

Chapter 7:
Effects of Treadmill Exercise on the
Respiratory Moisture Losses of Goats
of Different Breeds and Sexes

7.1 Experiment 13: Male and Female Saanen Goats

7.1.1 Introduction

Previous experiments in this series which involved Bali-cattle and swamp buffalo of different sexes working in the field, and male and female Saanen goats on a treadmill in the laboratory clearly demonstrated markedly different physiological reactions between the sexes. For example, in Experiment 5, male and female Saanen goats recorded RR's of 138 and 52/minute respectively after walking on a treadmill at 3 km/h at 30°C ET and when at rest. Within Anglo Nubian and Toggenburg (Experiment 6), RR differed significantly after 30, 45 and 60 min of exercise with magnitudes of 92, 115 and 81/min respectively. In so far as such increases in RR have a thermoregulatory role, it might reasonably be expected that they would be accompanied by increases in respiratory moisture loss (RML). Experiment 13 was therefore undertaken to establish the magnitude of the response in RML during exercise in male and female Saanen goats.

7.1.2 Materials and Methods

Two female and 2 male Saanen goats, with body weights varying from 44 to 58 kg (51.0 ± 5.7 kg), but having similar body condition scores (3.5) were used. A 2x2x4x6 factorial design (2 animals; 2 sexes; 4 times of measurement every 20 minutes and 6 days with 1 day resting in between) was employed. RML was measured by using an open circuit nose mask attached to each goat; moisture was measured by acid catch in a sample (2%) of respired air by the method described in Chapter 3.7. Both RR and RT were also measured routinely, and PCV was estimated from jugular blood samples taken before and after exercise.

7.1.3 Results

Respiration rate (RR):

For RR, analysis of variance revealed a significant time x sex interaction ($P < 0.05$). The rate of increase with time during exercise was significantly greater in males than in females, with mean differences between the sexes of 41, 66 and 89 breaths/min after 20, 40 and 60 min of exercise respectively (Fig. 39). Between times, the RR increased markedly and after 30 min the magnitudes were 156 and 69/min in males and females respectively. With respect to days, RR was found to differ significantly ($P > 0.05$). The highest mean RR was found on day 3, with a value of 105/minute.

Rectal temperature (RT):

No significant interactions were found in RT. Between the sexes RT differed significantly ($P < 0.05$; Table 21), with the highest values recorded in the male (39.8°C). With respect to days RT was found not to differ significantly ($P > 0.05$). With time during exercise there were significant differences in RT ($P < 0.001$); values increased markedly and after 60 minutes of exercise the mean figure was 40.7°C.

Table 21: Mean RT (°C) of male and female Saanen goats of similar body condition during treadmill exercise at 3 km/h and 30°C environmental temperature

| Sex: | male | | female | | SEM | | Level of significance | |
|--------------|-------|-------|--------|-------|-------|-------|-----------------------|-----------------------|
| RT: | 39.8a | | 39.6b | | 0.01 | | * | |
| Day : | D1 | D2 | D3 | D4 | D5 | D6 | SEM | Level of significance |
| RT: | 39.8a | 39.6a | 39.7a | 39.7a | 39.8a | 39.6a | 0.02 | ns |
| Times: (min) | 0 | 20 | 40 | 60 | SEM | | Level of significance | |
| RT: | 38.7a | 39.4b | 40.0c | 40.7d | 0.02 | | *** | |

Values within lines with dissimilar superscripts differ significantly (ns=non significant; * $P < 0.05$; *** $P < 0.001$)

Respiratory moisture loss (RML):

With RML, analysis of variance revealed a significant time x sex interaction ($P < 0.01$). Once again, as with RR (above), the rate of increase with time during exercise was significantly greater in males than females, the magnitudes of this sex difference averaged 334, 381 and 418 mg/min after 20, 40 and 60 min respectively (Fig. 39). After 60 min of exercise the RML increased markedly in both males and females with magnitudes 674 and 369 mg/min respectively. With respect to days, RML did differ significantly ($P < 0.001$ respectively); the highest RML was recorded on day 4, with a mean value of 550 mg/minute.

RML/breath:

The time x sex interaction with regards RML/breath also differed significantly ($P < 0.05$; Fig. 39); values decreased gradually in both sexes, by overall magnitudes of 6.1 and 3.4 mg after 60 min exercise in male and female goats respectively. For days the RML/breath was found to differ significantly ($P < 0.05$), day 1 was the highest with a mean value of 6.3 mg/breath. There were positive correlations between RML and RR, with correlation coefficients of 0.8 in both males and females, and linear regressions of $Y = 0.2X - 16$ and $Y = 0.2X - 11$ ($X = \text{RML}$ and $Y = \text{RR}$) in males and females respectively.

Packed Cell Volume (PCV)

PCV did not differ significantly ($P > 0.05$) with sex or day of experiment, but it did decline significantly ($P < 0.05$; Table 22) during exercise. After 60 minutes of exercise, PCV decreased by 6.1 percentage points (41.0 to 34.9%); similar patterns were also found in Hb concentration.

Table 22: Mean PCV and Haemoglobin concentration (Hb) in male and female Saanen goats during treadmill exercise at 30°C environmental temperature

| | PCV (%) | | SEM | Level of significance |
|-----------------------|-----------|------|------|-----------------------|
| Time (0-60 mins) | 41.0 | 34.9 | 0.2 | * |
| Sex (male and female) | 38.6 | 37.3 | 0.2 | ns |
| Day (1-2) | 39.0 | 36.9 | 0.2 | ns |
| | Hb (g/dl) | | SEM | Level of significance |
| Time (0-60 mins) | 12.4 | 10.8 | 0.01 | * |
| Sex (male and female) | 11.6 | 11.7 | 0.01 | ns |
| Day (1-2) | 11.5 | 11.6 | 0.01 | ns |

Values within lines with dissimilar superscripts differ significantly (ns=non significant; *P < 0.05)

