**Effects of method of conditioning on behavior of Boer and Spanish goats in pens with
barbed wire and electric fence strands**

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Abstract

In the first experiment, 40 Boer (B) and 40 Spanish (S) does were used to evaluate effects of treatments in the interval (IT) between periods of a Latin square design on behavior when exposed to fences with barbed wire strands for cattle and added electric fence strands for goats. The desire was to determine if an IT would eliminate period or carryover effects so that a Latin square could be used for consistent and accurate evaluation of different electric fence strand treatments. Breeds were split into two sets with five groups of four does. Evaluation pens (5; 2.4 × 3.7 m) had one side of barbed wire strands at 30, 56, 81, 107, and 132 cm from the ground. Fence treatments (FT) were electrified strands (6.0 kV) at 15 and 43 (LowHigh), 15 and 23 (LowMed), 15 (Low), 23 (Med), and 43 cm (High). Behavior was assessed once every 2 wk with different FT in the five periods of a 5 × 5 Latin square experiment. In the week between measurements, one set of each breed was exposed to a pen with no electric strands as IT-Yes and other sets were not (IT-No). There were interactions ($P < 0.05$) in the percentage of goats exiting pens of IT × period (28, 38, 18, 0, and 18% with IT-Yes and 45, 13, 0, 0, and 0% with IT-No in period 1, 2, 3, 4, and 5, respectively; SE = 4.9), IT × FT (5, 8, 15, 33, and 40% with IT-Yes and 5, 3, 18, 23, and 10% with IT-No for LowHigh, LowMed, Low, Med, and High, respectively; SE = 4.9), and IT × breed (8 and 32% with IT-Yes and 15 and 8% with IT-No for B and S, respectively; SE = 3.8). In the second study, 80 B and 75 S wethers and doelings were used to investigate effects of preliminary treatments (PT) on behavior when later exposed to different FT. Breeds were divided into two sets, each with five groups consisting of three or four animals and use of the same FT. The PT were imposed in five weekly and sequential exposures to evaluation pens: a common treatment for one set of each breed with moderate exposure to electric fence strands (BC and SC); mild exposure for the other set of B (BU); and greater exposure for the

other set of S (SU). BU was designed to increase and SU to decrease later interaction with fence strands and pen exit relative to BC and SC, respectively. Each group was thereafter exposed to one FT for 1 h in period 1 and 7 wk later in period 2. Set (BC, BU, SC, and SU) affected ($P < 0.05$) pen exit (21, 52, 57, and 8%; SE = 7.0), receipt of a shock (19, 30, 7, and 4%; SE = 4.8), and pen exit with a shock (6, 14, 6, and 2%, respectively; SE = 2.8). Period affected ($P < 0.01$) the percentage of animals exiting with shock (13 and 1%; SE = 2.0) but not the percentage exiting. In conclusion, exposing goats to barbed wire fence without electric strands between measurement periods was not sufficient to eliminate differences among periods of a Latin square design. Use of the same PT for B and S resulted in different behavior when later exposed to FT. The BU PT affected pen exit as anticipated; however, SU caused animals to be highly reluctant to exit and was not suitable for use.

Keywords: Adaptation method; Behavior; Breed; Electric fence; Goat; Interval treatment

1. Introduction

Advantages of co-grazing cattle and goats over mono-species-grazing of cattle include more efficient use of vegetation (Walker, 1994), improved productivity per unit pasture area (Hart, 2001), and a reduction in internal parasitism of goats (Sahlu et al., 2009). The most common method of modifying a cattle barbed wire fence for goat containment is to add one or more electric fence strands. However, there is only anecdotal evidence regarding how this can be best accomplished in terms of initial and maintenance costs and labor and effectiveness. Therefore, Goetsch et al. (2012) and Tsukahara et al. (2013) conducted initial studies to develop a model for evaluating different methods of modifying cattle barbed wire fence with electric

fence strands for goat containment. The overall goal of the project that these past studies and the experiments reported on here are a part of is to develop a consistent and accurate method of evaluating electric fence strand treatments with goats. The study model would allow fence treatments to be tested with minimal influences of other animal conditions such as breed, age, gender, and experience.

The earlier studies of Goetsch et al. (2012) and Tsukahara et al. (2013) and the present ones include an array of electric fence strand treatments designed for different likelihoods of receiving a shock and exiting evaluation pens. In the first experiment of Goetsch et al. (2012), pen exit was very low for all fence treatments and decreased with advancing period of a Latin square. With changes in several conditions for the second Latin square experiment, exit was unacceptably high regardless of fence treatment. This indicated marked influences of experimental design, adaptation procedures, or how animals were managed between measurement periods, factors that would need to receive additional research.

In the study of Tsukahara et al. (2013), two experimental designs (i.e., Latin square and completely randomized design) and breeds of goats (i.e., Boer and Spanish) were compared, and conditions before the first measurement period and between later periods (i.e., interval treatments) were evaluated. Behavior of Boer and Spanish goats differed, and pen exit decreased as period of the Latin square advanced. There were few and minor effects and interactions of preliminary and interval treatments. These studies indicated that there were effects of goat breed and conditioning before and during the evaluation period as well as among the different fence treatments. Therefore, the objective of the first experiment was to determine if a modified interval treatment would be useful to achieve similar behavior among periods of a Latin square. A second completely randomly designed experiment was performed to evaluate different

methods of adaptation to lessen behavior differences between Boer and Spanish goats so that both could be used in the model being developed.

