Chapter 6:

The Effects of Treadmill Exercise on Physiological Responses of Different Breeds of Goats

6.1 Introduction

A preliminary experiment in the field on swamp buffalo of different coat colour (normal and albino; Experiment 4) clearly revealed that the two types had different physiologically reactions to work; the black were more stressed than the albino during work in hot/dry season (RR 72 and 55/minute respectively; $P < 0.05$). This difference were very small and of doubtful biological significance, and the results suggest that more detailed (RML and SR) experiments are needed on breed differences under controlled, laboratory conditions.

With regards different breeds of goats, ARRUDA and PANT (1987) reported that while Bhuj and Caninde animals recovered normal body temperature within 45 minutes of completing exercise, Anglo Nubians required more than 60 minutes to recover ($P<0.05$), but that the former had significantly higher RR during exercise than the later ($P<0.05$). Such results suggest breed differences in thermoregulatory reactions during exercise or work at high temperatures. To test this general hypothesis, a series of laboratory experiments was undertaken (treadmill exercise at 30°C ET) with individuals of the Saanen, Toggenburg and Anglo Nubian breeds which: differed in body weight and feed intake (the normal field situation: Experiment 9), were similar in condition score and fed either at maintenance (Experiment 10) or below or above maintenance (Experiment 11), or which were exercised at 20, 30 or 40°C (Experiment 12).

6.2 Experiment 9: Responses in Saanen, Anglo Nubian and Toggenburg Goats at Different Body Weights and Feed Intakes

6.2.1 Materials and Methods

Six mature female goats, two Saanen (LW of 51.0 ± 1.0 kg), two Anglo Nubian (LW of 46.8 ± 6.3 kg) and two Toggenburg (LW of 41.5 ± 4.5 kg), of a similar condition score of 2.5 were used. In order to maintain the condition score of 2.5, the goats were individually fed a basal diet at the rate of 1.5% of their body weight.

A 5x3x3x2 factorial design was used in this experiment, the factors being 5 times of measurement (every 15 minutes; T0 = measurement before exercise and T4 = after 60 minutes of exercise), 3 days with 1 day resting in between, 3 different breeds and 2 animals in each breed.

6.2.2 Results

Respiration rate (RR):

For RR there was a significant time x breed interaction ($P < 0.01$), with values for the Anglo Nubian being lowest (Fig. 24). Between Anglo Nubian and Toggenburg, RR differed significantly after 30, 45 and 60 min of exercise with magnitudes of 92, 115 and 81/min respectively, while the Saanen was intermediate and values for it did not differ significantly from the other 2 breeds. With time, RR increased gradually in all breeds and differed significnatly, and after 1h the respective RR were 238, 221 and 303/min in the Saanen, Anglo Nubian and Toggenburg. Between days, RR did not differ significantly ($P > 0.05$).

Rectal temperature (RT):

For RT there was also a significant time x breed interaction ($P < 0.01$), with values for the Anglo Nubian being highest (Fig. 25). Significant differences between the 3 breeds were found after each of 30, 45 and 60 min exercise, with values in Anglo Nubian averaging 40.5, 41.0 and 41.3°C respectively. With time, the RT increased

gradually in all breeds, and after 1h exercise mean values were 40.8, 41.3 and 40.7°C in the Saanen, Anglo Nubian and Toggenburg respectively. Between days, RT differed significantly ($P < 0.05$), and decreased gradually from 40.3 to 39.9°C on days 1 and 3 respectively.

Skin temperature (ST):

For each of RST and EST there was a significant time x breed interaction ($P < 0.01$), with values for Anglo Nubian being generally highest in each case (Figs. 26 and 27). For example, mean RST values differed significantly between Anglo Nubians and Toggenburgs, with the differences averaging 0.3, 0.6, 0.4 and 0.4°C after 15, 30, 45 and 60 min exercise respectively. With time, RST increased gradually in each of the Saanen, Anglo Nubian and Toggenburg breeds, with mean values 38.4, 39.0 and 38.6°C respectively after 1h exercise. Between days, LST did not differ significantly ($P > 0.05$), however, RST and EST did differ significantly between days ($P < 0.05$ and $P < 0.01$ respectively). The highest RST was recorded on day 2 (37.9°C); values then decreased to 37.7°C on day3, while EST decreased gradually (36.1, 35.4 and 34.8°C) on days 1, 2, 3 respectively ($P < 0.01$). With regards breed, highest LST values were in the Anglo Nubian, with an overall mean of 37.9°C ($P < 0.05$; Table 18).

Table 18: Mean LST of female Saanen, Anglo Nubian and Toggenburg goats during exercise at 3.8 km/h on a treadmill at 30°C

Breed:	Saanen	A.Nubian	Toggenburg	SEM	Level of significance
LST:	37.7a	37.9b	37.6a	0.03	*
Day :	D1	D2	D3	SEM	Level of significance
LST:	37.9a	37.7a	37.5a	0.03	ns
Times: (min)	0	15	30	45	60	SEM	Level of significance
LST:	36.7a	37.6b	37.9bc	38.1cd	38.4d	0.03	**

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

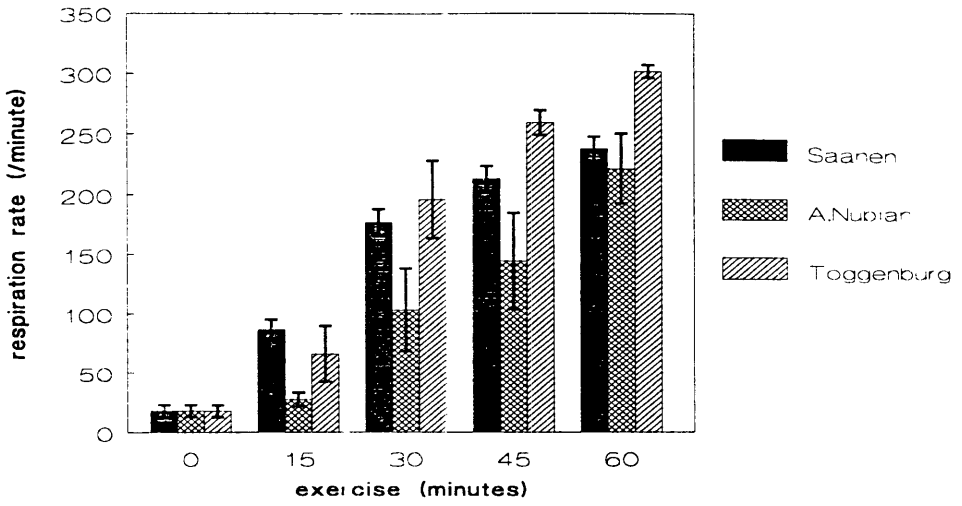


Fig. 24 Mean RR of Saanen, A.Nubian and Toggenburg goats at different body weights and feed intakes during treadmill exercise of 3.8 km/h speed and 30°C

