Cuellar, C., Bright, C., Zayas, G., Sproull, A., Obeso, S., Mateescu, R., Diehl, B., Hansen, P. (2026) Genetic differences in thermoregulatory ability between sheep reared in a hot, humid environment, *Proceedings 13th World Congress on Genetics Applied to Livestock Production* 23638: https://doi.org/10.31274/wcgalp.23638 ©2026 Cuellar, et al. CC BY-NC-ND

Genetic differences in thermoregulatory ability between sheep reared in a hot, humid environment

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Introduction

Since domestication about 10,000 years ago in the Near East, domestic sheep have expanded to locations throughout the world in a process involving selection for production traits, development of wool, introgression from wild relatives, and adaptation to local environments (Lv *et al.*, 2024). As a result, breeds of sheep differ in their resistance to the negative effects of heat stress (McManus *et al.*, 2020). Characterization of the genetic variability in thermotolerance and production traits between breeds can lead to genetic strategies to produce sheep that are both productive and adapted to hot climates. The objective of the present study was to test whether there are differences among breeds and breed crosses of sheep used for meat production in the southeast United States in ability to regulate body temperature during summer heat stress.

Materials & Methods

Experiments. The experiments were conducted in northern Florida during June-September 2025 for non-pregnant ewes on pasture. The experiments were conducted in three (Experiment 1) or one replicates (other experiments). For each replicate, vaginal temperature was recorded every 10 min for 5 days while ewes of various breed groups were co-mingled in a single pasture containing shade provided by trees. Sheep were allowed to engage in natural behaviours during the experimental period. Different sheep were used in each replicate. Each experiment was done at a separate location and at a different time. For Experiment 1, ewes were purebred Katahdin (KT; n=12), purebred Florida Native (FN; n=32) or an admixture of the two breeds that ranged from 25-75% of one breed (n=9). For experiment 2, ewes were FN crossbreds where the cross was with Finn (n=10), Lacaune (n=5), or St. Augustine (STA; n=8). For experiment 3, ewes were FN crossbreds where the cross was KT (n=8) or STA (n=9). Experiment 4 was conducted to compare regulation of vaginal temperatures between purebred Dorper (n=10) and Awassi (n=9). The experiments were approved by the University of Florida Institutional Care and Use Committee.

Collection and analysis of data. Vaginal temperature was measured at 10-min intervals for 5 days using an iButton 1922L (Maxim Integrated, San Jose, CA, USA) placed inside of a blank (i.e., no progesterone) controlled internal drug-releasing (CIDR) device (Zoetis, Kalamazoo, MI, USA) that was inserted into the vagina. The procedure was as described by Dikmen *et al*. (2014) except that a goat CIDR was used. Each iButton was set to 0.0625°C accuracy, inserted intravaginally in the morning of day 1 (at a variable time ranging from 0900 and 1100 H) and removed on the morning of day 5. Data collected for 24 h on each of days 2, 3 and 4 of the experiment were used for statistical analysis. Data on dry bulb temperature and humidity were collected from the Florida Automated Weather Network (www.fawn.ifas.ufl.edu) at the nearest weather station. Data for vaginal temperature were analysed by the GLIMMIX procedure of SAS v. 9.4 (SAS Institute Inc., Cary NC, USA).

The mathematical model for Experiment 1 included effects of breed (i.e., genetic group), time of day, replicate, and the interactions and with ewe nested within breed and replicate as a random effect. The model for other experiments was similar except without effects of replicate. Orthogonal contrasts were used to separate breed effects into individual one degree-of-freedom contrasts.

Results

Experiment 1. Vaginal temperature was higher (P=0.027) for KT than the other two groups, which were similar to each other (P=0.781). Average vaginal temperature was 39.45 ± 0.26°C for KT, 38.68 ± 0.16°C for FN and 38.78 ± 0.30°C for crosses. Average daily maximum temperature-humidity index during the three days of observation was 87.

Experiment 2. Finn crosses had higher (P=0.024) vaginal temperatures (39.58 ± 0.10°C) than Lacaune (39.17 ±0.15°C) or STA crosses (39.31 ± 0.12°C), which were not different from each other (P=0.475). There was a breed x time interaction that reflects that differences between genetic groups were least when vaginal temperatures peaked at ~1800 to 2000 H. Average daily maximum temperature-humidity index was 88.