2. Materials and methods

Protocols for both experiments were approved by the Langston University Animal Care and Use Committee.

2.1. Experiment 1

2.1.1. Study area

The study area was located at one end of a 0.4-ha pasture with abundant vegetation, including various grasses, forbs, and mimosa (*Albizia julibrisin*) trees. Six 2.4×3.7 m evaluation pens with three sides of welded wire mesh panels (16×20 cm openings; 4 gauge, 19 mm²), with plywood attached to minimize visual contact of goats between pens, were situated adjacent to one another. One short side of the pens had a portion used as a gate. The other short side had five strands of barbed wire (Style No. 33 of Sheffield Wire Products; 12.5 gauge [3 mm²] with 14 gauge [2 mm²] four-point barbs at 12.7cm spacing) at 31, 56, 81, 107, and 132 cm from the ground (Fig. 1). Points of the barbs had been ground blunt. Strands were attached to steel T-posts at the corners. The area was covered with a UV-resistant 24-mil poly shade (ClearSpan™, ClearSpan Fabric Structures Inc., CT, USA). Vegetation in evaluation pens was removed by clipping before each testing period. Soil Moisture Tester (Model KS-D1, Delmhorst Instrument Co., Towaco, NJ, USA) probes were installed at depths of 5, 10, and 15 cm at nine locations near the barbed wire fence side and between evaluation pens and the grounding site. Before each measurement period, soil moisture level was determined. When the level was very low, the ground surface under and near electric fence strands, as well as the area between evaluation pens and the grounding site, were wetted to ensure ample grounding upon electric

fence strand contact. The average meter reading was 83 ± 4.6 , 83 ± 3.6 , 85 ± 3.2 at 5, 10, and 15 cm depths, respectively, which is equivalent to an average of approximately 1200 resistance ohms.

2.1.2. Fence treatments

Electric fence strands were situated 13 cm from the barbed wire strands inside the evaluation pens, connected to insulators on two T-posts in the corners of each pen. There were five electric fence strand treatments (FT): two electric strands at 15 and 43 cm (LowHigh); two strands at 15 and 23 cm (LowMed); one strand at 15 cm (Low); one strand at 23 cm (Med); and one strand at 43 cm (High) from the ground (Fig. 1). Fence treatments were randomly assigned to evaluation pens each period. Electric fence strands were 14 gauge (2 mm²) XL aluminum wire of Gallagher USA (North Kansas City, MO, USA). A fence charger or energizer was connected to electric strands, with contact of a grounding strand varied to achieve 6.0 kV. Voltage was checked at the beginning, middle, and end of measurement periods.

2.1.3. Animals

Forty Spanish (3.0 yr initial age, SE = 0.21; 35.8 kg initial BW, SE = 0.68) and 40 Boer (3.7 yr, SE = 0.23; 51.5 kg, SE = 1.43) nursing does were selected. Most of the does had been used for similar experimentation the previous year. At the beginning of the adaptation period does, including some extras for later selection, were orally dewormed according to need determined with the FAMACHA[®] system (Van Wyk and Bath, 2002). During the adaptation period, does expressing an excessively low propensity for exit from evaluation pens or unsuitable health conditions were removed, with 40 Spanish and 40 Boer does ultimately selected for use. Each breed was split into two sets with five groups of four does based on BW.

2.1.4. Preliminary and interval treatments

The experiment was conducted for 10 wk from June 5 to August 9, 2012. It consisted of two breed-specific preliminary regimes (PR) for training to electric fence and study conditions, exposure to different fencing treatments (FT) in a 5×5 Latin square design with measurement on 1 day every 2 wk, and an interval period treatment (IT) imposed during the week between measurements of Latin square periods (Table 1).

In a 4-wk adaptation period each set of animals resided separately in four grass-based pastures and were supplemented with concentrate. Two strands of electric fence at approximately 6.0 kV were situated next to supplement troughs in each pen at 15 and 44 cm from the ground for animals to become trained to electric fence strands. The PR were imposed during this time as well, which involved sequential exposure to evaluation pens for training to recognize electric fence strands but not to an extent that later exit during the 10-wk experiment would be very low. The PR were based on behavioral differences noted by Tsukahara et al. (2013) and designed to achieve similar willingness of animals of both breeds to inspect the difficulty of exiting the pen because of the different FT and possibly to exit. That is, a relatively high degree of exposure to electrified fence strands during the adaptation period could result in very low pen exit later regardless of the particular FT. Conversely, little prior exposure would promote high levels of pen exit. Animals that did not voluntarily exit evaluation pens during the preliminary training sessions were encouraged to exit by observers by entering their flight zone or using mild physical force if necessary.