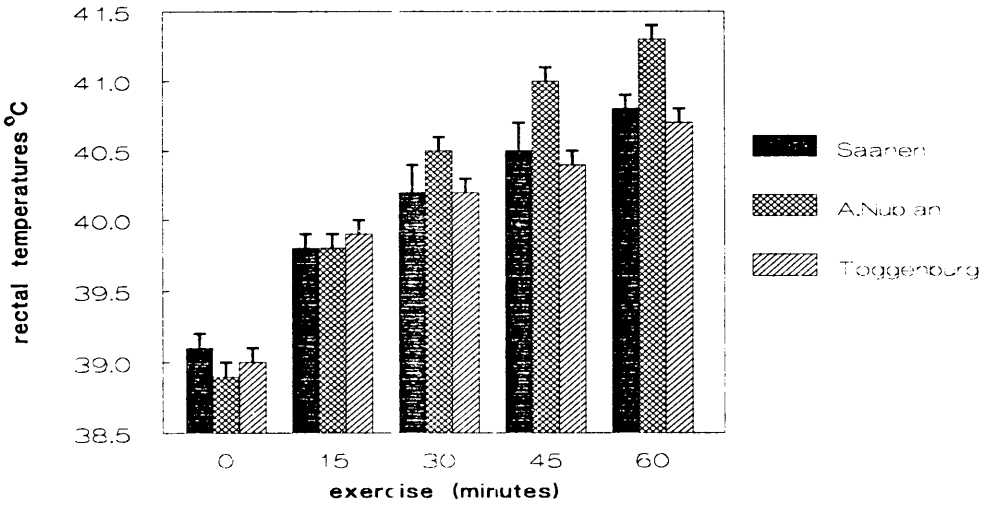


Fig. 25 Mean RT of Saanen, A.Nubian and Toggenburg goats of different body weights and feed intakes during treadmill exercise at 3.8 km/h speed and 30°C

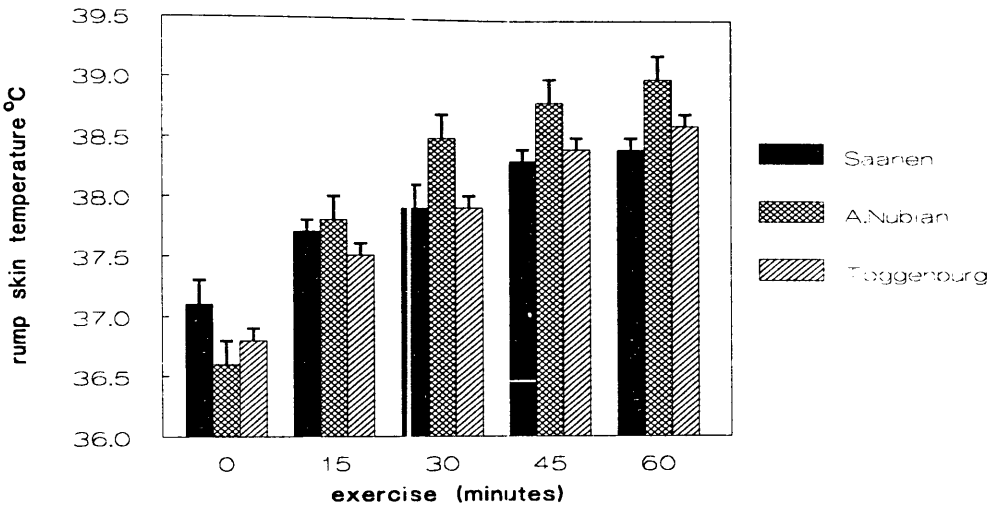


Fig. 26 Mean RST of Saanen, A.Nubian and Toggenburg goats of different body weights and feed intakes during treadmill exercise at 3.8 km/h speed and 30°C

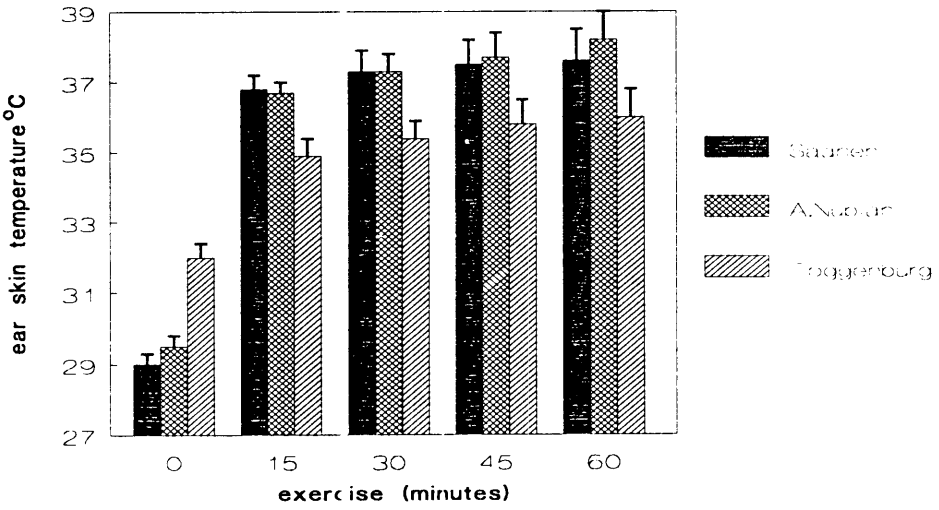


Fig. 27 Mean EST of Saanen, A.Nubian and Toggenburg goats of different body weights and feed intakes during treadmill exercise at 3.8 km/h speed and 30°C

6.3 Experiment 10: Responses in Saanen, Anglo Nubian and Toggenburg Goats of Similar Condition Scores and the Same Feed Intake

6.3.1 Materials and Methods

Six mature female goats (2 Saanen, 2 Anglo Nubian and 2 Toggenburg) were used. They were all in similar CS of 2.5 and were individually fed 750 g/d pelleted goat ration. The animals were exercised for 1 hour per day on 9 days and 1 day off between days of experiment, and measurements were taken at 15 min intervals during exercise. Thus, a 2x3x5x9 factorial design was employed (2 animals of each breed; 3 breeds; 5 measurements per day; and 9 days of experiment with 1 day resting in between). The parameters measured were RR, RT and ST (the last in the 3 positions: rump, loin and ear).

6.3.2 Results

Respiration rate (RR):

The breed x days interaction was significant ($P < 0.05$). The most clear-cut differences (Fig. 28) were for the Anglo-Nubian in which RR showed a clear decline (from 125 to 30/minute) between days 1 and 9, whereas the 2 other breeds maintained levels of 110-170/minute throughout. For RR there was also a significant time x breed ($P < 0.01$; Fig. 28) interaction. Anglo Nubians recorded the lowest RR response, and significant differences between the 3 breeds were observed after 30, 45 and 60 mins of exercise. At those times, values in Toggenburg, Saanen and Anglo Nubian were 176, 137 and 36; 241, 193 and 69; 288, 235 and 125/min respectively. Between times, RR increased gradually in each breed such that after 1h of exercise the magnitudes of the differences were 217, 171 and 108/min in Toggenburg, Saanen and Anglo Nubian animals respectively.

