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# Adrenocortical Response to ACTH in Angora and Spanish Goat Wethers<sup>1</sup>

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**ABSTRACT:** Angora goats do not cope well with stress compared with goats of other breeds. Our hypothesis that this involves subclinical primary hypoadrenocorticism associated with low cortisol release in response to ACTH stimulation was tested by measuring adrenocortical response (plasma cortisol) in six Spanish ( $37 \pm 2$  kg BW) and six Angora wethers ( $39 \pm 3$  kg BW) under simulated acute and chronic ACTH challenges. In Exp. 1 (acute ACTH challenge), wethers were dosed i.v. with high (2.5 IU/kg BW) or low (.4 IU/kg BW) quantities of ACTH. In Exp. 2 (chronic ACTH challenge), ACTH at the rate of .015 IU/(kg BW·min) or saline (.15 M NaCl) was infused i.v. at 15 mL/h for 6 h. The mean baseline plasma cortisol concentration before ACTH stimula-

tion was similar ( $P > .05$ ) between Angora and Spanish goats in Exp. 1 (averaged over days) and in Exp. 2. The cortisol concentration response area ( $\text{ng}/(\text{mL}\cdot\text{min}) \times 10^{-3}$ ) above the baseline was similar ( $P > .05$ ) between Angora and Spanish goats during low ( $7.6 \pm .5$  and  $9.0 \pm 1.7$ , respectively) and high ( $12.8 \pm 1.0$  and  $16.0 \pm 1.8$ , respectively) levels of acute ACTH challenge (Exp. 1) and during chronic ACTH challenge ( $45.1 \pm 5.9$  and  $41.8 \pm 7.3$ , respectively; Exp. 2). In conclusion, these data indicate that, under the conditions of this study, adrenocortical responsiveness to ACTH stimulation is not different between Angora and Spanish goat wethers and, thus, may not contribute to stress susceptibility in Angora goats.

Key Words: Goats, Stress, Fiber, Hydrocortisone

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## Introduction

Angora goats, on a BW basis, are the highest fleece-producing ruminant (Nixon et al., 1991; Litherland and Sahlü, 1997), but are susceptible to stress. Regardless of sex, Angora goats exhibit an apparent impaired capacity for gluconeogenesis and a consequent inability to raise blood glucose levels under cold and/or nutritional stresses (Wentzel et al., 1976, 1979; Fourie et al., 1985). This may contribute to abortions (Van Rensburg, 1971; Wentzel et al., 1976) and adult fatalities (Wentzel et al., 1979). Cronjé (1995) hypothesized that the decreased gluconeogenic

ability of Angora goats is simply due to nutrient partitioning to fiber production at the expense of labile body protein reserves and glucogenic precursors. However, subclinical hypoadrenocorticism could exist in Angora goats as well. Van Rensburg (1971) and Wentzel (1993) hypothesized that genetic selection for mohair production has been accompanied by coselection for hypoadrenocorticism, because cortisol inhibits fiber follicle activity. In primary hypoadrenocorticism, low cortisol production and blood levels result from low adrenal cortisol release in response to ACTH stimulation, because of factors such as low adrenal mass and atrophy or destruction of the adrenal cortices; secondary hypoadrenocorticism is the product of low pituitary ACTH production (Kintzer and Peterson, 1997). Integrity of the adrenal cortex of Angora goats has not been directly studied. Thus, in this study the hypothesis that Angora goats exhibit subclinical primary hypoadrenocorticism was tested by measuring plasma cortisol response in stress-tolerant Spanish and stress-intolerant Angora goats under conditions of simulated acute and chronic ACTH challenges.

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Table 1. Diet composition

Item	Concentration, %
<b>Ingredient</b>	
Ground corn	17.8
Wheat middlings	10.3
Dehydrated alfalfa	20.3
Cottonseed meal	14.5
Cottonseed hulls	29.7
Pellet binder <sup>a</sup>	4.8
Limestone	1.7
Trace-mineralized salt <sup>b</sup>	.7
Vitamin premix <sup>c</sup>	.2
<b>Nutrient</b>	
ME, Mcal/kg	2.46
CP, %	13.6
ADF, %	29.5
NDF, %	43.4
Ether extract, %	2.57
Calcium, %	1.01
Phosphorus, %	.51

<sup>a</sup>Approximately 80% molasses (DM basis).