Interval treatments were conducted in each of the 4 wk between the weeks when measurements of the five Latin square periods occurred. The interval treatments might also be termed ‘washout.’ One animal set of each breed was exposed (IT-Yes) to an evaluation pen with no electric strands (NES) after being fasted in a confinement facility for 16 h, and the other set

was not exposed (IT-No; Table 1). Kids were with does at all times except when in the evaluation area. Fasting was to provide motivation for exiting evaluation pens into the pasture with its abundant vegetation available for consumption. The assignment of sets within breed to IT was random. Conversely, in the previous study of Tsukahara et al. (2013) IT were imposed during the entire time when animals were in the pastures and not in the evaluation area. Furthermore, those pastures had either two or no electric fence strands at 6.0 kV situated next to troughs for supplemental pelleted concentrate, and the treatments did not have clear or the desired effects. That is, it was thought that continual presence of electric fence strands to maintain familiarity would prevent rapid exit from evaluation pens with FT most prohibitive to exit, but would not affect exit with FT imparting little exit deterrence. Therefore, in the present experiment IT were imposed in the evaluation pens for a short period of time. As during the preliminary period, animals were encouraged to exit if they did not quickly exit voluntarily. The purpose of IT-Yes was to eliminate memory of prior exposures to the evaluation pens with electric strands. That is, it was theorized that periodic exposure to IT-Yes in the same environment as where measurements occurred during the periods of the Latin square would refresh memory that they could easily exit pens with some of the FT.

2.1.5. Measures

Animals were fasted in a confinement facility for 16 h before being moved to the evaluation area for measurements, with kids present except when in the evaluation area. Each group of four animals was confined in an evaluation pen and continuously observed by three individuals for 1 h. During the observation period, color closed-circuit television cameras (WV-CP504, Panasonic System Networks Co., Ltd., Secaucus, NJ, USA) were used to record activity in order to improve accuracy of visual observation. The Observer XT Version 10.5 of Noldus

Information Technology (Wageningen, The Netherlands) was used to code Mpeg recordings, with re-analysis to ensure data integrity. Variables assessed based on previous experiments (Goetsch et al., 2012; Tsukahara et al., 2013) included exit from the pen with and without electric shock by touching electric strands and shock but not exit from the pen, all expressed as a percentage of the total number of animals, the number of unsuccessful exit attempts, and time taken to exit. An unsuccessful exit attempt was defined as when the head or a leg was beyond fence strands and exit did not occur. A shock was recorded when there was a discernible reaction upon contact with an electric fence strand. During period 2, measurements with a set of Boer goats were stopped because of an unexpected period of heavy rain. Therefore, the IT and measurements in that period were repeated for all groups.

2.1.6. *Statistical analysis*

Individual animal data of 400 observations were analyzed with the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC, USA). The model consisted of IT, breed, period, FT, and their two-way interactions, with a distribution of t-distribution and function of identity. There was a random statement for group within $IT \times \text{breed}$ and a second random statement for period that had a subject of individual animal with the residual option. This analysis is equivalent to and yielded very similar results as one with period as a repeated measure for continuous variables with the MIXED procedure of SAS. Exit time was recorded only when exit occurred, resulting in 63 observations; therefore, two-way interactions of $IT \times \text{period}$, $\text{breed} \times \text{period}$, and $\text{breed} \times \text{FT}$ were excluded from the model.

2.2. *Experiment 2*

The study area, FT, variables, and most other procedures were the same as in Experiment 1. The experiment occurred from August 27 to December 12, 2012. Forty Boer (B) wethers (4.9

mo initial age, SE = 0.09; 20.0 kg initial BW, SE = 0.65), 40 B doelings (5.4 mo, SE = 0.05; 22.3 kg, SE = 0.4), 33 Spanish (S) wethers (5.3 mo, SE = 0.06; 18.5 kg, SE = 0.62), and 42 S doelings (5.3 mo, SE = 0.05; 14.7 kg, SE = 0.43) plus some extra animals were used. Each animal type was divided into two sets based on initial BW and to maintain an equal ratio of genders.

The total length of the adaptation period was 5 wk. After all animals exited from evaluation pens with NES, preliminary treatments (PT) shown in Table 2 were imposed, with weekly measurement periods lasting no more than 30 min. One set of each breed (SC and BC) was subjected to a common (C) PT and the other set of each breed was exposed to a different or unique (U) PT (SU or BU). Based on differences in initial behavior of each breed, BU and SU were designed with intent to achieve similar behavior during the subsequent experiment, with differences between BC and SC expected. Animals that were very reluctant to inspect barbed wire and/or electric fence strands during the PT measurement periods were excluded from the experiment. Each set was divided into 10 groups of three or four animals. That is, each set (BC, BU, SC, and SU) had two duplicate sets of five groups. After the preliminary period, each group was exposed to one FT for 1-h in period 1 and 7 wk later in period 2. Animals were exposed to the same FT in both periods as a repeated measure.

Individual animal data of 309 observations (155 and 154 observations for period 1 and 2, respectively) were analyzed with the GLIMMIX procedure. Gender had no significant effect on any variable in a preliminary analysis and was removed from the model. The model consisted of animal set (i.e., SC, BC, SU, and BU), FT, their interaction, and period with a distribution of t-distribution and function of identity. There was a random statement for group within set and a second random statement for period as a repeated measure that had a subject of group within set

with the residual option. Exit time was recorded only when exit occurred, resulting in limited number of observations ($n = 105$). Consequently, the interaction was excluded from the model.