Rectal temperature (RT):

The breed x days interaction for RT was significant ($P < 0.05$; Fig. 29). However, the differences between breeds were far less clear than for RR (above), and it can be concluded that in each breed, values declined from day 1 to day 9. Viewed overall, there was a tendency for RT to be highest in the Anglo Nubian. There was also a significant time x breed ($P < 0.01$; Fig. 29) interaction. With time, RT increased gradually after 1h of exercise, by mean magnitudes 1.2, 1.9 and 1.4°C in the Saanen, Anglo Nubian and Toggenburg breeds respectively. Examination of Fig. 29 reveals that after an initial (0-15 mins) rapid rise, RT in the Toggenburg and Saanen breeds tended to increase relatively slowly, whereas in the Anglo Nubian a faster rate of increase in RT was maintained through 60 mins of exercise. As a result, RT in the Anglo Nubians exceeded that of the other two breeds at 30, 45 and 60 mins.

Skin temperature (ST):

The breed x days interaction were significant for each of RST, LST and EST ($P < 0.05$). For these parameters, however, the differences between breeds were generally small (Figs. 30-31), and it can be concluded that in each breed, values declined from day 1 to day 9. Viewed overall (Figs. 30-31), there was a tendency for all skin temperatures to be highest in the Anglo Nubian, and from Fig. 31 it is clear that EST was lowest in the Toggenburg. With respect to different times during exercise, there were progressive and statistically significant increases ($P < 0.001$) in all parameters measured, and after 1h exercise the magnitudes of the increases were 1.8, 1.4 and 1.3°C in RST, LST and EST respectively.

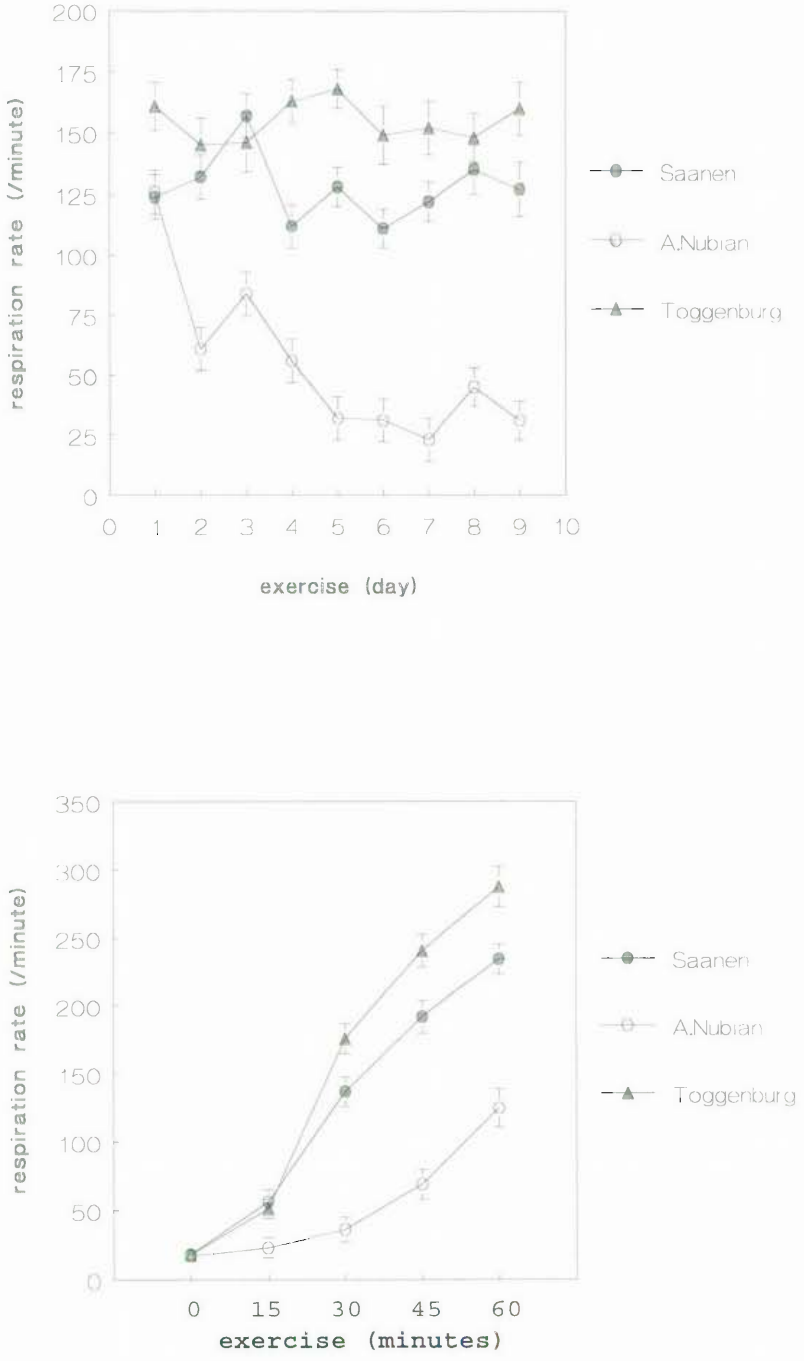


Fig. 28 Mean RR of Saanen, A.Nubian and Toggenburg goats during treadmill exercise at 3.8 km/h and 30°C, and when of similar condition score and feed intake (750 g/d)