<sup>b</sup>Contained 94 to 95% NaCl and more than .2% Mn, .16% ferrous Fe, .14% ferric Fe, .033% Cu, .1% Zn, .007% I, and .005% Co (air-dry basis).

<sup>c</sup>Contained at least 2,200 IU/g vitamin A, 2,200 IU/g vitamin D<sub>3</sub>, and .2 IU/g vitamin E (air-dry basis).

## Materials and Methods

### Animals

Two- to 4-year-old Angora ( $n = 6$ ;  $39 \pm 3$  kg BW) and Spanish ( $n = 6$ ;  $37$  kg  $\pm$  2 kg BW) goat wethers, as well as one replacement animal for each breed, were selected for use in two experiments. Animals were adapted to an approximately 50% concentrate, pelleted diet (Table 1) for 7 d. Then, wethers were placed in metabolism crates for 21 d prior to the start of infusions and sampling of Exp. 1. During this 21-d period, goats were adapted to human handling and the experimental setting. Goats were positioned to allow visual, olfactory, and auditory contact with at least two other goats. Animals were weighed at 6-d intervals throughout the 39-d study (total days of Exp. 1 and 2). Fleece weight represented fiber produced in the preceding 6 mo. Fleece data from two previous shearings were used to determine daily grams of clean fiber production; percentage clean fiber was determined on fiber samples according to ASTM (1988) procedures. Individual BW was corrected for predicted fleece weight accumulated since the last shearing, based on individual fiber production potential.

Experiments were conducted in the winter (i.e., January and February) in a room of an enclosed building, without stringent temperature control (mean  $\pm$  SE; minimum,  $8 \pm 1$ ; maximum,  $20 \pm 1.3^\circ\text{C}$ ). Light was provided from 0800 to 1700, and there was no attempt made to simulate the outside diurnal light pattern. Day and night light meter readings at animal

head height varied between 120 and 425 lux (light meter type 214; General Electric, Cleveland, OH). The diet was fed once daily (1600) for BW maintenance (101.4 kcal ME/kg BW<sup>.75</sup>) and mohair production (10.95 kcal ME/g), based on NRC (1981) recommendations. Because of large temperature fluctuations, the amount of feed offered was adjusted after each weighing to maintain constant BW.

### Test Runs

A preliminary study with four wethers (two Angora and two Spanish goats) confirmed that porcine ACTH (Corticotropin A; Sigma Chemical Co., St. Louis, MO) increases plasma cortisol in goats. It also established ACTH doses producing maximum (high; 14.9 and  $14.3 \times 10^{-3}$  ng/(mL·min)) and approximately 50% of maximum (low; 6.9 and  $7.6 \times 10^{-3}$  ng/(mL·min)) responses, measured as integrated responses in cortisol production in Angora and Spanish goat wethers, respectively. The high dose (2.5 IU/kg BW) was chosen to produce and maintain a maximum peak response for at least 30 min. The expected maximum cortisol response of 80 to 120 ng/mL was based on other reports for goats (Mellor, 1991; Veenliet et al., 1995; Nwe et al., 1996). The low dose (.4 IU/kg BW) was chosen to produce approximately 50% of the response area of the high dose. The preset requirements were met with the choice of the first two doses.

### Experiment 1: Acute ACTH Challenge

Polyethylene catheters (.86 mm i.d. and 1.27 o.d.; Clay Adams, Becton Dickinson, Parsippany, NJ) were placed percutaneously into a jugular vein 24 h before Exp. 1 and remained in situ during Exp. 1 and 2. Catheters were taped to the neck and extended along the spine to terminate near the middle of the back to minimize disturbance of the animal while sampling. Patency of catheters was maintained by periodic flushing with sterile saline containing 40 IU/mL heparin. Animals were injected i.v. with 2.5 (high) and .4 IU/kg BW (low) of ACTH on d 1 and 4, respectively. Blood samples were collected 30, 15, and 1 min before ACTH injection and 10, 20, 30, 40, 60, 80, 100, 120, 140, 160, 180, 210, 240, 270, 300, 330, and 360 min later.