3. Results

3.1. Experiment 1

Of the 400 individual observations, there were 63 exits (29, 20, 7, 0, 7 for period 1, 2, 3, 4, and 5, respectively). Exits occurred between 0.06 min (i.e., 3.8 s) and 33.2 min, and 67% were within 1 min after entering the evaluation pens. Exit attempts were observed from 0 to 5 times per animal within the 1-h observation period. Table 3 shows significant effects of many of the sources of variation, and for some variables such as the percentage of animals exiting evaluation pens and animals exiting pens without shock, each source had a significant effect. Moreover, there were numerous interactions ($P < 0.05$), including IT $\times$ breed, IT $\times$ FT, IT $\times$ period, breed $\times$ FT, and breed $\times$ period for the percentage of goats exiting evaluation pens (Table 3). Conversely, for the percentage of animals receiving a shock, there was only a main effect of IT ($P = 0.02$) and interaction between breed and period ($P = 0.01$). Exposing goats to an evaluation pen with NES between periods (i.e., IT-Yes) increased exit by Spanish does but had no effect with Boer (Table 4). Interactions in pen exit between FT and IT and breed involved less or no effects with FT presumably providing the greatest exit deterrence (i.e., LowHigh, LowMed, and Low, Table 4 and 5). The interaction in exit involving period of the Latin square at least in part was because no animals exited in period 4. There were interactions between IT and breed and period as well as between breed and period for the number of exit attempts per animal. The number was increased by IT-Yes for Spanish does but not Boer, was greater in period 2 for IT-Yes and Spanish does than for other treatments, and decreased as period advanced.

The total number of does receiving a shock was increased ($P = 0.02$) by IT-Yes, which was also the case for goats being shocked and not exiting evaluation pens ($P = 0.03$) regardless of breed (Tables 3 and 4). The interaction in goats receiving a shock between period and breed was mainly due to the highest percentage for Boer goats in period 1 compared with Boers in other periods and Spanish goats in each period. Animals subjected to IT-No and LowMed required more time to exit from the LowMed pen than did animals of other IT $\times$ FT.

3.2. Experiment 2

A total of 105 exits (57 and 48 for period 1 and 2, respectively) were observed. Exits occurred between 0.06 (i.e., 3.3 sec) and 52 min, and 67% were within 1 min after entering the evaluation pens. Exit attempts were observed from 0 to 9 times per animal within the 1-h observation period. Animal set affected ($P < 0.05$) each variable except for the time to exit (Table 6). There were interactions between set and FT for exit and exit without shock ($P \leq 0.01$). The C and U PT were expected to have opposite effects with Boer and Spanish goats. In this regard, exit was greater ($P < 0.05$) for BU vs. BC with the two FT having a Med electric fence strand (i.e., Med and LowMed) and exit was less ($P < 0.05$) for SU vs. SC with all FT except LowMed (Table 7). For set main effect means, the percentage of SC exiting evaluation pens was greater than SU (57 and 9% for SC and SU, respectively), whereas an opposite difference between BC and BU was observed with Boer goats (21 and 52% for BC and BU, respectively; $SE = 7.0$). The effect of set in the number of exit attempts corresponded to that in the percentage of animals exiting. More Boer goats subjected to the U PT received shocks than did goats of other sets, and there was a similar tendency for the percentage of animals exiting with receipt of a shock. The percentage of goats receiving a shock without exiting was greater in period 2 vs. 1.

More Spanish goats subjected to the PT of C exited without receiving a shock, followed by BU then BC and SU (51, 38, 14, and 6% for SC, BU, BC, and SU, respectively; SE = 7.0).

4. Discussion

4.1. Experiment 1

4.1.1. Preliminary regime and breed

The decision to have different PR for Boer and Spanish does was based on observations of behavior in earlier studies. Also, in wk 1 of the preliminary period 100 and 62.5% of Spanish and Boer goats, respectively, voluntarily exited pens without encouragement. In addition, voluntary exit without encouragement was 97.5, 100, and 100% by Spanish goats in wk 2, 3, and 4, and that by Boer goats was 72.5, 70.0, 72.5, and 95.0% in wk 2, the first and second exposures in wk 3, and wk 4, respectively. However, it is realized that this confounds breed with PR. This consideration contributed to conduct of Experiment 2 to support need for a different adaptation protocol for Boer and Spanish goats in order to have more similar results during the subsequent experimental period(s), which would be necessary for meaningful use of both breeds in the evaluation model being developed. That is, a common PR that results in very high pen exit by one breed regardless of FT and very low exit by the other breed is not desirable. In this case, different PR that result in similar behavior for both breeds are preferred. Moreover, it is desirable that FT have the same effects with both breeds.

4.1.2. Interval treatment and breed

The greater reluctance of Boer goats to interact with the barbed wire fence and electric fence strand(s) may have been responsible for increased exit due to IT-Yes by Spanish and not Boer goats. This was despite lesser exposure of Boer vs. Spanish goats to electric fence strands during the preliminary period, which may indicate greater sensitivity of Boer than Spanish goats.

Thus, conditioning of Boer goats should entail less exposure to electric fence strands so that later there is potential for pen exit with some FT. Similarly, it would seem that Boer goats would be less likely to exit a grazing area with one or more electric fence strands being fully or partially grounded at very low or 0 kV.