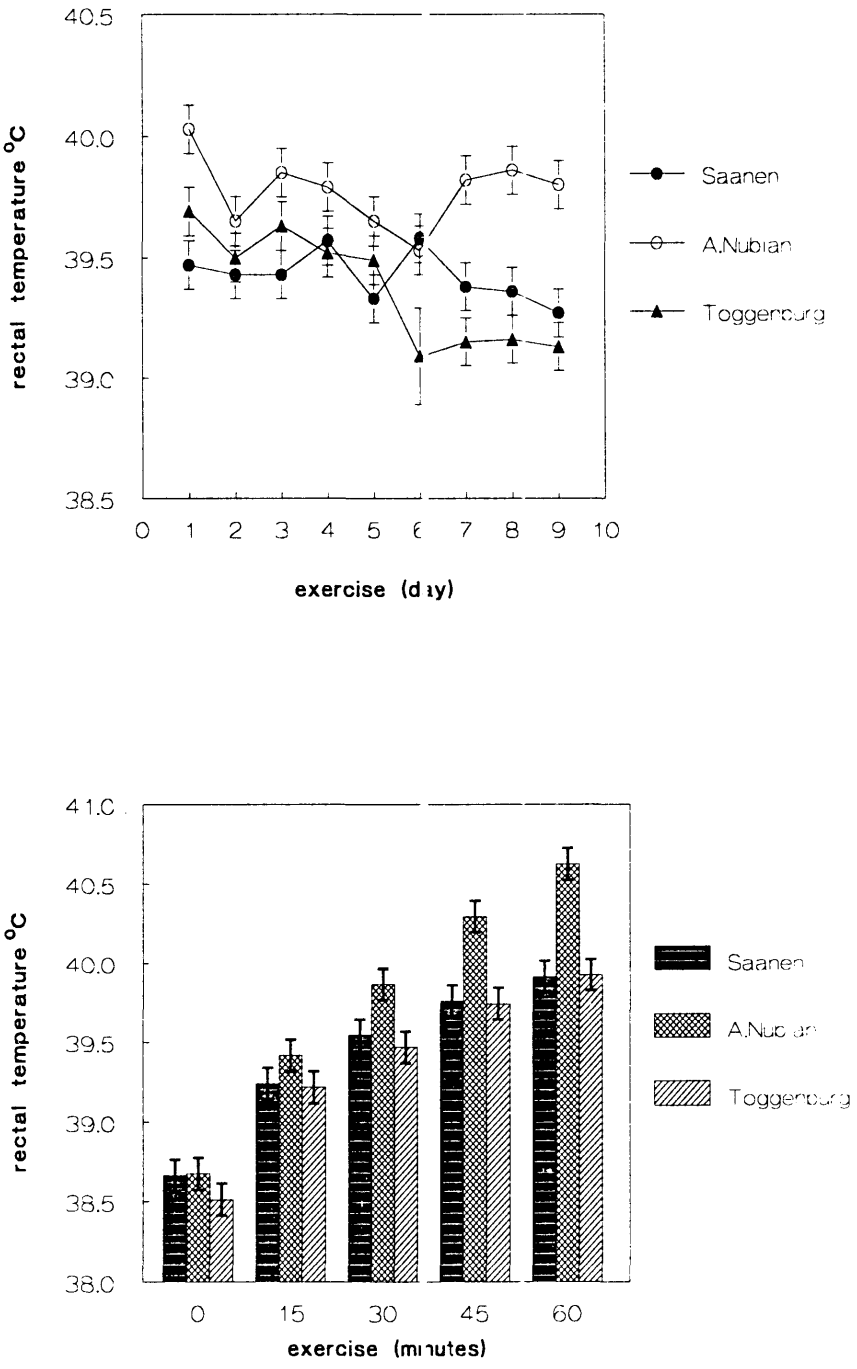
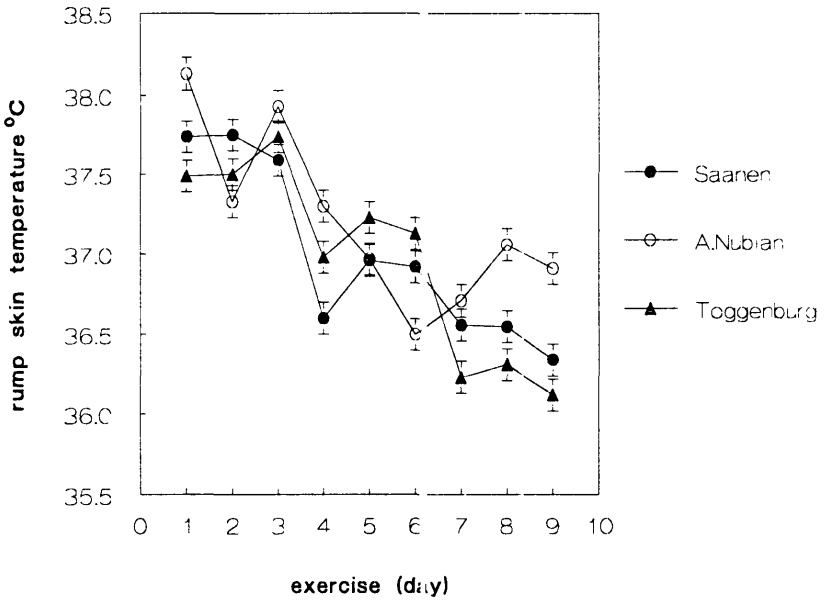


Fig. 29 Mean RT of Saanen, A.Nubian and Toggenburg goats during treadmill exercise at 3.8 km/h and 30°C, and when of similar condition score and feed intake (750 g/d)



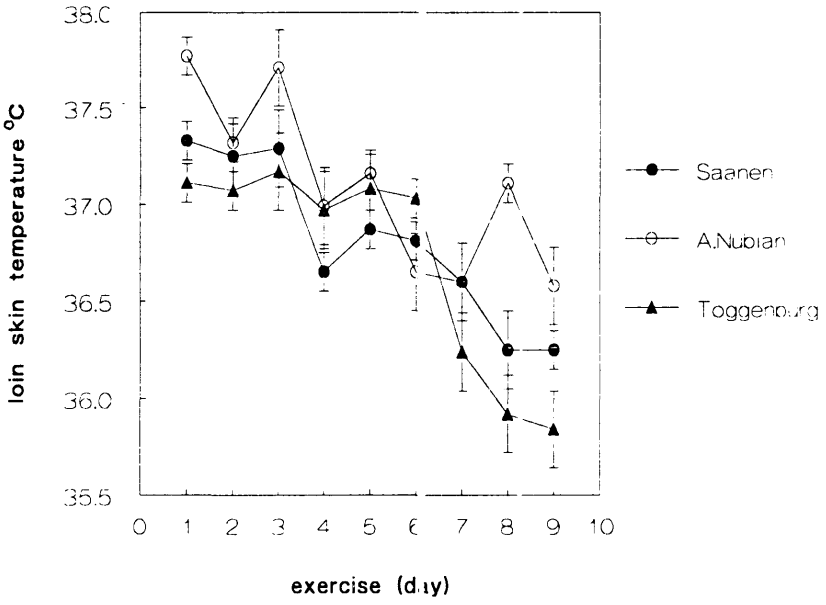


Fig. 30 Mean RST and LST of Saanen, A.Nubian and Toggenburg goats during treadmill exercise at 3.8 km/h and 30°C, and when of similar condition score and feed intake (750 g/d)