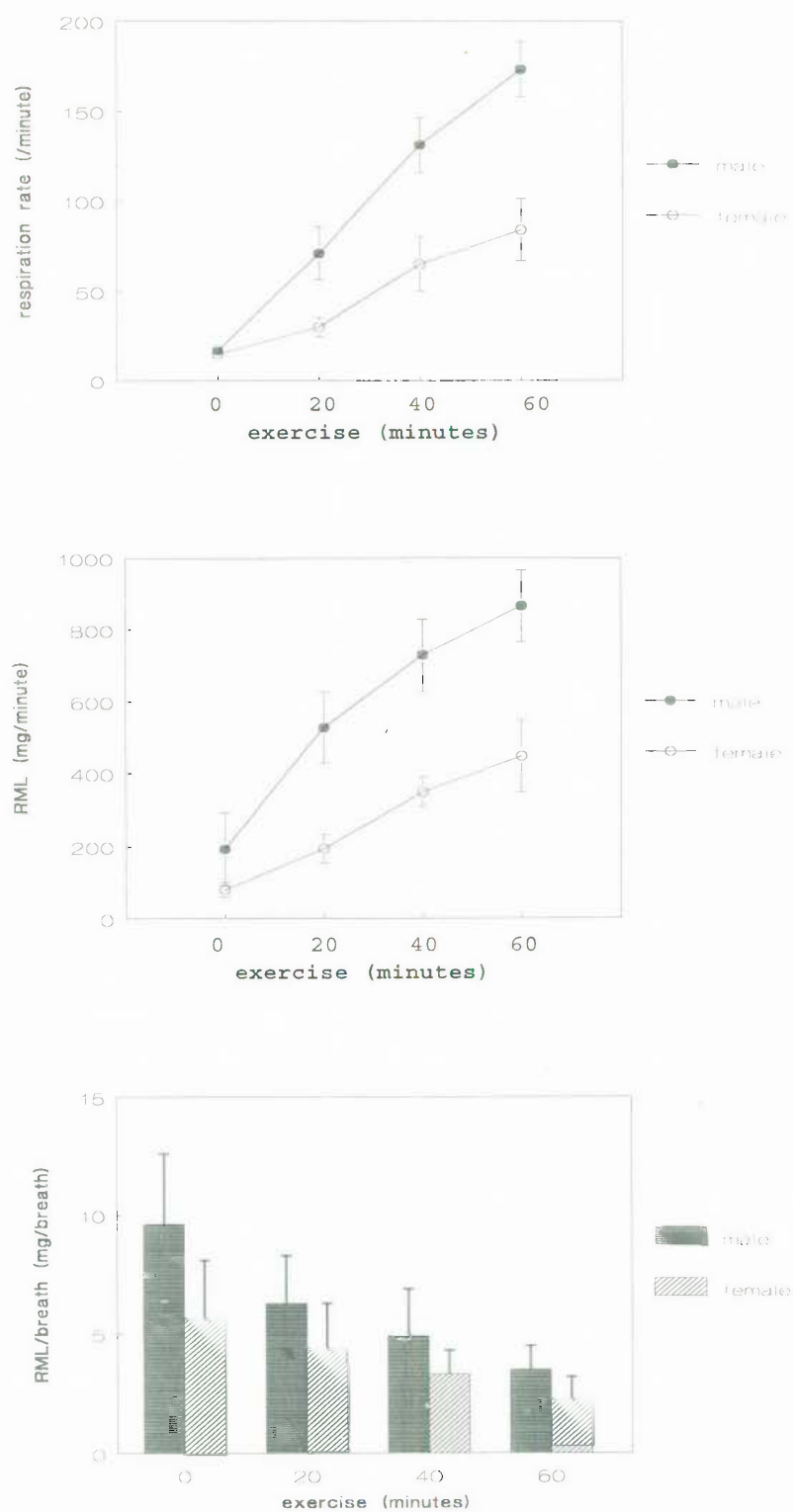


Fig. 39

Mean RR (/minute), RML (mg/minute) and RML/breath (mg/breath) of male and female Saanen goats during treadmill exercise at 3 km/h and 30° C environmental temperature

7.2 Experiment 14: Saanen and Toggenburg Goats

7.2.1 Introduction

Previous experiments on black and white swamp buffalo in the field and on the Saanen, Anglo Nubian and Toggenburg goats in the laboratory clearly revealed different physiological reactions during work or exercise between the breeds. Those significant responses were particularly noted for RR. For example, the RR after 60 min of exercise (3.8 km/h at 30°C) in Saanen, Anglo Nubian and Toggenburg goats in Experiment 9 were 146, 103 and 168/minute respectively. The experiment reported here was designed to investigate the relationship between RR and RML (respiratory moisture loss), and thus the extent to which differences in RR contributed to differences in the thermoregulatory responses to exercise.

7.2.2 Materials and Methods

Two Saanen and 2 Toggenburg goats with body weights varying from 46 to 64 kg (53.0 ± 7.0 kg) and similar condition scores of 3.5 were used at a treadmill speed of 3 km/h and an ET of 30°C. A 2x2x4x6 factorial design (2 animals; 2 breeds; 4 times of measurement at 20 minute intervals and 6 days with 1 day resting in between) was employed. RML was measured by using an open circuit system attached via a nose mask to the head of each goat. Samples of inlet and outlet air were passed through acid catches and gas meters to estimate RML. Both RR and RT were also measured as previously described.

Blood was collected prior to and after exercise for the estimation of haematocrit and haemoglobin. Animals were fed a standard diet at the rate of 1.5% of body weight; and water was available *ad libitum*.

7.2.3 Results

Respiration rate (RR):

A significant time x breed interaction (Fig. 40) was found in RR ($P < 0.01$); values increased remarkably in both the Saanen and Toggenburg breeds to reach means of

130 and 223/minute after 60 minutes. On a statistical basis the Toggenburg goats had higher values ($P < 0.05$) of RR than Saanens with the magnitudes of those differences averaging 45, 58 and 93/min after 20, 40 and 60 min exercise respectively. Between days, the RR was found to differ significantly ($P < 0.01$) and the highest value of 124/min was recorded on day 6.

Rectal temperature (RT):

A significant time x breed interaction (Fig. 40) was found in RT ($P < 0.01$), the Saanens were less stressed than Toggenburgs with values of 40.4 and 40.8°C respectively after 60 min exercise. On a statistical basis the Toggenburg goats had higher values of RT than Saanens with magnitudes of the difference averaging 0.1 (NS), 0.3 and 0.5°C ($P < 0.05$ respectively) after 20, 40 and 60 min exercise. For days, the RT was found to differ significantly ($P < 0.05$), and overall values decreased gradually from days 1 to 6 by a magnitude of 0.8°C.