4.1.3. Interval treatment and fence treatment

The IT-Yes increased exit from High and Med evaluation pens but not from pens with other FT. Because it was easier for goats to exit High and Med pens compared with the other FT, the IT-Yes was effective in stimulating goats to inspect the FT and to recognize that some allowed easier exit than others did. As noted earlier, in the preceding week IT-Yes goats were placed in the same evaluation pens with barbed wire but no electric fence strands (i.e., NES), from which they exited voluntarily or did so with some encouragement by observers. This suggests that if animals are periodically placed in a grazing area with an electric fence strand that might be very low or high from the ground or at low voltage, pen exit at a later time with other FT would not be changed. But, this would not necessarily be true if the animals remained in the same area with FT allowing ready exit from pens.

4.1.4. Interval treatment and period

Increased pen exit due to IT-Yes in periods 2, 3, and 5 was expected. Conversely, decreased exit in period 1 and no effect in period 4 were not anticipated. No reasons can be given for these latter findings. This is because the IT-Yes exposure was not imposed in wk 1 of period 1 before the measurement period in wk 2. Also, there were no differences in how IT-Yes was implemented between measurements in periods 3 and 4 compared with segments of time between measurements in periods 2 and 3 and periods 4 and 5. Nonetheless, the lack of a consistent effect of IT-Yes across periods indicates that carryover effects were not eliminated.

4.1.5. *Breed and fence treatment*

The breed $\times$ FT interaction in pen exit was primarily because of greater values for Spanish goats in High and Med pens compared with the other FT. This contrasts smaller magnitudes of difference in exit by Boer goats, with a significant difference only between LowHigh and High. This was presumably because of the smaller size and possibly greater agility of Spanish vs. Boer goats. Such animal characteristics should be considered when developing a strategy for modifying a cattle barbed wire fence for goat containment.

The breed $\times$ FT interaction reflects a greater desire and(or) capability of Spanish vs. Boer goats to exit pens because of innate behavioral differences and(or) physical characteristics of Spanish that allowed greater exit with the Med FT. It appears that the desire to exit of Spanish goats was slightly less affected by repeated FT exposure compared with Boer goats. Spanish goats also interacted less with fence strands in the latter than earlier periods, but they generally did maintain greater interaction than Boer goats. Nonetheless, use of Latin square design in this type of evaluation would not seem acceptable for either breed regardless of differences in behavior or physical characteristics.

4.2. *Experiment 2*

4.2.1. *Animal set means*

Differences between C and U with Boer goats in variables such as exit were generally as expected. That is, based on observations in previous experiments it was felt that the same level of exposure of both breeds to electric fence strands would cause Boer goats to be reluctant to examine the FT and exit pens with some of the FT. Furthermore, a significant interaction among animal set and FT could have been expected for some variables, such as observed for the percentage of animals exiting. That is, the pens with the High FT were the easiest to exit from.

Therefore, less influence of PT was expected with the High FT compared with the LowHigh and LowMed FT.

Even though changes for Boer goats due to PT were as desired (e.g., similar exit for BU and SC), exit for SU was considerably less than for other sets. In fact, exit was 0% or near that level with the LowHigh, LowMed, and Med FT. In accordance, it was surprising that the effect of one additional exposure to electric fence strands in the preliminary period with SU vs. SC had such marked effect on variables, notably a decrease in pen exit from 57 to 9%.

The set means reflect the difficulty in determining an appropriate adaptation procedure so that differences among FT can be accurately and consistently evaluated in a later measurement period. However, to address these means, expected levels of exit during the measurement period first should be discussed. It is anticipated that all or nearly all animals would exit a pen with the High FT. It is also expected that few or no animals would exit from a LowHigh pen. The number of animals exiting a LowMed pen might be slightly greater than for LowHigh because of the open space for LowMed without an electric strand between the first and second barbed wire strand from the ground. Perhaps a reasonable expected percentage of animals exiting a LowMed pen is 25%. Similarly, exit levels of 50 and 75% can be postulated for Low and Med, respectively. Hence, an exit level averaged over all FT of approximately 50% seems reasonable. Therefore, it would appear that the BU and SC sets yielded the desired levels of exit. The BC set resulted in greater reluctance to interact with fence strands to achieve pen exit than targeted, but not to the extent realized with the SU set. The percentage of SU goats voluntarily exiting pens without encouragement during the preliminary period was 95, 97, 95, 29, and 3% in wk 0, 1, 2, 3, and 4, respectively. Therefore, it seems that an unanticipated threshold in behavioral modification was reached during the last week of the preliminary period and the third

consecutive weekly exposure to the LowHigh FT. It appears that either the exposure to LowHigh in wk 4 should have been omitted, or perhaps use of NES in an additional week of the preliminary period might have been considered. In this regard, NES in the final preliminary period week was somewhat effective in increasing voluntary exit by SC (97, 92, 95, 32, and 51%), although this was not the case for BC (98, 78, 58, 10, and 10% in wk 0, 1, 2, 3, and 4, respectively). Conversely, voluntary exit for BU was high each week in accordance with weekly exposures to pens from which exit was relatively easy (95, 98, 100, 75, and 83% in wk 0, 1, 2, 3, and 4, respectively).