### Experiment 2: Chronic ACTH Challenge

In this study, chronic ACTH stimulation was defined as that exceeding any sustained, maximum stimulation expected to be experienced naturally by an animal, and was set at a period of 6 h. The aim was to stimulate maximally for a period of time greater than that with pulse dosing of Exp. 1. Animals were fitted with a second jugular catheter 25 h prior to infusions of Exp. 2, which commenced 14 d after the end of Exp. 1. Catheterizing and catheter maintenance procedures were similar to those in Exp. 1. On d 15

and 18, six animals (three per breed) received a 6-h infusion of .015 IU ACTH/(kg BW·min) to induce chronic ACTH stimulation, and the other six animals were infused with saline (.15 M NaCl) for a crossover design. An infusion rate of 15 mL/h was used via electronic syringe pumps (Harvard Apparatus Inc., South Natick, MA). The ACTH was solubilized in sterile saline containing .4% (wt/vol) BSA (96 to 99% pure; Sigma Chemical). Three baseline samples were collected at 80, 30, and 1 min before ACTH infusion and at 30-min intervals for 6 h thereafter.

#### Blood Handling Procedures and Radioimmunoassays

Before sampling, 1.5 mL of fluid was discarded to dispose of saline-heparin flushing solution. A 5-mL blood sample was collected into prechilled vacutainers containing sodium heparin (Becton Dickinson Vacutainer Systems, Rutherford, NJ) and held in an ice bath until centrifugation ( $1,500 \times g$  for 15 min at 4°C) to separate plasma. One person collected all samples. Plasma was stored at -20°C pending analysis. Plasma cortisol was analyzed using a radioimmunoassay kit (Kit no. FI 9303; ICN Biomedicals, Costa Mesa, CA). The assay uses cortisol calibrators in human serum and rabbit anti-cortisol antibodies and was previously validated for goats in this laboratory (Sahlu et al., 1992). The assay has a sensitivity of 1 ng/mL, and average inter- and intraassay coefficients of variation for pooled caprine plasma samples were  $8.54 \pm 2.37$  and  $6.31 \pm 1.73\%$ , respectively. All samples were analyzed in duplicate.

#### Data and Statistical Analyses

For Exp. 1, analysis of plasma concentrations of cortisol in response to ACTH challenges were performed by repeated measures analysis over time using GLM procedures (SAS, 1989). The statistical model included breed, treatment, and the breed  $\times$  treatment interaction. Total integrated cortisol responses, expressed as area under the cortisol curve (AUC), were determined using SAS (1989). Baseline values were calculated as the average of three samples collected prior to ACTH stimulation. An adjusted AUC (AUC<sub>adj</sub>; or response area) was determined as total area between actual cortisol response and the baseline, up to where two consecutive values had returned to baseline. Analysis of variance was conducted for AUC<sub>adj</sub>, peak, and time to peak as a completely randomized design with a factorial arrangement of treatments, with breed, dose, and their interaction as main effects.

In Exp. 2, baseline cortisol concentrations during saline infusion were regressed over time, within breed. Total AUC (AUC<sub>tot</sub>) was estimated as the total area between the actual cortisol response data and zero. Total area under the saline curve (AUS<sub>tot</sub>) was estimated as total area between actual response and

Table 2. Cortisol concentration before ACTH treatment

Experiment	ACTH treatment <sup>a</sup>	Breed	
		Angora	Spanish
		— ng/mL; mean $\pm$ SE <sup>b</sup> —	
1	Low acute	8.9 $\pm$ 1.2	9.0 $\pm$ .7
	High acute	4.6 $\pm$ .2 <sup>c</sup>	8.0 $\pm$ 1.0 <sup>d</sup>
2	Chronic	5.2 $\pm$ 1.2	6.8 $\pm$ .6
	Saline	3.3 $\pm$ .8	4.8 $\pm$ .8

<sup>a</sup>Exp. 1: low and high acute = ACTH dosed at .4 and 2.5 IU/kg BW, respectively; Exp. 2: chronic = ACTH infused at .015 IU/(kg BW·min), and saline = .15 M NaCl, with infusion at 15 mL/h for 6 h.

<sup>b</sup>Values are averages of three samples taken before dosage or infusion; n = 6.

<sup>c,d</sup>Within a row, means lacking a common superscript differ ( $P < .01$ ).

zero. The effect of day on AUC<sub>tot</sub> and AUS<sub>tot</sub> was investigated through a one-way analysis of variance, by analyzing breeds separately. Because no differences were found between days ( $P > .05$ ), AUC<sub>tot</sub> was adjusted for AUS<sub>tot</sub>. Adjusted AUC, AUS<sub>tot</sub>, peak concentration, and time to peak were analyzed as a completely randomized one-way analysis of variance, with breed as the main effect. Total AUS was regressed against fleece production within and between breeds. Differences were considered significant with  $P < .05$ .