Respiratory moisture loss (RML):

The day x breed interaction for RML was significant ($P < 0.01$); once again the Saanens were less stressed compared to Toggenburgs except on day 1 (N.S. Fig. 41) with mean differences of 113, 61, 91, 134 and 79 mg/min on days 2, 3, 4, 5 and 6 respectively. The effect of time on RML was highly significant; values increased markedly by 459.2 mg/min during 1h of exercise.

RML/breath:

The time x breed interaction for RML/breath was significant ($P < 0.05$; Fig. 40); values decreased gradually by magnitudes of 4.0 and 6.5 mg during 60 min exercise in Saanen and Toggenburg goats respectively. With day, RML/breath did not differ significantly ($P > 0.05$). Significant correlation between RML and RR were found; with correlation coefficients of 0.8 and 0.9, and linear regression of $Y = 0.2X - 16$ and $Y = 0.4X - 56$ in Saanens and Toggenburgs respectively ($X = \text{RML}$ and $Y = \text{RR}$).

Packed cell volume (PCV):

For both PCV and Hb, values declined significantly ($P < 0.05$; Table 23) during exercise by an average of 5.5 percentage points and 1.5 g/dl respectively.

Table 23: Mean PCV and Haemoglobin (Hb) values in Saanen and Toggenburg goats before and after treadmill exercise at 3 km/h and 30°C environmental temperature for 1 hour

| | PCV (%) | | SEM | Level of significance |
|-------------------------------|-----------|------|-----|-----------------------|
| Time (0-1h) | 35.8 | 30.3 | 0.5 | * |
| Breed (Saanen and Toggenburg) | 34.0 | 32.0 | 0.5 | ns |
| | Hb (g/dl) | | SEM | Level of significance |
| Time (0-1h) | 10.5 | 9.0 | 0.2 | ns |
| Breed (Saanen and Toggenburg) | 10.3 | 9.2 | 0.2 | ns |

Values within lines with dissimilar superscripts differ significantly (ns=non significant; * $P < 0.05$)

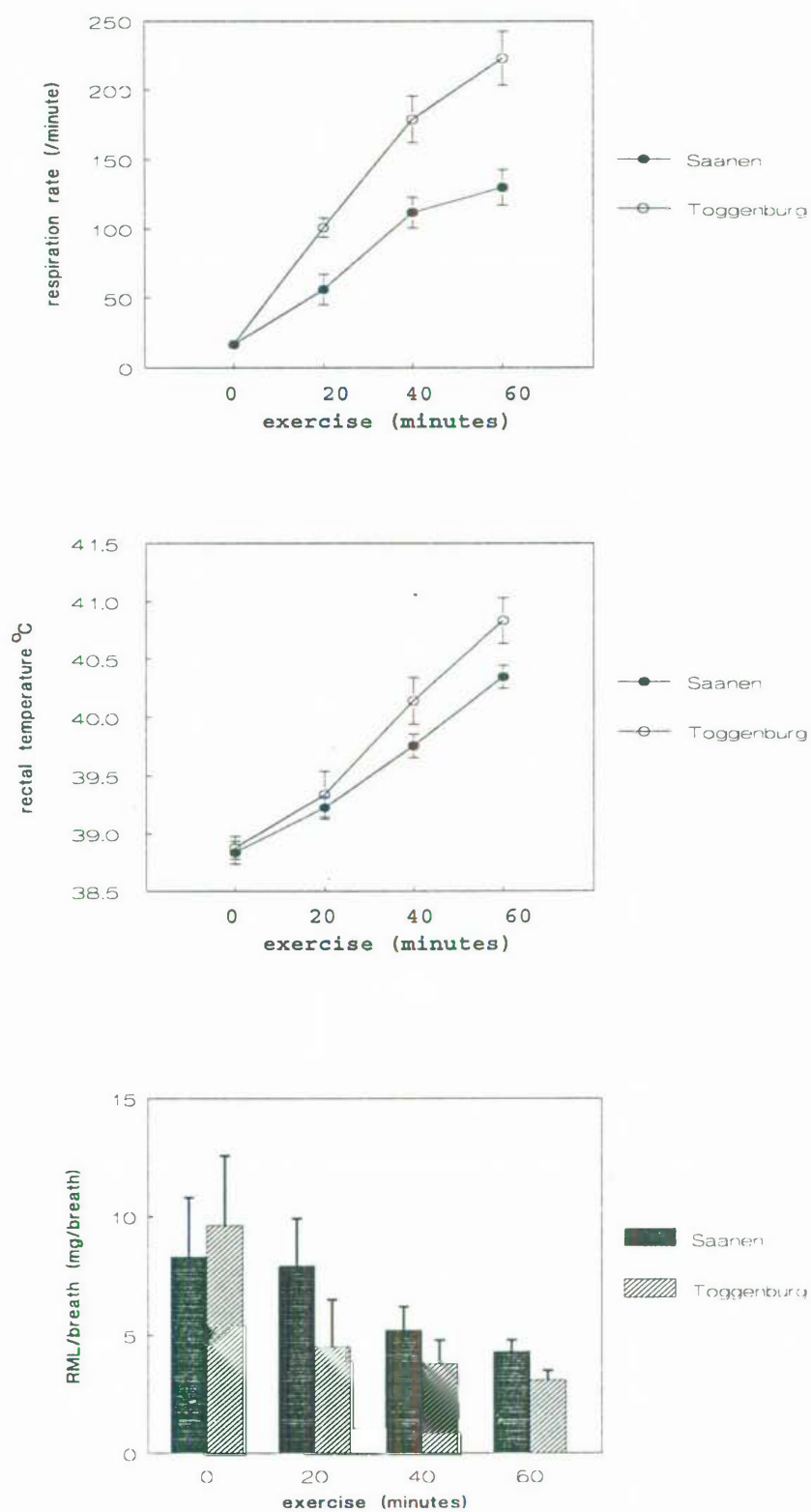


Fig. 40

Mean RR (/minute), RT (°C) and RML/breath (mg/breath) of Saanen and Toggenburg goats during treadmill exercise at 3 km/h and 30°C environmental temperature