Use of the same PT for Boer and Spanish goats resulted in different behavior when later exposed to the various FT. This indicates need to consider unique behavioral characteristics when developing an adaptation method, and also supports use of different PR for the two breeds in Experiment 1. However, the U PT for Spanish goats in Experiment 2 was highly prohibitive to exit and would not be suitable. This finding and substantial effects of PT on pen exit by Boer goats suggest that different adaptation protocols should entail relatively little prior exposure to electric fence strands. Furthermore, such effects are relatively long-lasting, as even the interval of 7 wk did not prevent influence on behavior of prior exposure to electric fence strands.

4.2.2. Animal set $\times$ fence treatment means

The interaction between animal set and FT in pen exit has largely been addressed earlier, so only some additional aspects will receive attention here. First, it is notable that differences among FT for BU were less than for SC. The levels for SC were fairly close to expectations, such as very high exit for the High FT. Lower exit by SC with LowMed vs. LowHigh may relate to the small size and low height of Spanish goats, with relatively smaller differences between LowMed and LowHigh for both BC and BU. Similarly, the size of Spanish goats and perhaps

greater agility probably facilitated much greater exit than by Boer goats with the Low FT. The BU set was designed to minimize reluctance to interact with fence strands so that exit during the measurement period would occur with the High FT. But, it also resulted in some animals not exiting, as opposed to 100% exit by SC with the High FT.

For some laboratory determinations, standard samples may be included in different runs for adjusting readings of samples of interest. The same has been considered in development of this method of evaluating different types of additions of one or more electric fence strands to cattle barbed wire fence for goat containment. That is, one or two standard FT could be used to adjust determinations at a particular time with a specific set of animals so that valid comparisons could be made among runs. Such standard FT should result in fairly consistent values from run to run. Examples are pen exit from 90 to 100% for High and perhaps 0 to 10% for LowHigh. However, results in this experiment are not very encouraging in this regard, although for BU and SC exit with High had only a slightly greater range of 80 to 100%. It would seem that if such a method of adjustment was developed, separate or unique ones for different goat breeds would be necessary.

5. Conclusions

The Latin square experimental design in which animals are exposed to different fence treatments in repeated periods does not appear suitable, even with an intervention between measurement periods designed to decrease carryover effects. The experimental model being developed should consider breed, as behavior of Boer and Spanish goats can be considerably different in many instances in addition to unique physical characteristics. Impact of a lesser likelihood of Boer goats to exit evaluation pens designed to be difficult to exit from can be decreased by minimizing exposure to electric fence strands during the adaptation process rather

413 than use of a common regime also used with Spanish goats. However, relatively high levels of
414 exposure can limit exit from evaluation pens by Spanish goats regardless of the particular fence
415 treatment.

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Table 1Preliminary regimes¹ and experimental procedures of Experiment 1

Wk ²	Spanish		Boer	
	Set 1 (n = 20)	Set 2 (n =20)	Set 3 (n = 20)	Set 4 (n =20)
PR 1	NES	NES	NES	NES
PR 2	Low	Low	NES	NES
PR 2 ³			Low	Low
PR 3	High	High	High	High
PR 4	Moderate	Moderate	NES	NES
Wk 1	Period 1	Period 1	Period 1	Period 1
Wk 2	IT-Yes	IT-No	IT-Yes	IT-No
Wk 3 ⁴	Period 2'	Period 2'	Period 2'	Period 2'
Wk 4	IT and Period 2	IT and Period 2	IT and Period 2	IT and Period 2
Wk 5	IT-Yes	IT-No	IT-Yes	IT-No
Wk 6	Period 3	Period 3	Period 3	Period 3
Wk 7	IT-Yes	IT-No	IT-Yes	IT-No
Wk 8	Period 4	Period 4	Period 4	Period 4
Wk 9	IT-Yes	IT-No	IT-Yes	IT-No
Wk 10	Period 5	Period 5	Period 5	Period 5

¹NES = no electric strands; Low = electric fence strand at 15.2 cm from the ground with 0.0 kV; High = electric fence strand at 43.2 cm with 3.0 kV; Moderate = electric fence strand at 22.9 cm with 4.0 kV; IT = interval treatment; IT-Yes = exposure to NES; IT-No = no exposure.

²PR = preliminary regime week; Wk = week of the experimental period.

³In PR 2, Boer goats were exposed to an additional preliminary treatment 2-3 days after the first.

⁴Period 2' measurement in Wk 3 was aborted by unexpected heavy rain, then IT and Period 2 were repeated in Wk 4.

Table 2

Preliminary treatments of Experiment 2

Week	Preliminary treatment ¹		
	Boer and Spanish – Common	Boer – Unique	Spanish – Unique
1	NES	NES	NES
2	Low (0.0 kV)	NES	Low
3	LowHigh	Low (0.0 kV)	LowHigh
4	LowHigh	Low (6.0 kV)	LowHigh
5	NES	NES	LowHigh

¹NES = no electric fence strand; Low = one strand at 15.2 cm from the ground; LowHigh = strands at 15.2 and 43.2 cm and 6.0 kV.