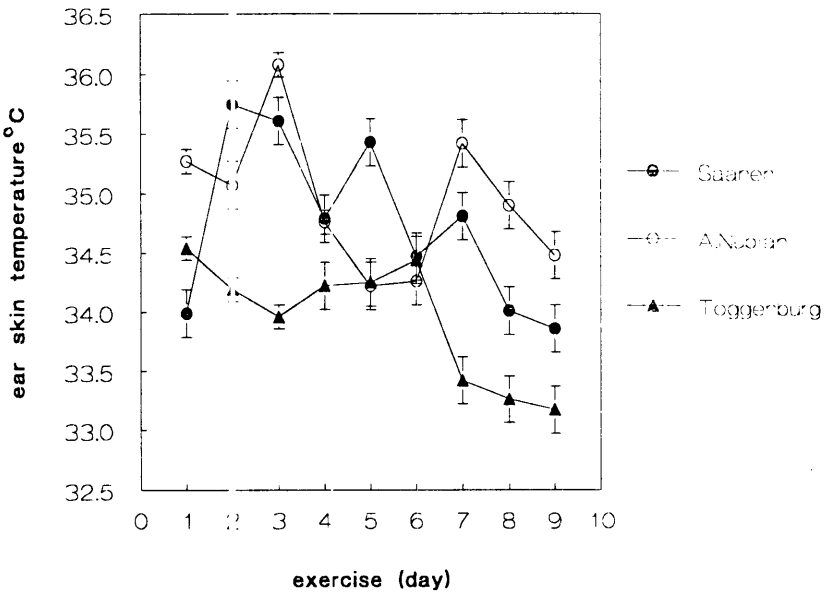


Fig. 31 Mean EST of Saanen, A.Nubian and Toggenburg goats during treadmill exercise at 3.8 km/h and 30°C, and when of similar condition score and feed intake (750 g/d)

6.4 Experiment 11: Responses of Saanen, Anglo Nubian and Toggenburg Goats of Similar Condition Scores but Different Feed Intakes (500 or 1000 g/day)

6.4.1 Materials and Methods

A split-plot design was employed (5 days with 1 day resting in between; 5 measurements at 15 minutes intervals on each day; 3 different breeds; 2 animals of each breed; and 2 replicates in time). All animals were similar in CS (2.5) and three animals were exercised every day with 1 day. Two levels of feeding (500 and 1000 g/d) were employed and exercise was at 3.8 km/h.

6.4.2 Results

All feed offered was consumed.

Respiration rate (RR):

The time x breed interaction for RR was significant ($P < 0.001$). The Anglo Nubian was clearly less stressed than the Saanen, and particularly the Toggenburg (Fig. 32). The Anglo Nubian not only recorded lower values at each time, but also experienced a slower (delayed) onset of panting. Significant differences between each of the breeds were found after 15, 30, 45 and 60 min of exercise, with mean values of 236, 168 and 297/min being recorded in the Saanen Anglo Nubian and Toggenburg respectively after 1h of exercise. With time, RR increased significantly, with slopes (linear regression) of 2.6, 3.7 and 4.6 in Anglo Nubian, Saanen and Toggenburg respectively. Feed intake had significant effects on RR ($P < 0.01$); values at 1000g/d feed intake were higher by an average of 43/minute. Between days, RR did not vary significantly ($P > 0.05$).

Rectal temperature (RT):

The time x breed interaction for RT was significant ($P < 0.001$). The Anglo Nubian recorded the highest RT (Fig. 33) and after 1h of exercise respective values were 39.6, 39.7 and 40.3°C in the Toggenburg, Saanen and Anglo Nubian. With time RT increased gradually in each breed, with slopes 0.019, 0.027 and 0.017°C/min in Saanen, Anglo Nubian and Toggenburg respectively. For RT, the interactions between day x breed and breed x feed intake were also significant at $P < 0.01$ (Fig. 33), but in both cases the trends were similar in all breeds and it is concluded that the existence of the interaction did not invalidate the comparison of main effects. In the case of the breed x feed intake interaction, animals fed 1000g/d reacted more than those fed only 500g/d, but the magnitudes of the differences were only about 0.5, 0.4 and 0.3°C in the Saanen, Anglo Nubian and Toggenburg breeds respectively.

Skin temperature (ST):

The breed x feed intake interactions for RST was significant ($P < 0.05$; Fig. 34) and the breed trends were consistent; values were uniformly higher in animals fed 1000g/d by differences of 0.2, 0.4 and 0.5°C in the Saanen, Anglo Nubian and

Toggenburg respectively. Between days, RST did not vary significantly ($P > 0.05$), but there were highly significant differences in RST ($P < 0.001$) with time during exercise; the greatest increases (mean 0.5°C) were recorded during the first 15 minutes.

For LST, the day x breed interaction was also significant ($P < 0.05$; Fig. 35); while the Anglo Nubian again responded most, the actual differences between days were not large. There were highly significant differences in LST ($P < 0.001$) with time during exercise; the greatest increases (mean 0.4°C) were recorded during the first 15 minutes of exercise. Feed intake had significant effects on LST ($P < 0.01$), values at 1000g/d feed intake were higher by 0.4°C than those at an intake of 500 g/d.

For EST the breed x feeding interaction ($P < 0.05$) indicated a non-significant effect in the Saanens, but higher values ($P<0.05$) in both Anglo Nubians and Toggenburgs fed at the higher level (Fig. 36). Between days, no significant effects were found in EST ($P > 0.05$). There were highly significant differences in EST ($P < 0.001$) with time during exercise; the greatest increases (mean 5.7°C) were recorded during the first 15 minutes of exercise. At the end of exercise (60 minutes), EST in the 3 breeds averaged 35.8°C.

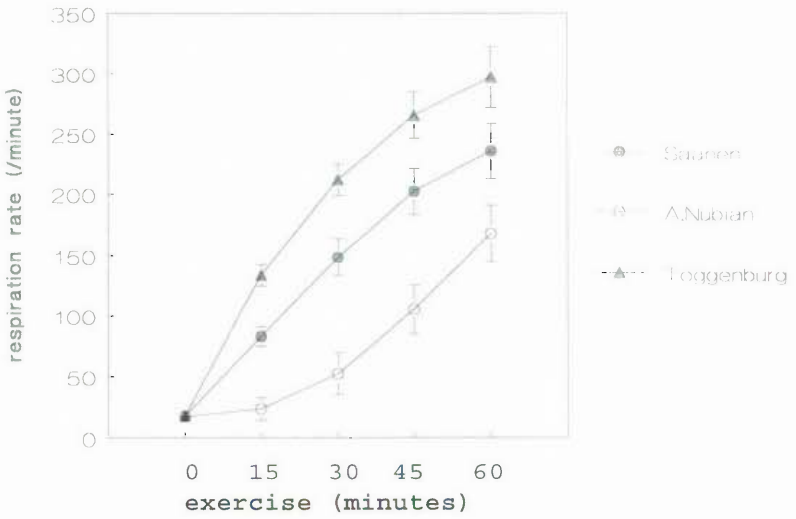


Fig. 32 Mean RR of Saanen, A.Nubian and Toggenburg goats during treadmill exercise at 3.8 km/h and 30°C for 1 hour (values are means from feed intakes of 500 and 1000 g/d