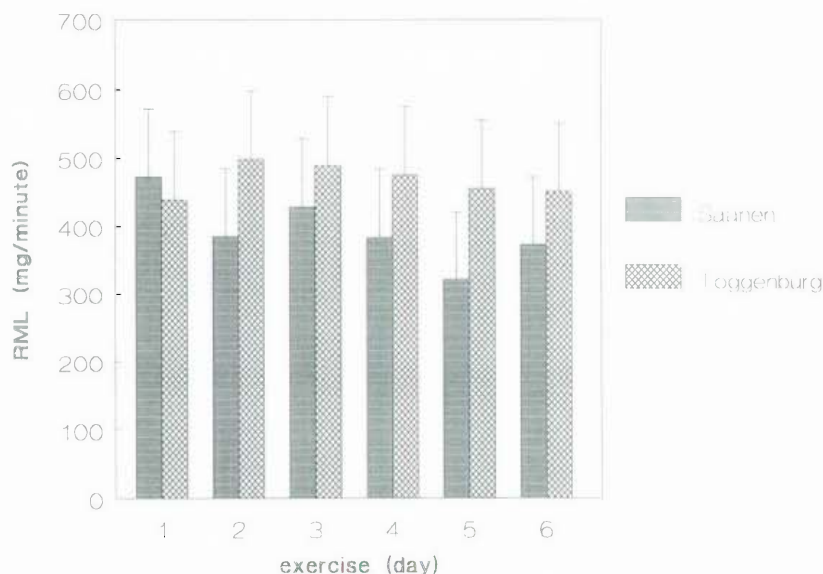


Fig. 41 Mean RML of Saanen and Toggenburg goats during treadmill exercise at 3 km/h and 30°C environmental temperature

7.3 Discussion

Overall, it can be concluded that an increase in RR was followed by a proportionally rise in RML in both different sexes and breeds, and at different times during exercise. Such a finding is in general agreement with the results of ALEXANDER and WILLIAMS (1962), who reported that RML in heat stressed lambs (not exercised) was approximately proportional to RR, and who concluded that RML increased by the equivalent of from 25 to 110 g/m²/h as RR increased by from 100 to 400/min respectively. However, between days in the current work the extent of the relationship between RR and RML was not proportional. The author observed during the experiment differences in the nature of the panting responses. Sometimes it appeared "deep/slow", while at other times it was "shallow/fast". It is possible that during "deep/slow" panting (lower RR) the animals produced more RML/breath than during "shallow/fast" (higher RR but lower RML), and that this could have influenced the day-to-day results. So far, no evidence has been found that supports this possibility, and the author thus suggests the

need for further detailed experiments to be conducted on this basis in the future.

RR, RT and RML all increased with time, males were more stressed than females and Saanens were more tolerant than Toggenburgs. Such results clearly confirm the results of the previous experiments conducted in both the field and the laboratory. Additionally, from the current sex x time interactions, it appears that the increase in RML with time during exercise can be described by the linear equations $Y=11.1X + 245$ and $Y=6.3X + 78$ for male and female goats respectively. From the breed x time interactions, the linear equations $Y=8.5X + 214$ and $Y=6.8X + 189$ were developed for Toggenburg and Saanen respectively. These equations clearly demonstrate that the rate of increase of RML (slope) in males was higher than in females and in the Toggenburg was higher than in the Saanen. In other words, males were more affected by exercise than females, and Toggenburgs were more affected than Saanens. Possible reasons for these differences, including basal metabolic rate, muscle mass, stride length, hair coat type and genetic inheritance have been mentioned previously.

However, there was an interesting result when the differences between Saanens and Toggenburgs in the current experiment were compared to those in Experiment 12 (Chapter 6), particularly for RR and RT. In Experiment 12, the RR's of the Saanen and Toggenburg breeds after 30 minutes of exercise were 62 and 99/min, with respective RT's of 39.6 and 39.4°C. In contrast, the corresponding figures in the current experiment were 79 vs 130/min and 39.5 vs 39.8°C respectively after 60 min of exercise. It seems likely that during the shorter period of exercise (30 min) only an irregular pattern of response was expressed, but when the animals had a longer period of exercise (60 min) they showed a clear cut pattern, with the Saanen more tolerant than the Toggenburg (a rise in RR followed by a marked increase in RT).

The current results were again in general agreement with MURRAY and YEATES (1967), who found in cattle an increase in mean RR with time after both a fast and a slow walk (75 vs 150/min and 80 vs 125/min), as well as in RT (38.9 vs 40°C and 38.3 vs 39.4°C). Such responses could be due to an increase in oxygen consumption for metabolic processes, a greater rate of heat production, and as a consequence an increase

in RT. Such facts also support the findings of BIRD *et al.* (1981), who reported that exercise increased oxygen uptake by the hind limb by 6-7 fold. In addition, JUDSON *et al.* (1976) recorded that at rest the total entry rate of blood glucose was 0.44 ± 0.03 mmol/min, while during exercise the rate increased to 0.84 ± 0.004 mmol/min. A similar pattern was also reported by HARMAN and PETHICK (1994).

It was found in Experiment 13 that when RR increased from 16 to 129/min, RML per respiration declined from 8 to 5 mg/respiration respectively. A similar pattern occurred in Experiment 14; when RR increased from 17 to 177/min, RML per respiration declined from 9 to 3 mg/respiration respectively. Overall, the current investigations revealed the same pattern of response as reported by ALEXANDER and WILLIAMS (1962), who reported that in heat stressed sheep there was a linear relationship between RR and RML per respiration. That is, when the RR increased from 100 to 400/min, RML per respiration declined from 20 to 4 mg/respiration respectively.

Decreases in both PCV and Hb after exercise in the different sexes and breeds studied in this chapter confirm previous results.