Experiment 3. Vaginal temperatures were lower (P=0.045) for KT x FN crosses than STA x FN crosses (39.08 ± 0.07°C vs 39.30 ± 0.07°C). There was a breed x time interaction (P=0.007) with breed differences least at ~1500 to 1700 H when vaginal temperatures peaked. Average daily maximum temperature-humidity index was 87.

Experiment 4. Vaginal temperatures were not affected by the main effect of breed (P=0.985) but there was a breed x time interaction (P<0.0001) because vaginal temperatures were lower for Dorper from ~2200 H to ~1000 H but not at other times. For example, vaginal temperature at 0600 H was 39.00 ± 0.11°C for Dorper vs 39.39 ± 0.11°C for Awassi whereas vaginal temperature at 1900 H was 40.08 ± 0.11°C for Dorper vs 39.94 ± 0.12°C for Awassi. Average daily maximum temperature-humidity index was 89.

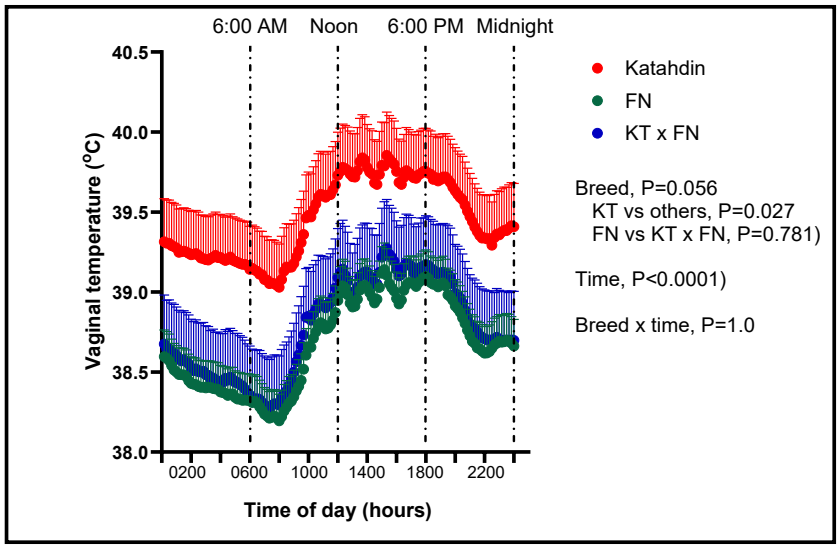

Figure 1. Differences in body temperature between genetic groups in Experiment 1. Data are least-squares means ± SEM. FN=Florida Native; KT=Katahdin.

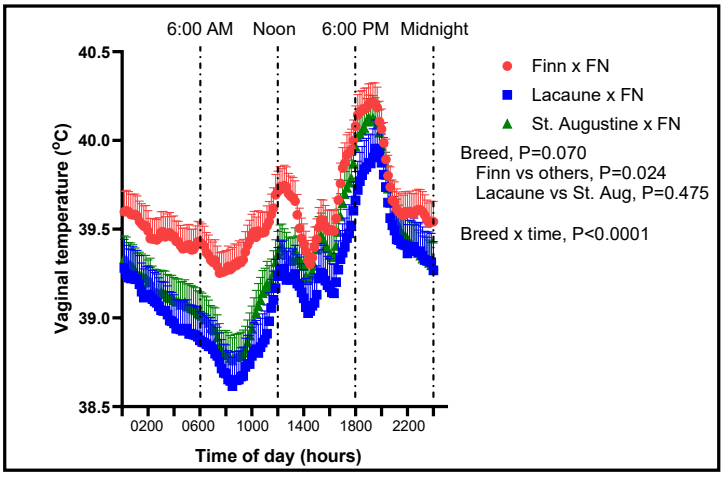

Figure 2. Differences in body temperature between genetic groups in Experiment 2. Data are least-squares means + SEM. FN=Florida Native; St. Aug.=Saint Augustine.

