reason for greater shrinkage in the F group after 21-h holding, in the present study, is not clear. One possible explanation is the diurnal changes in gut fill in goats due to daily feeding times. Gelaye et al. (1997) reported that goats consumed only 13.1% of their ration after midnight (2400 to 0600 h). In the present experiment, 14-h holding corresponded with 2400 h. If does
reduced their intake at night, this might have been reflected in liveweight loss after 21-h holding. In short-term feed deprivation, liveweight change is mainly due to gut fill variation (Chilliard et al., 1995). Another possible reason for increased shrinkage is the change in digesta passage rate due to a switch from forage to concentrate diet. When concentrates are included in the diet, gut digesta mass decreases (Kouakou et al., 1997) and digesta passage rate from the rumen increases (Poore et al., 1990). The F does were fed only concentrates in the holding pens, but were raised primarily on free-range pasture. It is likely that both diurnal changes in gut fill and changes in digesta passage rate would have contributed to a 6% liveweight loss in F goats after 21 h of holding. Transportation plus holding could further increase weight loss in goats (Knowles, 1999). Kannan et al. (2000) reported that a 2-h transportation, combined with 18 h of feed deprivation, resulted in approximately 10% liveweight shrinkage in Spanish does. Dehydration significantly contributes to weight losses during prolonged transportation (Tarrant et al., 1992).

In a previous study we found that Spanish goats subjected to a 2-h transportation and an 18-h feed deprivation showed elevated cortisol concentrations (Kannan et al., 2000). Fasting has also been shown to elevate circulating levels of corticosteroids in sheep (Murayama et al., 1986), cattle (Ward et al., 1992), swine (Becker et al., 1992), and poultry (Kannan and Mench, 1996). The absence of the effect of feed withdrawal on plasma cortisol concentrations in the present study may be due to the short duration of fasting without lengthy transportation, or due to the novelty of holding pens. Strange environment may be a potent stressor in small ruminants (Moberg and Wood, 1982) that may mask any effects of short-term feed deprivation. Olsson et al. (1995) reported that catching sight of feed resulted in a short-lasting increase in plasma cortisol concentration in goats. In our study, although the FD group did not have access to feed, the animals were penned adjacent to the F groups as the pens were randomly allotted to TRT groups. Cortisol concentrations were influenced by TIME, primarily due to elevated levels at 0 h of holding. These animals were not held in pens, but were subjected to loading and unloading procedures in quick succession before blood sampling. Relocation of animals from smaller enclosure in the pasture to the experimental holding pen area did not exceed 5 min. Loading onto a transport trailer markedly elevates plasma cortisol concentrations in sheep (Broom et al., 1996) and goats (Kannan et al., 2000).

Glucocorticoids that are released during stress are known to suppress the immune system (Munck et al., 1984). The differential leukocyte counts were not influenced by feed deprivation in Spanish goats in this study. Transportation combined with feed deprivation for 18 h decreases the lymphocyte counts and increases neutrophil counts and neutrophil-to-lymphocyte ratio in goats (Kannan et al., 2000). Perhaps, preslaughter feed deprivation alone is not a severe enough stress to cause changes in the cortisol response as well as leukocyte counts in Spanish goats. Minton and Blecha (1990) suggested that both intensity and duration of stressors may be important in bringing about changes in immunological functions.

The variation in glucose concentrations due to TRT in the 0-h holding group resulted in a TRT × TIME interaction effect. The 0-h goats were the controls for holding time effects and were treated alike, but these

![Figure 8](image-url)
animals were randomly assigned to TRT groups for statistical analysis purposes. Therefore, the difference in glucose concentrations among animals at 0 h of holding is because of random individual variation among animals, and may not bear significance to this study. During the initial hours of fasting, small ruminants utilize glucose as their primary source of energy. Blood-glucose concentrations increase due to breakdown of glycogen from liver (Murray et al., 1990). After about 24 h of fasting, blood glucose levels start falling since glycogen present in liver depletes (Gregory, 1998). In the present experiment, the trends in glucose concentration in both TRT groups over time are similar to the trends in cortisol concentration. Sanhouri et al. (1992) observed that as a response to stress, elevation of glucose concentration was preceded by an elevation in cortisol concentration. Likely, glucose concentrations also reflected the psychological stress due to strange holding pen environment, rather than feed deprivation.

The enzyme CK leaks from sarcoplasm of muscle cells into the bloodstream as a response to physical stress or exercise (Healy and Falk, 1974), due to increased permeability of muscle cell membrane, the sarcolemma (Tollersrud et al., 1971). Physical injuries, such as tearing of muscle fibers, may also cause an elevated blood CK activity (Gregory, 1998), and, therefore, plasma CK activity is a good indicator of muscular activity or damage (Wilson et al., 1990). In the present study, plasma CK activities were greater than those reported by Kannan et al. (2000) as response to transportation plus holding. In Spanish goats, vigorous physical activity, such as herding, loading and unloading procedures, are more important in determining plasma CK activity than transportation or feed deprivation (Kannan et al., 2000). The authors also suggested that bruising may increase in horned goats under crowded conditions, resulting in elevated CK activities. In the present study, the goats used were older, heavier, and horned. Horn size and BW are major determinants of dominance hierarchy in goats (Collias, 1956).