Overall, it can be said in summary that an increase in RR was proportionally followed by an increase in RML, particularly in comparisons between different sexes, breeds and times of exercise. This clearly confirmed previous experiments in both the field and laboratory that animals with high RR tended to exhibit relatively lower RT, presumably as a response to higher RML. As such, the current results quite clearly demonstrate that between sexes, the male is more affected compared to female, and between breeds, the Toggenburg is more affected than Saanen; eg. males had higher RR and RML, including higher RML/breath, than females, but despite this their RT was also higher. Such a result could arise from either a correspondingly high rate of heat production in males, from a relatively higher evaporative loss from sweating in females, or a combination of the two. The experiment reported in Chapter 8 was undertaken specifically to examine the hypothesis that differences between the sexes in sweating rate could explain the overall responses observed here.

Chapter 8:
Effects of Treadmill Exercise on
Cutaneous Moisture Losses in Goats of
Different Sexes and Breeds

8.1 Experiment 15: Different Sexes

8.1.1 Introduction

Goats are "sweating animals" even though they are classified as "poor" sweaters (ROBERTSHAW, 1968). As shown in previous experiments reported in this thesis, sex had significant effects on RR, RT, ST and RML in both cattle and goats during work and exercise. In male and female goats for example (Experiment 6), the male had a higher ST than females; 37.9 and 37.5°C respectively. The males also had higher RR and RT than females. It is well known that, in general, sweating rate (SR) increases as skin temperature increases, and the hypothesis in the current experiment was thus that during exercise there are differences in SR between males and females that are proportional to differences in ST.

8.1.2 Materials and Methods

This experiment was set up to measure sweating rate. Two male (50.5 ± 3.5 kg in body weight) and 2 female (49.0 ± 3.0 kg) Saanen goats, aged 3 and 4 years respectively, were employed. All animals were fed a basal diet at the rate of 1.5% of body weight. A 2x2x4x6 factorial design as used in experiment 3 was employed. The factors were: 2 sexes, 2 goats of each sex, 4 different times of measurements (T0=before exercise; T1 to T3 at 20 minute intervals during exercise and 6 days and 1 day off. RR, RT, SR and blood parameters were measured as explained in General Materials and Methods. The treadmill was set at 3 km/h and the ET was 30°C.

8.1.3 Results

Respiration rate (RR):

The results of the time x sex interaction showed that RR again differed significantly between the sexes ($P < 0.01$); values increased markedly with time and the males were more stressed than the females with the difference averaging 26 and 60/min after 40 and 60 min exercise respectively (Fig. 42). Between days, RR was significantly different ($P < 0.01$), and decreased gradually between day 1 and 6 by a total of 63/minute.

Rectal temperature (RT):

In the absence of significant interactions, the sex differences for RT were found not to differ significantly ($P > 0.05$). Between days, RT did differ significantly ($P < 0.05$; Table 24) and it decreased gradually between days 1 and 6 by an average of 0.7°C . The results of times during exercise showed that RT again differed significantly ($P < 0.001$), and increased markedly, with values of 40.1°C being reached after 1h.

Sweating rate (SR):

The time x sex interaction for LSR was significant ($P < 0.05$); the males being more stressed than females to the extent of 25, 6 (NS) and 4 $\text{g}/\text{m}^2/\text{h}$ (NS) after 20, 40 and 60 min of exercise respectively (Fig. 42). Between days, LSR was significantly different ($P < 0.05$) and decreased gradually between days 1 and 6 by an average of 38.4 $\text{g}/\text{m}^2/\text{h}$.

Since there were no significant interactions for RSR and ESR, between sexes the RSR differed significantly ($P < 0.05$ Table 24) with higher values recorded in the male than the female by an average of 65.0 $\text{g}/\text{m}^2/\text{h}$. Between days, RSR was also significantly different ($P < 0.01$), and decreased gradually between days 1 and 6 by a total of 37.1 $\text{g}/\text{m}^2/\text{h}$. The results of times during exercise showed that RSR again differed significantly ($P < 0.001$). In this case maximum RSR was recorded after 20 minutes and values then declined to 70.8 $\text{g}/\text{m}^2/\text{h}$ after 1 hour. Changes in ESR followed similar trends to RSR, but the actual values recorded were generally lower than for RSR (Table 24).

Table 24: Mean RT (°C), rump sweating rate (RSR=g/m²/h) and ear sweating rate (ESR=g/m²/h) of male and female Saanen goats of similar body condition during 3km/h treadmill exercise at 30°C environmental temperature

| Sex: | male | | female | | SEM | | Level of significance | |
|-----------------|-------|--------|--------|--------|--------|--------|-----------------------|-----------------------|
| RT: | 39.5a | | 39.6a | | 0.002 | | ns | |
| RSR: | 65.0a | | 59.5b | | 0.2 | | * | |
| ESR: | 56.4a | | 49.9b | | 0.3 | | * | |
| Day : | D1 | D2 | D3 | D4 | D5 | D6 | SEM | Level of significance |
| RT: | 40.0a | 39.7b | 39.6bc | 39.5c | 39.3d | 39.3d | 0.010 | * |
| RSR: | 84.9a | 67.2b | 66.6bc | 66.4d | 50.4de | 47.8f | 0.7 | ** |
| ESR: | 89.4a | 74.9ab | 53.0c | 52.2cd | 33.2e | 26.1ef | 0.8 | * |
| Times: (min) | 0 | 20 | 40 | 60 | SEM | | Level of significance | |
| RT: | 39.0a | 39.4b | 39.8c | 40.1d | 0.004 | | *** | |
| RSR: | 7.5a | 86.3b | 84.3c | 90.8d | 0.5 | | *** | |
| ESR: | 8.1a | 79.9b | 68.2c | 66.4d | 0.5 | | *** | |

Values within lines with dissimilar superscripts differ significantly (ns=non significant; *P < 0.05; **P < 0.01; ***P < 0.001)