## Results

### Animal Health and BW Changes

Animals maintained good health throughout the study. Energy intake by Spanish wethers was 19% greater than the NRC (1981)-recommended maintenance energy requirement; energy intake for Angora wethers was 22% greater than recommended for maintenance plus mohair. Change in BW over the entire 39 d for Exp. 1 and 2 averaged -3 g/d for Spanish and -7 g/d for Angora; thus, animals were assumed at a maintenance level of feed intake.

### Basal Cortisol

Within day, Spanish goats showed higher ( $P < .01$ ) basal concentrations only before the high acute ACTH treatment in Exp. 1 (Table 2). However, both groups were well within the physiological range of 1 to 15 ng/mL reported for other breeds of goats (Eriksson and Teräväinen, 1989; Mellor, 1991; Al-Dehneh et al., 1994), and the difference was negligible relative to change with ACTH treatment (Figure 1). Preinfusion basal cortisol concentration in Exp. 2 was similar ( $P > .10$ ) between breeds. Feeding did not affect cortisol concentration during saline infusion (240 to 300 min;

Table 3. Adrenocortical responsiveness to low (.4 IU/kg BW) and high (2.5 IU/kg BW) doses of ACTH (acute stimulation) in Spanish and Angora goat wethers (Exp. 1)

Item	Angora		Spanish		Probability		
	High acute <sup>a</sup>	Low acute <sup>a</sup>	High acute	Low acute	Breed	Dose	Breed × dose
	Mean ± SE <sup>b</sup>						
AUC <sub>adj</sub> , ng/(mL·min) × 10 <sup>-3c</sup>	12.8 ± 1.0	7.6 ± .5	16.0 ± 1.8	9.0 ± 1.7	.11	.0003	.52
Peak, ng/mL	94.3 ± 7.8	94.8 ± .5	127.4 ± 22.9	104.3 ± 13.5	.12	.40	.38
Time to peak, min	58.3 ± 9.1	33.3 ± 5.4	41.7 ± 8.7	25.0 ± 4.7	.07	.005	.54

<sup>a</sup>Low and high acute = ACTH dosed i.v. at .4 and 2.5 IU/kg BW, respectively.

<sup>b</sup>n = 6.

<sup>c</sup>AUC<sub>adj</sub> = adjusted area under the cortisol curve, calculated as the total area between actual cortisol response and the baseline.

Figure 2); no pre- or postprandial peaks were observed for either of the breeds. Clean fiber production was not correlated ( $P > .10$ ) with AUS<sub>tot</sub> over all data or within breed.

#### Experiment 1: Adrenocortical Response to Acute ACTH Stimulation

In response to high and low ACTH stimulation, absolute time trends of cortisol release were similar for Angora and Spanish wethers (Figure 1), and, although treatment was highly significant ( $P < .001$ ), neither breed nor the breed × treatment interaction was significant ( $P > .05$ ). Analyzed by analysis of variance, response area (AUC<sub>adj</sub>), peak, and time to reach peak concentration were similar in Angora and Spanish wethers (Table 3). Interactions between goat breed and ACTH dose were not significant ( $P > .05$ ). Plasma cortisol level was increased ( $P < .05$ ) by both low and high doses of ACTH, and the level peaked at 20 to 80 min after ACTH dosage in both groups (Figure 1).

In both breeds, the high ACTH dose evoked greater ( $P < .001$ ) adrenal response (AUC<sub>adj</sub>) than did the low ACTH dose, by increasing duration of the elevated cortisol concentration rather than the peak (Figure 1; Table 3). Cortisol concentrations returned to the baseline approximately 60 min earlier for low vs high ACTH stimulation. The AUC<sub>adj</sub> with low ACTH stimulation averaged 61% of that with high stimulation. In response to maximum stimulation, one Spanish goat wether had a substantially higher peak cortisol concentration (i.e., 240 ng/mL) than did other wethers (i.e., 80 to 120 ng/mL). Omitting data of this wether resulted in an AUC<sub>adj</sub> of  $14.3 \pm .8 \times 10^{-3}$  ng/mL and a peak cortisol concentration of  $107 \pm 6$  ng/mL for Spanish wethers, which was similar to Angora values.