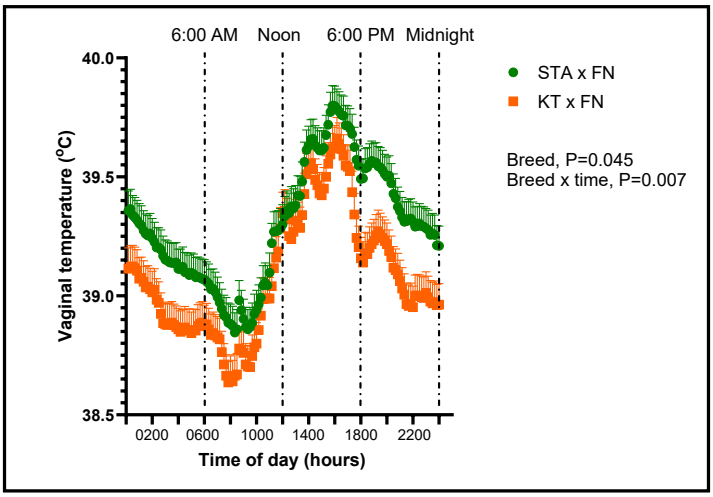

Figure 3. Differences in body temperature between genetic groups in Experiment 3. Data are least-squares means ± SEM. FN=Florida Native; KT=Katahdin and STA=Saint Augustine.

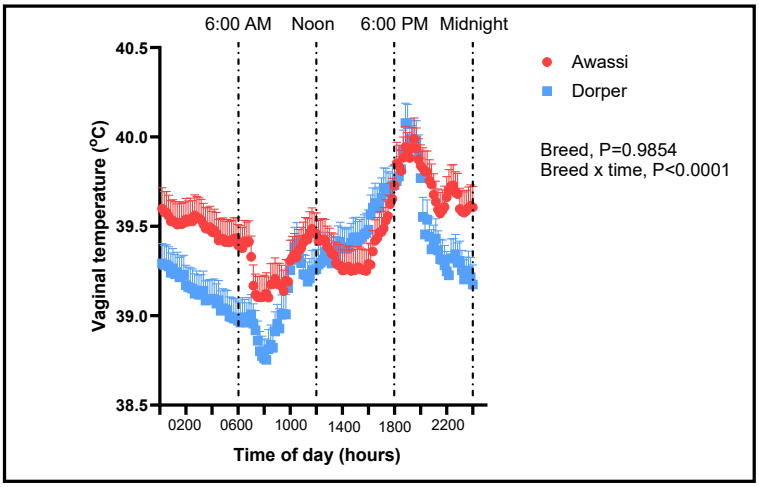

Figure 4. Differences in body temperature between genetic groups in Experiment 4. Data are least-squares means + SEM.

Discussion

All of the sheep used in this study were either breeds that arose in hot climates or were crossbreds that included genetics from breeds from hot climates. Nonetheless, none of the sheep were capable of maintaining homeothermy during the summer afternoons in which they were studied. Vaginal temperatures reached maximum temperatures in the late afternoon or evening that were above 39°C and, in some experiments with some genetic groups, above 40°C. Thus, hyperthermia and the associated changes in physiology and production associated with it can occur even in sheep considered adapted to hot climates. It is clear, however, that there are differences in ability to regulate body temperature even among these genetic groups derived from adapted breeds of sheep. Ewes of the Florida Native breed were better able to regulate vaginal temperature than purebred Katahdin ewes in Experiment 1. Crosses of Katahdin and Florida Native were similar to purebred Florida Native ewes in regulating vaginal temperature in Experiment 1 and Katahdin x Florida Native ewes in Experiment 2 regulated vaginal temperature slightly better than crosses of Saint Augustine x Florida Native ewes. The Saint Augustine is a composite breed that was developed for Florida. Current results would indicate it is less able to regulate vaginal temperature during heat stress than the Katahdin and is more similar in this regard to the Lacaune developed in France. Not surprisingly, crosses with Finn sheep, developed in Northern Europe, were less able to regulate vaginal temperature than those with Saint Augustine or Lacaune. In the last experiment, involving Dorper sheep, developed for arid regions of South Africa, and Awassi sheep that arose in the Near East, differences between breeds were small.

Conclusions

Results demonstrate that heat stress can cause hyperthermia even in breeds of sheep that were developed in hot climates and that the ability to regulate body temperature varies among genetic groups. Further research is being conducted to uncover genetic architecture underlying breed differences in regulating vaginal temperature.

Acknowledgements

Research was funded in part by Zoetis Inc. The authors thank Carol Postley of Fairmeadow Farm, Louise Hall of Windlestone Ranch, and Clay Whitehead of the University of Florida for allowing access to sheep and help with the experiments. Thanks are also extended to Rosabel Ramirez for technical assistance.

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