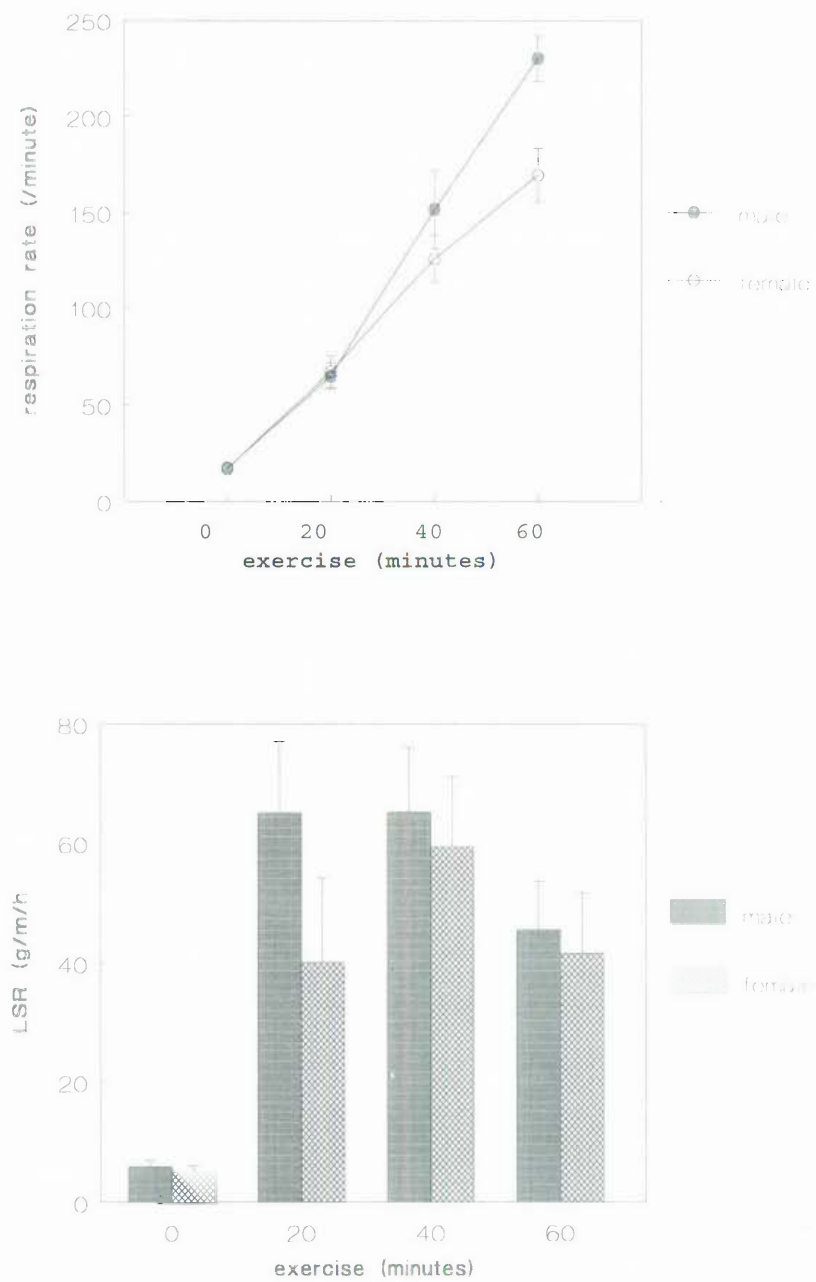


Fig. 42 Mean RR (/minute) and LSR (g/m²/h) of male and female Saanen goats during treadmill exercise at 3 km/h and 30°C environmental temperature

8.2 Experiment 16: Different Breeds

8.2.1 Introduction

A previous experiment on breed differences (Experiment 9) showed ST to differ significantly (37.7, 37.9 and 37.6°C) in Saanens, Anglo Nubians and Toggenburgs respectively, when the corresponding RR were 146, 103 and 168/minute. On the other hand, breed differences in sweating rate are well documented in cattle (DOWLING, 1958; SCHLEGER and TURNER, 1955; and FINCH *et al.*, 1982), and increases in ST are known to be followed by increases in SR in cattle as well (TANEJA, 1959b). The hypothesis to be tested in this experiment was thus that there are breed differences in SR in goats during exercise.

8.2.2 Materials and Methods

Six female goats, with 2 animals of each of 3 breeds (Anglo Nubian, Saanen and Toggenburg) were employed. Body weights varied from 44 to 54 kg, but all animals were in a body condition score of 3.0. A basal diet was given at the rate of 1.5% of each individual's body weight and water was available *ad-lib*. A 2x3x4x6 factorial design was employed, with 2 animals of each breed, 3 different breeds, 4 different times of measurements (T0=before exercise; T1 to T3 at 20 minute intervals during exercise), and 6 days with 1 day resting in between. RR, RT, SR and blood parameters were measured as previously described and the treadmill was set at 3 km/h and ET at 30°C.

8.2.3 Results

Respiration rate (RR):

For RR, the interaction between time x breed was significant at $P < 0.01$; RR increased gradually with time in all 3 breeds, but the interaction indicated that Toggenburgs were more stressed than Saanens, and Anglo Nubians with less so, mean increases during 1 h of exercise of 233, 175 and 114/minute respectively (Fig. 43). With different days of exercise, results were also found to be significantly different for RR ($P <$

0.05), and values decreased gradually from day 4 to reach an overall mean of 87/minute on day 6.

Rectal temperature (RT):

No significant interactions were detected for RT, and the breeds did differ significantly ($P < 0.001$; Table 25). The highest RT was recorded in the Anglo Nubian, then followed the Saanen and Toggenburg breeds, with respective values of 39.5, 39.4 and 39.1°C. On different days of exercise, RT also differed significantly ($P < 0.05$), and decreased gradually from day 4 to reach an overall mean of 39.3°C on day 6. Very consistent results between the breeds with respect to different times during exercise yielded statistically significant results for RT ($P < 0.001$), and values increased to reach a mean of 39.7°C after 1h.

Sweating rate (SR):

For LSR, the interaction between time x breed was significant ($P < 0.01$); the Toggenburgs were the most intolerant breed, particularly in the first 20 minutes of exercise (Fig. 43). On different days of exercise, LSR results were also found to differ ($P < 0.05$). LSR decreased gradually from day 4 to reach an overall mean of 39.1 g/m²/h on day 6.