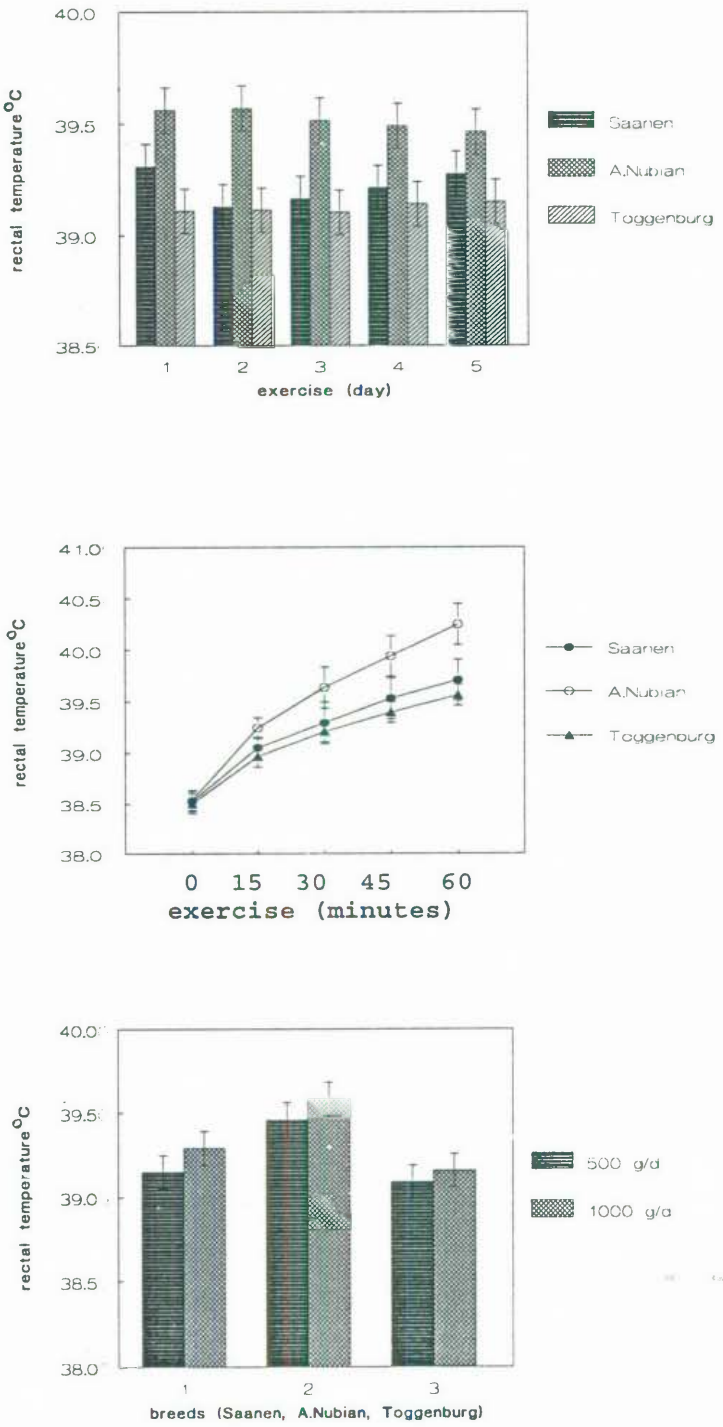


Fig. 33 Mean RT of Saanen, A.Nubian and Toggenburg goats during treadmill exercise for 1 hour at 3.8 km/h and 30°C, and at feed intakes of 500 or 1000 g/d

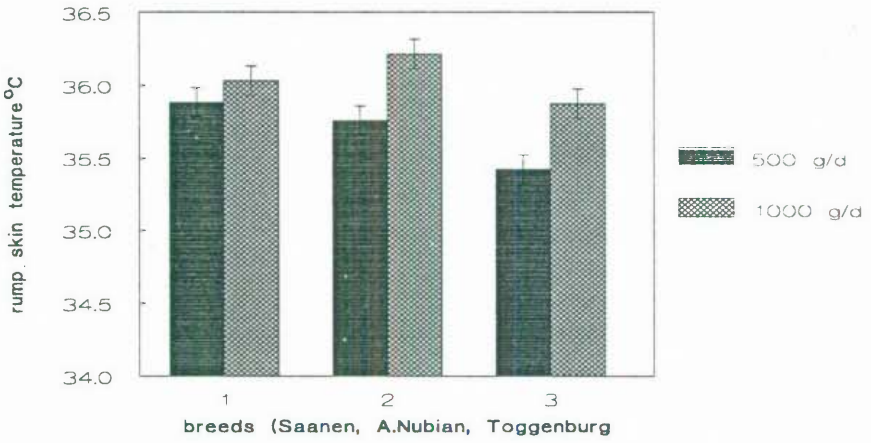


Fig. 34 Mean RST of Saanen, A.Nubian and Toggenburg goats during treadmill exercise for 1 hour at 3.8 km/h, 30°C, and feed intakes of 500 or 1000 g/d

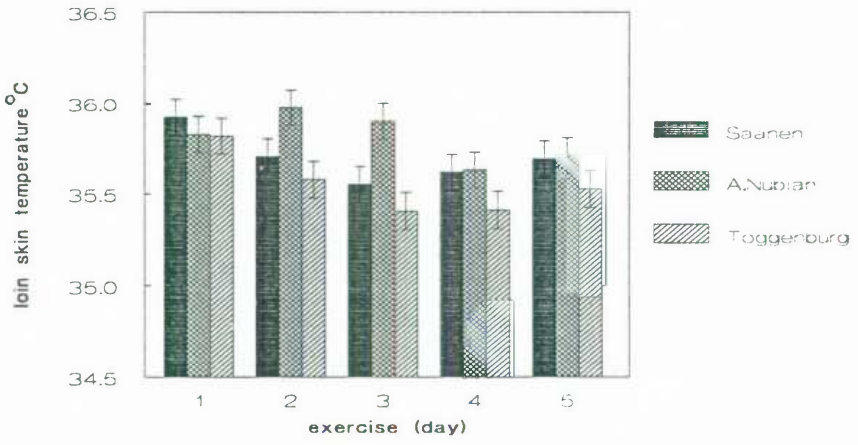


Fig. 35 Mean LST of Saanen, A.Nubian and Toggenburg goats during treadmill exercise for 1 hour at 3.8 km/h, 30°C (values are means at feed intakes of 500 or 1000 g/d)