Table 3*P* values of interval treatment (IT), breed, period, fence treatment, and their interactions for behavior of does in evaluation pens (Experiment 1)

Source of variation	Variable						
	Exit	Exit attempt	Shock	Shock without exit	Exit with shock	Exit without shock	Exit time
IT	0.04	<0.01	0.02	0.03	0.38	0.05	0.24
Breed	0.04	0.13	0.02	0.01	1.00	0.01	0.02
Period	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07
Fence treatment	<0.01	0.96	0.74	0.93	0.58	<0.01	0.36
IT × breed	<0.01	0.01	0.66	0.12	0.19	<0.01	0.79
IT × period	<0.01	<0.01	0.34	0.31	0.10	<0.01	
IT × fence treatment	0.03	0.82	0.75	0.93	0.87	0.03	0.04
Breed × period	0.01	0.04	0.01	0.15	0.05	0.03	
Breed × fence treatment	0.04	0.79	0.83	0.93	0.19	0.03	

Table 4

Effects of interval treatment (IT) and its interactions between breed, fence treatment, and period on behavior of does in evaluation pens (Experiment 1)

Item	IT ¹			Breed			Fence treatment ²						Period ³					
	Yes	No	SEM	Boer	Spanish	SEM	LowHigh	LowMed	Low	Med	High	SEM	1	2	3	4	5	SEM
Exit (%)																		
IT-Yes				8.0 ^b	32.0 ^a	3.78	5.0 ^{de}	7.5 ^{de}	15.0 ^{cde}	32.5 ^{ab}	40.0 ^a	4.94	27.5 ^{bc}	37.5 ^{ab}	17.5 ^{cd}	0.0 ^e	17.5 ^{cd}	4.94
IT-No				15.0 ^b	8.0 ^b		5.0 ^{de}	2.5 ^e	17.5 ^{cd}	10.0 ^{cde}	22.5 ^{bc}		45.0 ^a	12.5 ^{de}	0.0 ^e	0.0 ^e	0.0 ^e	
Exit attempt (number)																		
IT-Yes				0.4 ^b	0.7 ^a	0.07							0.7 ^{abc}	1.0 ^a	0.5 ^{bcd}	0.0 ^e	0.4 ^{cd}	0.11
IT-No				0.3 ^b	0.2 ^b								0.8 ^{ab}	0.3 ^{de}	0.0 ^e	0.0 ^e	0.0 ^e	
Shock (%)	18.0 ^a	9.5 ^b	2.37															
Shock without exit (%)	11.5 ^a	5.0 ^b	1.95	12.5 ^a	4.0 ^b	1.95							20.0 ^a	8.8 ^b	7.5 ^b	1.3 ^b	3.8 ^b	3.08
Exit without shock (%)																		
IT-Yes				3.0 ^b	24.0 ^a	3.10	0.0 ^c	2.5 ^c	7.5 ^c	25.0 ^{ab}	32.5 ^a	4.21	17.5 ^{ab}	25.0 ^a	7.5 ^{bc}	0.0 ^c	17.5 ^{ab}	4.21
IT-No				9.0 ^b	5.0 ^b		2.5 ^c	0.0 ^c	7.5 ^c	5.0 ^c	20.0 ^b		27.5 ^a	7.5 ^{bc}	0.0 ^c	0.0 ^c	0.0 ^c	
Exit time (min)				12.4 ^a	4.0 ^b	2.73												
IT-Yes							9.2 ^{abc}	1.9 ^c	5.0 ^{bc}	5.9 ^{bc}	7.7 ^{bc}	4.58						
IT-No							8.0 ^{abc}	25.4 ^a	12.1 ^{ab}	4.4 ^{bc}	2.1 ^c							

¹Yes = exposure between periods to an evaluation pen with no electric fence strand; No = no exposure.²LowHigh = electric fence strands at 15.2 and 43.2 cm; LowMed = strands at 15.2 and 22.9 cm; Low = one strand at 15.2 cm; Med = one strand at 22.9 cm; High = one strand at 43.2 cm; 6kV.³Periods of the Latin square.^{a-e}Means within IT, breed, IT × breed, IT × fence treatment, or IT × period grouping without a common superscript latter differ ($P < 0.05$).

Table 5Effects of interactions between breed $\times$ fence treatment and breed $\times$ period on behavior of does in evaluation pens (Experiment 1)