With respect to breeds, RSR was found not to differ significantly ($P > 0.05$; Table 25), but ESR did differ significantly ($P < 0.05$). With ESR, the Saanen recorded slightly higher values (56.2 g/m²/h) compared to Anglo Nubian and Toggenburg (55.0 and 50.3g/m²/h respectively). Very consistent results for the different times during exercise yielded statistically significant results for RSR and ESR ($P < 0.001$), a steep increase was found in ESR during the first 20 minutes of exercise, then it gradually decreased to a mean value of 66.8 g/m²/h after 1h. With regards to RSR, gradual increases were found in

the first and second 20 minutes periods (with respective magnitudes 89.0 and 90.8 g/m²/h), then values declined to a level of 83.7 g/m²/h after 1h.

Table 25: Mean RT (°C), rump sweating rate (RSR=g/m²/h) and ear sweating rate (ESR=g/m²/h) of female Anglo Nubian, Saanen and Toggenburg goats with 3 km/h treadmill exercise at 30°C environmental temperature

| Breed: | A.Nubian | | Saanen | | Toggenburg | | SEM | Level of significance |
|--------------|----------|--------|--------|--------|------------|--------|-------|-----------------------|
| RT: | 39.5a | | 39.4a | | 39.1b | | 0.003 | *** |
| RSR: | 71.8a | | 66.9a | | 65.6a | | 0.3 | ns |
| ESR: | 55.0a | | 56.2a | | 50.3b | | 0.2 | * |
| Day : | D1 | D2 | D3 | D4 | D5 | D6 | SEM | Level of significance |
| RT: | 39.3ab | 39.2a | 39.4bc | 39.5c | 39.4bc | 39.3ab | 0.006 | * |
| RSR: | 91.2a | 79.0b | 65.0c | 57.5c | 51.8d | 53.8d | 0.6 | ** |
| ESR: | 69.5a | 62.0ab | 57.2bc | 50.1cd | 45.6e | 38.7f | 0.3 | ** |
| Times: (min) | 0 | 20 | 40 | 60 | | | SEM | Level of significance |
| RT: | 38.9a | 39.2b | 39.5c | 39.7d | | | 0.004 | *** |
| RSR: | 8.7a | 89.0bc | 90.8b | 33.7c | | | 0.4 | *** |
| ESR: | 7.1ab | 72.7a | 68.9bc | 56.8c | | | 0.2 | *** |

Values within lines with dissimilar superscripts differ significantly (ns=non significant; *P < 0.05; **P < 0.01; ***P < 0.001)

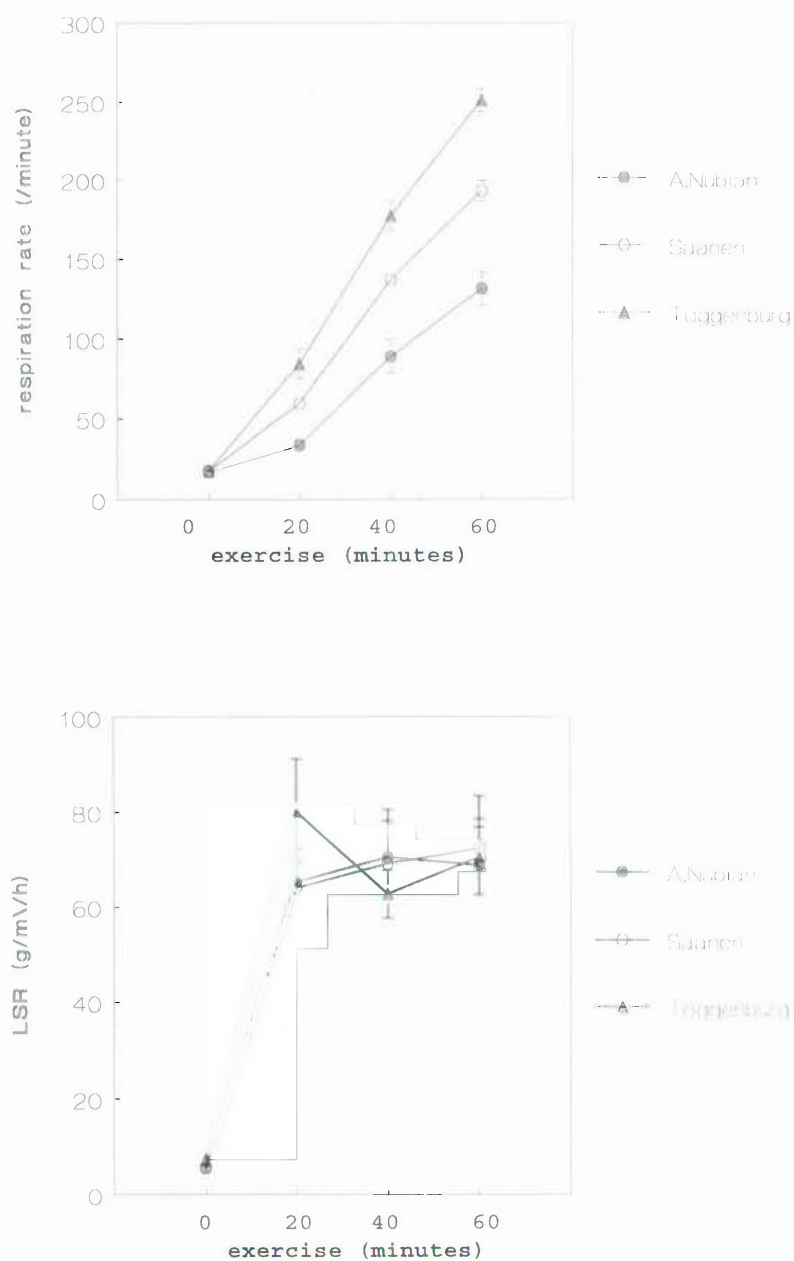


Fig. 43 Mean RR (/minute) and LSR (g/m²/h) of A.Nubian, Saanen and Toggenburg goats during treadmill exercise at 3 km/h and 30°C environmental temperature

8.3 Discussion

Overall, it can be seen that male goats sweated more than females, and this result is in general agreement with DMI'EL *et al.* (1979) who reported that SR in male and

female black Beduin goats averaged 146 ± 42.5 and 130 ± 41 g/m²/h on the thorax area respectively during exercise at 2.7 km/h for 30 min. Such differences could be due to differences in sweat gland density, which have been demonstrated by DMIEL *et al.* in male and female Beduin goats (2.5 ± 0.1 and 1.8 ± 0.1 glands/mm² respectively). Other possible reasons such as sweat gland size, the density of dermal arteries, nerves and the percentage of active follicles have been described as affecting SR in different breeds. Additionally, differences between SR in males and females in the current study could have been associated with differences in age: 3 and 4 years respectively. BIANCA and HALES (1970) reported that age affected sweating rate in cattle; e.g. the rate of moisture loss from the skin per unit of metabolic body size ($W^{0.75}$) at 46°C ET was greater in newborn calves than in those 1-year old (190 vs 165 g/m²/h), possibly due to a greater percentage of active follicles in young rather than older animals (SCHLEGER and BEAN, 1971).