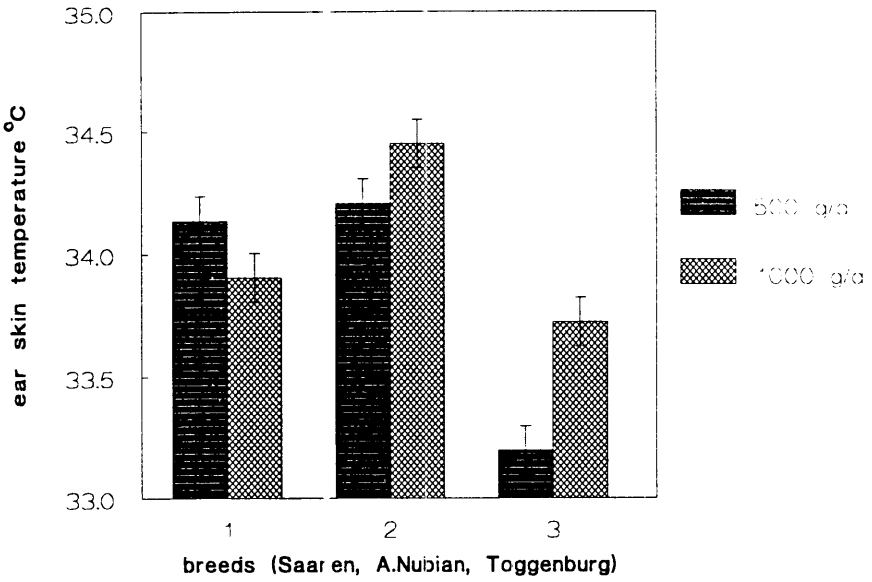


Fig. 36 Mean EST of Saanen, A.Nubian and Toggenburg goats during treadmill exercise for 1 hour at 3.8 km/h, 30°C, and at feed intakes of 500 or 1000 g/d

6.5 Experiment 12: Responses in Saanen and Toggenburg Goats Exercised on a Treadmill at Temperatures of 20, 30 and 40°C

6.5.1 Materials and Methods

Individuals of two different breeds of goat, the Toggenburg (LW of 50.5 ± 5.5 kg) and Saanen (LW of 47.5 ± 2.5 kg), having similar body condition scores of 3.0 were employed. The goats were fed individually at the rate of 1.5% of their body weight. A 2x2x3x3x4 factorial design (2 animals of each breed; 2 breeds; 3 different temperatures: 20, 30 and 40°C; 3 days with 1 day resting in between; and 4 measurements per day at 10 minute intervals) was used. The treadmill was set to run at 3 km/h, and, in addition, PCV was assessed before and after exercise.

6.5.2 Results

Respiration rate (RR):

The significant time x breed interaction observed in RR ($P < 0.001$; Fig. 37) clearly suggests that the RR response in Toggenburgs was much more rapid than in Saanens. Significant differences were found between Toggenburg and Saanen after 10, 20 and 30 min exercise; and mean values in the two breeds at the end of exercise were 178 and 112/min respectively. The breed x temperature interaction was also significant ($P < 0.01$); and the tendency was for the difference between Toggenburg and Saanen to increase as ET increased (Fig. 37). The Toggenburgs had a higher RR than Saanens at all temperatures, and the differerences averaged 22, 34 and 55/min at 20, 30 and 40°C respectively. With different temperature levels, the RR increased gradually in both breeds, and in the highest ET of 40 °C the RR after 30 min of exercise were 140 and 85/min in Toggenburg and Saaner respectively. These trends being similar, it was concluded that the interaction did not interfere with interpretation of the main effects. Between days RR differed significantly ($P < 0.05$) and decreased gradually from 91/min on day 1 to 68/min on day 3.

Rectal temperature (RT):

In the absence of significant interactions, RT increased progressively ($P < 0.001$) with increasing temperature (Table 19), but the overall difference was only 0.3°C. Although differences between the breeds in RT were also significant ($P < 0.01$), the Toggenburg was in fact lower than Saanen. but only by small margin (39.4 vs 39.6°C respectively). RT did not differ significantly between days ($P > 0.05$). but increased progressively with time during exercise ($P < 0.001$) by a mean value of with magnitude 1.3°C after 30 min of exercise.

Respiratory moisture loss (RML):

The breed x temperature interaction, for RML was significant ($P < 0.01$); and the tendency was for the difference between Toggenburg and Saanen to increase as ET

increased (Fig. 38). The differences between breeds were significant, with values for the Toggenburg higher than for the Saanen, and this was consistent at each temperature level (mean differences of 46, 76 and 104 mg/min at 20, 30 and 40°C respectively). With temperature levels, RML significantly increased in both the Toggenburg and Saanen, with slopes (linear regression) 13.8 and 6.4 mg/min/min respectively. These trends being similar, it was concluded that the interaction did not interfere with interpretation of the main effects. Between days, RMI differed significantly ($P < 0.05$) and decreased gradually between days 1 and 3 (from a mean of 380.3 to 330.4 mg/min) respectively. RML increased progressively with time during exercise ($P < 0.001$) with respective values of 156.5 and 576.1 mg/min before and after exercise.

Packed cell volume (PCV):

Before and after exercise, PCV was found to differ significantly ($P < 0.05$; Table 20); values increased during exercise from 32.7 to 35.2 %.

Table 19: Mean RT (°C) of female Saanen and Toggenburg goats during treadmill exercise at 3.0 km/h at 20, 30 or 40°C

Temperatures	20	30	40°C		SEM	Level of significance
RT:	39.4a	39.6ab	39.7b		0.01	*
Breed:	Saanen		Toggenburg		SEM	Level of significance
RT:	39.6a		39.4b		0.004	**
Day :	D1	D2	D3		SEM	Level of significance
RT:	39.8a	39.5a	39.4a		0.01	ns
Times: (min)	0	10	20	30	SEM	Level of significance
RT:	38.9a	39.3b	39.8c	40.2d	0.01	***

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

Table 20: Mean PCV (%) in Saanen and Toggenburg goats during treadmill exercise at 20, 30 or 40°C

	PCV (%)			SEM	Level of significance
Time (0-30 mins)	32.7	35.2		0.1	*
Breeds (Saanen and Toggenburg)	34.0	33.9		0.1	ns
Day (1-2)	33.9	34.0		0.1	ns
Temperature level (20, 30 and 40°C)	34.3	35.0	32.6	0.2	ns