The spike in CK activity when measured after 7-h holding may be due to the higher frequency of agonistic encounters in both TRT groups during the first few hours of holding. After encountering a physical stress, plasma CK activity in Spanish goats increases after a lag time of about 2 h (Kannan et al., 2000). Frequencies of agonistic encounters were also greater in the FD group than in F group, particularly during the third period of behavioral observation (9- to 10-h holding). This period approximately coincided with the time when the 14-h holding groups were penned. Under intensive conditions, goats normally show an increase in agonistic activity at feeding times (Pretorius, 1970). Interestingly, the CK activities were relatively greater in the FD group when measured after 14- and 21-h holding. After the previously penned goats had settled down, the arrival of more animals in the holding area appears to have stimulated further agonistic behaviors.

Fasting results in increased protein catabolism in animal’s body, which results in increased urea nitrogen concentrations in circulation (Gregory, 1998). Increased PUN concentrations in response to nutritional stress has been previously reported in goats (Kouakou et al., 1999; Kannan et al., 2000). In the present experiment, the absence of TRT effect on PUN concentrations may be related to prolonged elevation of cortisol concentrations in both TRT. Corticosteroid itself brings about breakdown of some proteins and nucleic acids in muscles (Baxter and Rousseau, 1979). It is not clear to what extent cortisol-induced protein breakdown can contribute to increasing PUN concentrations.

Feed restriction elevates plasma NEFA concentrations in goats (Kouakou et al., 1999). The greater NEFA concentrations in FD than in the F group, particularly at 7- and 21-h holding, may be due to feed deprivation. During fasting, FFA become the main source of energy in muscles after liver glycogen depletes, resulting in a decrease in blood glucose and an increase in NEFA concentrations (Gregory, 1998). Prolonged exercise also causes an increase in plasma NEFA concentration (Brody, 1999). Knowles et al. (1995) reported that plasma NEFA concentrations increased in sheep subjected to transportation stress or feed deprivation for 24 h. The elevated plasma NEFA concentrations noticed in the present study in both TRT at 0-h holding may be due to lipolysis induced by catecholamines (Cryer, 1980).

Animals are moved from holding pens to forcing pens before they enter single-file races leading to the stunning chute. In facilities of certain designs, animals undergo social isolation when they are in the races due to partitions created by sliding doors. When goats are slaughtered in abattoirs designed for other species, they often lose visual contact with the animal in front of them because of their smaller body size. The importance of proper facility design in minimizing animal stress and stress-related meat quality problems has been emphasized by Grandin (1990; 1996). The ideal design is a single-file chute where an animal can see at least three body lengths up the chute from the forcing pen (Grandin, 1996). Constant visual contact with the animal in front will facilitate smooth movement of animals through single-file races and may reduce stress during the time immediately prior to slaughter. The benefits of careful livestock-hauling procedures will be lost if animals are exposed to stressors minutes before slaughter (Weeding et al., 1993; Grigor et al., 1999).

The results show that isolation of goats from their social group can cause increased emotional stress, reflected by elevated cortisol concentrations. When social isolation was not combined with holding treatment, the stress levels were significantly lower in goats that were able to maintain visual contact with other animals. It should be considered that cortisol concentrations may still have been on the increase as it takes 10 to 20 min for cortisol concentrations to peak in circulation after a stressor is imposed (Lay et al., 1992). Blood samples in the present study were collected immediately after
the 15-min I or IV PTRT. Social isolation also causes elevation in cortisol concentration in sheep (Moberg et al., 1980; Pierzchala et al., 1985; Parrott et al., 1994). However, Price and Thos (1980) reported that goats are more social than sheep, based on social interactions initiated per unit time and on the behaviors exhibited when socially isolated.

Although plasma glucose and NEFA concentrations were not influenced by PTRT, the trends were similar to that of cortisol. Social isolation significantly elevates plasma glucose (Apple et al., 1995) and FFA concentrations (Pierzchala et al., 1985) in lambs. In our experiment, the isolation PTRT lasted only for 15 min. In lambs, glucose concentrations increase with increasing duration of restraint and isolation stress, while FFA concentrations peak at 1 h after stress treatment is imposed (Apple et al., 1995). By applying these results to a commercial preslaughter situation, evidently the longer the animals remain in isolation, the greater will be the emotional stress they experience. Small ruminants do not readily adapt to social isolation, as repeated application of isolation stress evokes a greater increase in circulating cortisol concentrations (Niezgoda et al., 1987). Grandin (1998) emphasized that animals should not be left in a restrainer or stunning pen at slaughter facilities for prolonged durations, such as during lunch or coffee breaks.

Feed deprivation alone did not significantly affect the stress responses of goats during holding. The results indicate that novelty of environment during preslaughter holding may be a more potent stressor than food deprivation in goats. However, live weight shrinkage in goats may increase with increasing feed-withdrawal times. Stress can significantly increase when goats are socially isolated and remain for extended durations in single-file races at slaughter plants. When goats are slaughtered in facilities intended for other animals, prolonged isolation with no visual contact with other animals is likely to further increase stress levels prior to slaughter.

**Implications**

Goat meat (chevon) production systems are still in their infancy in the United States, although chevon demand has increased in recent years. There is a lack of information on preslaughter management of goats under commercial situations. The results of the present experiment show that feed deprivation results in a live weight loss of up to 7% over a period of 21 h. The shrinkage could be more if feed deprivation is combined with transportation. The novelty of environment in lairages (holding areas) is a more potent stressor in goats than feed deprivation. It is stressful to goats when they are socially isolated for prolonged durations, particularly where they lose visual contact with other goats in single-file races. Better preslaughter management of livestock reduces animal distress and economic losses due to reduced meat quality.

**Literature Cited**