Item	Fence treatment ²					SEM	Period ³					SEM
	LowHigh	LowMed	Low	Med	High		1	2	3	4	5	
Exit (%)												
Boer	0.0 ^e	7.5 ^{cde}	15.0 ^{bcd}	10.0 ^{cde}	25.0 ^{ab}	4.94	37.5 ^a	12.5 ^{bc}	7.5 ^{bc}	0.0 ^c	0.0 ^c	4.94
Spanish	10.0 ^{cde}	2.5 ^{de}	17.5 ^{bc}	32.5 ^a	37.5 ^a		35.0 ^a	37.5 ^a	10.0 ^{bc}	0.0 ^c	17.5 ^b	
Exit attempt (number)												
Boer							0.8 ^a	0.4 ^{bc}	0.3 ^{cde}	0.0 ^c	0.1 ^{cde}	0.11
Spanish							0.7 ^{ab}	0.9 ^a	0.3 ^{cde}	0.0 ^c	0.3 ^{cd}	
Shock (%)												
Boer							50.0 ^a	17.5 ^b	15.0 ^{bc}	0.0 ^d	7.5 ^{bcd}	5.31
Spanish							17.5 ^b	17.5 ^b	10.0 ^{bcd}	2.5 ^{cd}	0.0 ^d	
Exit with shock (%)												
Boer							20.0 ^a	5.0 ^{bc}	2.5 ^c	0.0 ^c	0.0 ^c	3.50
Spanish							7.5 ^{bc}	12.5 ^{ab}	7.5 ^{bc}	0.0 ^c	0.0 ^c	
Exit without shock (%)												
Boer	0.0 ^d	0.0 ^d	7.5 ^{cd}	5.0 ^d	17.5 ^{bc}	4.21	17.5 ^{ab}	7.5 ^{bc}	5.0 ^c	0.0 ^c	0.0 ^c	4.21
Spanish	2.5 ^d	2.5 ^d	7.5 ^{cd}	25.0 ^{ab}	35.0 ^a		27.5 ^a	25.0 ^a	2.5 ^c	0.0 ^c	17.5 ^{ab}	

¹LowHigh = electric fence strands at 15.2 and 43.2 cm; LowMed = strands at 15.2 and 22.9 cm; Low = one strand at 15.2 cm; Med = one strand at 22.9 cm; High = one strand at 43.2 cm; 6kV.

³2-wk periods of the Latin square.

^{a-e}Means within IT, breed, IT $\times$ breed, IT $\times$ fence treatment, breed $\times$ fence treatment, IT $\times$ period, or breed $\times$ period grouping without a common superscript latter differ ($P < 0.05$).

Table 6*P* values of animal set, fence treatment, and their interaction and period for behavior of growing meat goats in evaluation pens (Experiment 2)

Source of variation	Variable						
	Exit	Exit attempt	Shock	Shock without exit	Exit with shock	Exit without shock	Exit time
Set	< 0.01	< 0.01	< 0.01	0.01	0.04	< 0.01	0.09
Fence treatment	< 0.01	0.20	0.18	0.38	0.08	< 0.01	0.07
Set × fence treatment	< 0.01	0.31	0.84	0.89	0.15	0.01	0.82
Period	0.13	0.77	0.48	0.02	< 0.01	0.16	

Table 7

Effects of animal set, fence treatment, and their interaction and period on behavior of growing meat goats in evaluation pens (Experiment 2)

Item	Set ¹					Fence treatment ²						Period ³		
	BC	BU	SC	SU	SEM	LowHigh	LowMed	Low	Med	High	SEM	1	2	SEM
Exit (%)														
BC						12.2 ^{de}	0.0 ^e	18.6 ^{cde}	12.5 ^{de}	62.6 ^{bc}	13.98			
BU						29.9 ^{cde}	53.4 ^{bcd}	32.8 ^{cde}	75.0 ^{abc}	68.6 ^{abc}				
SC						46.4 ^{cd}	3.6 ^e	93.2 ^a	55.0 ^{bc}	89.0 ^{ab}				
SU						0.9 ^e	1.3 ^e	24.3 ^{cde}	0.0 ^e	16.0 ^{de}				
Exit attempt (number)	0.48 ^b	0.75 ^a	0.71 ^{ab}	0.10 ^c	0.093									
Shock (%)	19.0 ^{ab}	30.4 ^a	6.9 ^{bc}	3.6 ^c	4.76									
Shock without exit (%)	12.5 ^a	16.4 ^a	1.2 ^b	1.2 ^b	3.70							3.6 ^b	12.1 ^a	2.56
Exit with shock (%)	6.4 ^{ab}	14.0 ^a	5.8 ^b	2.4 ^b	2.80							13.1 ^a	1.2 ^b	1.98
Exit without shock (%)														
BC						0.1 ^f	0.0 ^f	5.8 ^{ef}	6.3 ^{ef}	62.2 ^{abc}	13.73			
BU						26.8 ^{cdef}	38.0 ^{cdef}	16.3 ^{def}	43.8 ^{bcd}	64.3 ^{abc}				
SC						36.5 ^{cdef}	0.8 ^f	77.6 ^{ab}	51.9 ^{bcd}	90.5 ^a				
SU						7.1 ^{ef}	1.3 ^f	6.5 ^{ef}	0.0 ^f	17.2 ^{def}				

¹BC = Boer common, BU = Boer unique, SC = Spanish common, SU = Spanish unique.²LowHigh = electric fence strands at 15.2 and 43.2 cm; LowMed = strands at 15.2 and 22.9 cm; Low = one strand at 15.2 cm; Med = one strand at 22.9 cm; 6.0 kV; High = one strand at 43.2 cm.³Period 2 occurred 7 wk after period 1.^{a-f}Means within set, period, or set × fence treatment grouping without a common superscript latter differ ($P < 0.05$).

Fig. 1. A diagram of an evaluation pen showing heights of five strands of barbed wire (-x-) and electric strands (-) from the ground. Electric fence strands were situated 13 cm from the barbed wire strands inside the evaluation pens, connected to insulators on two T-posts in the corners of each pen. Each pen had sides of welded wire mesh panels and plywood attached to minimize visual contact of goats between pens.