#### Experiment 2: Adrenocortical Response to Chronic ACTH Stimulation

Plasma cortisol during saline infusion (AUS<sub>tot</sub>) was similar in Spanish and Angora goats (Table 4). Cortisol concentration remained stable throughout the

infusion period (Figure 2) and was not correlated ( $P > .05$ ) with time within breed. Continuous infusion of .015 IU/(kg BW·min) ACTH produced a rapid and substantial increase ( $P < .001$ ) in plasma cortisol above baseline concentration that was similar between breed groups (Figure 2). The AUC<sub>adj</sub>, peak plateau value, and time to plateau were similar between breeds ( $P > .05$ ).

Individual wether cortisol plateau concentrations were equal to or higher than peaks in Exp. 1, and we

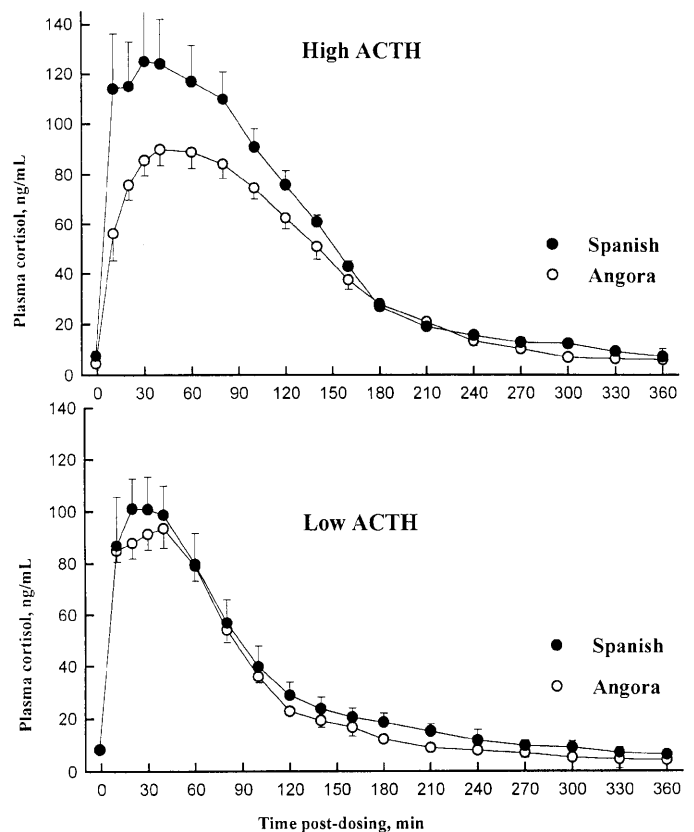


Figure 1. Mean ( $\pm$  SE) plasma cortisol concentrations in Spanish and Angora goat wethers (n = 6) dosed i.v. with 2.5 (high) or .4 (low) IU of ACTH/kg of BW. Standard error bars not visible are contained within the circle.

Table 4. Adrenocortical response of Angora and Spanish goat wethers to chronic (6 h) infusion of ACTH with .015 IU/(kg BW·min) (Exp. 2)

Item	Breed		Probability
	Angora	Spanish	
	Mean ± SE <sup>a</sup>		
AUC <sub>adj</sub> , ng/(mL·min) × 10 <sup>-3bc</sup>	45.1 ± 5.9	41.8 ± 7.3	.80
AUS <sub>tot</sub> , ng/(mL·min) × 10 <sup>-3de</sup>	.29 ± 1.29	.15 ± .50	.17
Peak, ng/mL <sup>c</sup>	150 ± 19	138 ± 22	.69
Time to peak, min	200 ± 33	145 ± 39	.30

<sup>a</sup>n = 6.

<sup>b</sup>AUC<sub>adj</sub> = adjusted area under the cortisol curve, calculated as the total area between actual cortisol response and the baseline.

<sup>c</sup>6-h infusion of ACTH at .015 IU/(kg BW·min) and 15 mL/h.

<sup>d</sup>AUS<sub>tot</sub> = total area under the saline curve.

<sup>e</sup>6-h infusion of .15 M NaCl at 15 mL/h.

assumed that all animals were stimulated maximally during the entire 6-h infusion. The mean plateau concentration for Spanish wethers was similar to that for highest ACTH stimulation in Exp. 1. A failed catheter in Exp. 2 necessitated using the spare Angora goat. This animal, and the Spanish goat in Exp. 1 previously discussed, produced peak cortisol concentrations of 200 to 240 ng/mL during chronic ACTH infusion. As a result, the mean peak cortisol concentration of Angora goats averaged 56 ng/mL higher than in Exp. 1.