The current results confirm the existence of breed differences in SR in goats, and thus extend the report of FINCH *et al.* (1982) of a similar situation in cattle. Such breed differences could be due to differences in sweat gland size and density. For example, JENKINSON and ROBERTSHAW (1971) reported that the mean sweat gland density on the upper thorax of five British Saanen goats was 1.7 glands/mm² with a range of 1.0 to 2.7 glands/mm², whereas in the Black Bedouin goat sweat gland density varied from 1.7 to 2.6 glands/mm² with a mean of 2.1 glands/mm². In cattle, TURNER *et al.* (1962) reported that the mean number of sweat glands per square centimetre on the midside region of Sindhi, Sahiwal, Jersey, Friesian and Red Poll cattle were 1509, 1507, 1005, 996 and 981 respectively. NAY and HAYMAN (1956) also reported that Zebus had much larger (longer and greater diameter) sweat glands than European cattle.

SR varied with different positions (rump, loin and ear). These results are in general agreement with SCHLEGER and BEAN (1971) who found differences in SR between positions on cattle, for example, the shoulder and flank had sweating rates of 648 g/m²/h vs 601 g/m²/h respectively. Such differences could also be due to variation in the density of dermal arteries, nerves and the percentage of active follicles.

RSR and ESR declined after 40 min of exercise within days and also between days (Experiments 15 and 16). Such a situation is in general agreement with

WIKANTADI (1983) who reported that during initial exposure to 40°C, SR in Saanen goats rose to peak levels of from 40 to 50 g/m²/h, but by the end of 2.75 hours of exposure the SR had declined to values of from 24.5 to 28.5 g/m²/h. That decrease in SR could be due to sweat gland 'fatigue' as a result of the glands losing their ability to discharge sweat to the skin surface. WIKANTADI (1983) suggested that the loss of the gland's ability to secrete could arise through a reduction in stored secretions, a failure of secretory rate to match discharge rate, or failure of the discharge mechanism. Such reasons support those of JENKINSON and ROBERTSHAW (1971) and JOHNSON (1973). Alternatively, the decline in the magnitude of SR might be a result of a decreasing demand on the sweat glands due to compensation by other adaptive (heat loss) mechanisms, e.g. RR and RT. Data in Tables 33 and 34 of the current experiment in part answer the latter possibility in the affirmative, in that RR gradually increased with time during exercise (a highly significant trend).

Additionally, the results of the current study (Table 34) and of Experiments 9, 10 and 11 (Tables 24, 25 and 26 of Chapter 6 respectively) showed that the relatively high SR in Anglo Nubians was associated with a high ST and RT, but a low RR. Such facts are in general agreement with TANEJA (1959b) who observed that an increase in ST of from 37.6 to 39.8°C after exposure to high temperature was followed by a progressive increase in SR of from 214.9 to 427.5 g/m²/h in Shorthorn cattle. The corresponding increase in Zebu crosses was from 229.6 to 377.2 g/m²/h, associated with an increase in ST of only 1.7°C. In conclusion, a higher SR in the Anglo Nubian did not reduce the stress level noticeably, and the fact that both ST and RT remained high could be due to low RR and RML (Experiment 12). Therefore, the result might be interpreted as indicating that the Anglo Nubian breed relies more on sweating than panting, whereas the Saanen and Toggenburg rely mainly on panting for heat dissipation.

Another possibility is that differences in sweat gland output exist between the sexes and breeds. For example, JENKINSON and ROBERTSHAW (1971) have

calculated the secretion rate of individual sweat glands from the upper thorax of Saanen and Black Bedouin goats to be 13 nl/h and 66 nl/h respectively.

Overall, it can be said that SF was an important thermoregulatory avenue in the goats studied. For example, results from Experiment 5 revealed that lower RT and ST (rump, loin and ear) in males as compared to females could be explained on the basis of a higher SR in the male (Table 32). Such facts are in general agreement with FINCH *et al.* (1982) who studied different breeds of cattle (Brahman=B; Brahman x Hereford-Shorthorn cross-breeds=BX; and Shorthorn=S) and reported that the relationship between SR and RT was greater for B (294 g/m².h/°C) than for S (194 g/m².h/°C) and BX (146 g/m².h/°C) and this fact could help to explain why the mean RT in B was lower than in other breeds (38.7, 39.3 and 39.7°C for B, BX and S respectively). Similar results were presented by SCHLEGER and TURNER (1965), who found that Brahman x Shorthorn had higher SR than Shorthorn when grazing at 11.00, 14.00 and 16.00h daily (temperature vary from 22 to 37°C): 406 vs 377, 621 vs 519 and 473 vs 427 g/m²/h respectively. Under these conditions the Brahman crossbreds again showed significantly lower RT (37.2°C) than the Shorthorns (38.9°C).

Overall, it can be concluded that the male had a higher SR than the female. The current results also confirm those from previous experiments in which higher RR was associated with a lower RT. In the different breeds, Toggenburgs sweated less than Saanens and A.Nubians, but not significantly so. There were, however, significant differences in RR and RML, with a negative association with RT, presumably through greater evaporative cooling. Both thermoregulatory avenues, namely RML and SR, thus require further investigation. Particular questions which require answers are:

1. What are the effects on overall thermoregulation if the efficiency of RML is artificially reduced, as, for example, in animals in a very humid environment? and,
2. The sweating rate of goats (eg. typically 70-90 g/m²/h during exercise) is low in comparison to that in cattle. What are the consequences of blocking

the evaporation of sweat, or of artificially enhancing it by sprinkling the animals with water?

These questions will be examined in Chapter 9, which follows.