## Discussion

This study was designed to directly test primary adrenocortical function in Angora and Spanish goat wethers by measuring cortisol production in response to exogenous ACTH challenges. Wethers were chosen as a model in this study because the inability to maintain normoglycemia is a breed- rather than sex-related problem (Wentzel et al., 1976, 1979; Fourie et al., 1985).

### Basal Cortisol

Angora wethers exhibited basal plasma cortisol concentrations similar to those of the Spanish wethers. The concentrations also correspond to those reported for other breeds of goats (Eriksson and Teräväinen, 1989; Sahlu et al., 1993; Nwe et al., 1996). In contrast, lower plasma cortisol concentrations were reported in Angora relative to Spanish goat doelings (Jia et al., 1995) and to Nubian and Alpine doe- and bucklings (Hart et al., 1993). However, only single blood samples were taken in these two studies. Basal plasma cortisol concentrations can be highly variable, being influenced by a combination of factors such as the episodic, pulsatile nature of cortisol secretion (Scobie and Hynd, 1995), diurnal and circadian rhythms of cortisol secretion (Broom and Johnson, 1993), fleece length (Salem et al., 1991),

and stressfulness of the sampling protocol as perceived by the animal (Parrot et al., 1988; Cooper et al., 1989).

Differences in the stressfulness of sampling protocols that may exacerbate breed-handling interactions may have contributed to breed differences reported by Hart et al. (1993) and Jia et al. (1995). In those studies, animals were physically restrained, the necks clipped, and the blood sample collected through venipuncture (T. Sahlu, personal communication). In comparison, animals in this study were well adapted to human presence, and the sampling protocol almost totally excluded physical contact. In addition, caution should be exerted when drawing conclusions based on the mean of only one sample and ignoring possible interaction between breed and time. During

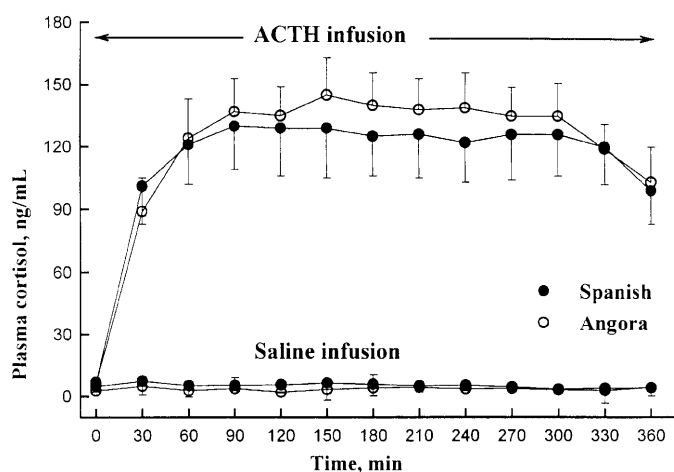


Figure 2. Mean ( $\pm$  SE) plasma cortisol concentrations in Spanish and Angora goat wethers ( $n = 6$ ) during 6-h i.v. infusion of saline or .015 IU of ACTH/(kg BW·min) at .15 mL/h in Spanish and Angora goat wethers ( $n = 6$ /group). Standard error bars not visible are contained within the circle. Goats were fed between 240 and 300 min after infusion.

saline infusion (Exp. 2), absolute means of cortisol concentrations were slightly higher in Spanish wethers for 0 to 3 h, but virtually identical from 3 to 6 h. Spanish wethers exhibited higher pretreatment basal cortisol concentrations in Exp. 1 preceding low ACTH stimulation. But, nonsignificant interactions between breed and day in Exp. 1 and between breed and time in Exp. 2 with saline infusion indicate a random distribution of breeds over time.

#### *Fiber Production*

Independent of degree of affliction, hypoadrenocorticism in humans and other animals (Addison's disease) is accompanied by low concentrations of plasma cortisol (Knowlton, 1971). The apparent normal basal cortisol plasma concentrations of Angora goats in this study seem to challenge the hypothesis of Van Rensburg (1971) and Wentzel (1993) that increased mohair production is a result of subclinical hypoadrenocorticism. Average clean fiber production over a 12-mo period was 5.6 times greater in the Angora ( $13.4 \pm 1$  g/d) than in the Spanish wethers ( $2.4 \pm .4$  g/d), yet Angora wethers exhibited similar circulating cortisol concentrations, and fiber production and AUS<sub>tot</sub> were not correlated.

In sheep, only circulating plasma cortisol concentrations above and below a normal physiological range of 1 to 10 ng/mL (Bassett and Hinks, 1969) inhibit wool growth. Effects seem to be time- and dose-dependent (Scobie and Hynd, 1995), with concentrations at the extreme ranges exerting influence on fiber production. Wool growth rate was decreased after prolonged ( $> 1.2$  d) elevation of plasma cortisol concentrations above 30 ng/mL (Chapman and Basset, 1970; Wallace, 1979; Scobie and Hynd, 1995) and in adrenalectomized sheep (Scobie and Hynd, 1995). A "normal" basal cortisol seems necessary to maintain fiber production (Scobie and Hynd, 1995).

There is little information on the effect of cortisol on mohair production. In Angora goats, brief ( $< 180$  min) intradermal infusion of increasing levels of cortisol had little effect on amino acid metabolism in the skin and, by inference, mohair growth (Pierzynowski et al., 1996). On the other hand, Herselman and Pieterse (1992) reported a 25% decrease in mohair production following prolonged ( $> 1.2$  d) cortisol treatment. Even though only limited information is available, fiber production in Angora goats, compared with wool sheep, seems to respond to cortisol similarly. The normal circulating cortisol concentrations found in this study should be conducive to normal follicle activity and fiber production.

#### *Cortisol Response to ACTH*

Peak cortisol concentrations for Angora and Spanish wethers were similar to those in reports for other breeds of goats (Mellor, 1991; Veenvliet et al., 1995;

Nwe et al., 1996). Overall, based on all criteria tested, Angora wethers seemed similar to Spanish wethers in ability to produce cortisol after acute and during chronic ACTH challenges. In accordance, Angora goat wethers seem capable of mounting an appropriate response to ACTH stimulation and may not suffer from primary hypoadrenocorticism. However, Escobar et al. (1998) reported that the plasma cortisol response to a single injection of ACTH was greater in non-Angora than Angora does, but plasma cortisol response to seven daily injections of ACTH was similar in both breeds of goats.

Cronjé (1992, 1995) provided information on the status of the whole hypothalamo-pituitary-adrenal cortex axis of Angora bucks and does. No evidence of hypoadrenocorticism was found following insulin-induced hypoglycemia in a comparison of high and low mohair-producing Angora bucks (Cronjé, 1995). Similarly, nongravid Angora and Boer does showed similar glucose clearance rates following a glucose tolerance test (Cronjé, 1992). Also, no indication of a hypoglycemic tail, typical in subjects with adrenal insufficiency (Caraway, 1982), was observed in either breed (Cronjé, 1992).

But it is too early to rule out the possible role of adrenal aberrations in stress-related abortions of Angora does. Recently, Escobar et al. (1998) reported a reduced adrenocortical response to acute ACTH stimulation by habitually aborting Angora does, compared with that of non-Angora does. These seemingly conflicting reports on the status of the adrenal integrity of Angora goats emphasize need for further research to elucidate roles of sex, physiological state, and abortion history in the genetic lineage in the integrity of the hypothalamo-pituitary-adrenal cortex axis. The role of cortisol receptors (e.g., number and ability to respond) in target tissues in influencing the ability to access gluconeogenic precursors during stress also warrants investigation. Consideration should also be given to using larger numbers of experimental subjects to investigate a problem in which differences may be marginal.

In conclusion, the hypothesis that Angora goats exhibit subclinical primary hypoadrenocorticism was rejected because the adrenocortical response to ACTH stimulation was similar in Angora and Spanish goats. Furthermore, plasma cortisol response to ACTH stimulation in Angora goats indicated adequate adrenocortical response regardless of how the response compared with that in Spanish or non-Angora goats.

#### **Implications**

The adrenal cortex in Angora goat wethers seems to be fully capable of mounting an appropriate cortisol response to adrenocorticotrophic hormone stimulation. Thus, the ability of Angora goats to cope with stress

may involve factors other than the capacity of the adrenal cortex to produce cortisol. However, possible changes in hypothalamic-pituitary-adrenal cortex axis function due to pregnancy and/or dysfunction in cell-signaling mechanisms for cortisol action may play a role in the well-established stress intolerance of Angora goats.

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