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

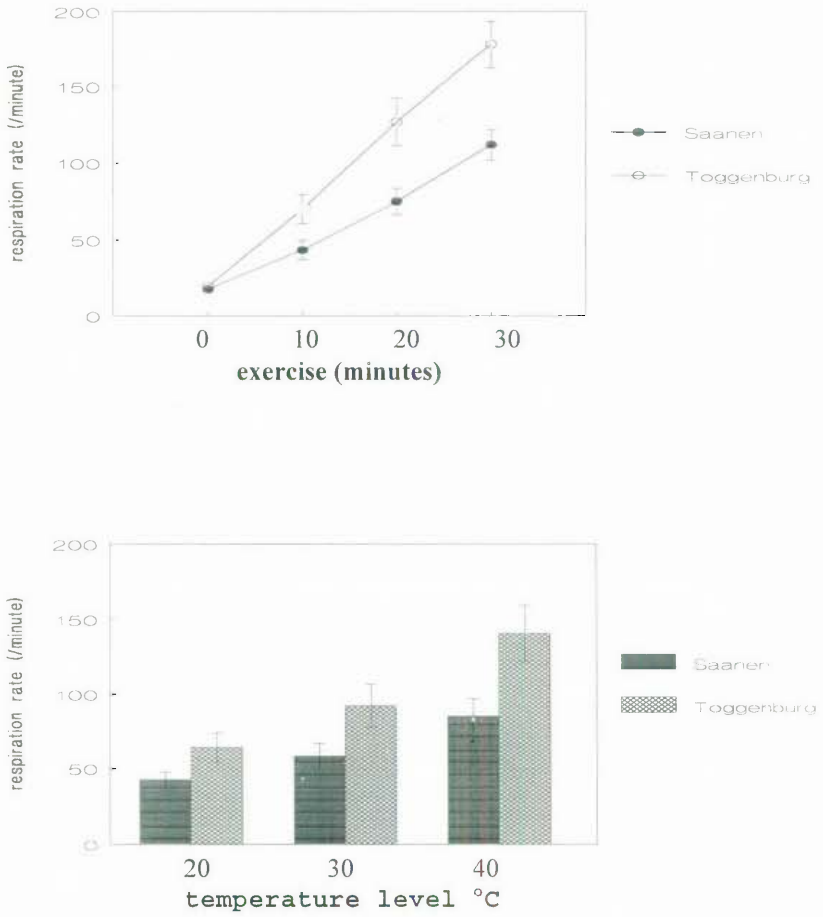


Fig. 37 Mean RR (/minute) of Saanen and Toggenburg goats during treadmill exercise at 3 km/h as affected by time (top) and ET (bottom)

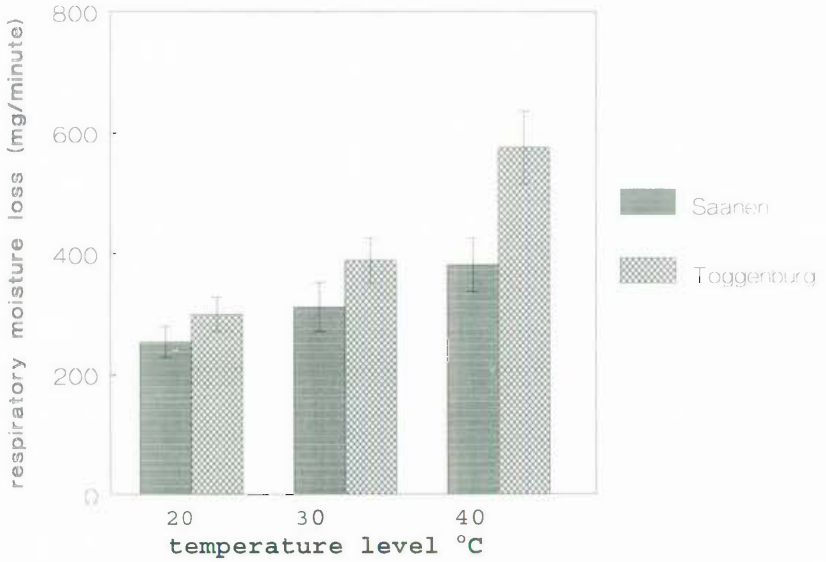


Fig. 38 Mean RML (mg/minute) of Saanen and Toggenburg goats during treadmill exercise at 3 km/h and either 20, 30 or 40°C

6.6 Discussion

Overall, the current investigations revealed the same pattern of responses as reported in Experiments 4 and 5; namely, RR, RT and ST each rose significantly with increasing time during exercise. These findings are thus in accordance with MURRAY and YEATES (1967), who found in cattle that RR and RT increased with time during both fast and slow walking. Apart from thermoregulation (respiratory evaporative cooling), such increases in RR could in part be due to increased oxygen consumption for metabolic processes, which produce more heat which in turn would contribute to the increase in RT. This suggestion is in general agreement with BIRD *et al.* (1981), who reported that exercise increased oxygen uptake by the hind limb by 6-7 fold, and with JUDSON *et al.* (1976), who found that the total entry rate of blood glucose when sheep were at rest was 0.44 ± 0.03 mmol/min, while during exercise it increased to 0.84 ± 0.004mmol/min. A similar pattern was also reported by HARMAN and PETHICK (1994).

From the results of Experiments 9 to 12 it can be concluded that there was a definite effect of breed on the physiological responses during exercise. Of those tested, the Toggenburg had the higest RR, followed by the Saanen and Anglo Nubian. For example, in Experiment 11 the mean RR's of Toggenburg, Saanen and Anglo Nubian animals were 185, 137 and 73/minute and the slopes of their linear regressions (with time during exercise) were 5.1, 3.8 and 3.5/min/min respectively. Clearly, these breeds differed physiologically; the Toggenburg reacted most to exercise and can thus be classed as the most intolerant breed. This finding is in general agreement with BIANCA and KUNZ (1978), who found significant differences between the Swiss, Saanen and Toggenburg breeds, with corresponding increases in RR of 237, 246 and 222/minute respectively when animals were exposed to high environmental temperature. However, the conflicting results between the current experiments (in which RR in Saanen and Toggenburg averaged 137 and 185/minute respectively) and that of BIANCA and KUNZ (Saanen and Toggenburg mean values of 246 and 222/min; ie. the reverse) could be due to differences in either age or sex (BRODY, 1945), or that exercise was the stressor here compared to high ET in the work of BIANCA and KUNZ.

Results recorded were also in general agreement with BRODY (1945), who suggested that basal metabolism differed between breeds; and who quoted heat production relationships for Toggenburg and Saanen goats of $Y=155X^{0.710}$ and $Y=192X^{0.596}$ respectively (Y=heat production and X=body weight). These equations indicate that the Toggenburg produces more heat than the Saanen, and is thus likely to experience greater heat stress at high temperature or during exercise.

Differences in respiratory moisture loss (RML) could be another explanation for the observed differences between breeds. Results in Experiments 9, 10 and 11 clearly showed that the Anglo Nubian had a lower RR than both Saanen and Toggenburg, and that RML increased with increasing RR (Experiment 12). For example, in Saanens and Toggenburgs, RR of 62 and 99/min corresponded to RML of 316 and 421 mg/min respectively. The current results are in general agreement with ALEXANDER and WILLIAMS (1962), who indicated that RML increased from 417 to 1833 mg/minute as

RR increased by from 100 to 400/min respectively in sheep. This phenomenon will be discussed in more detail in Chapter 7 (Experiment 14).

Differences in sweating rate (SR) could be another explanation for part of the differences between breeds. Results in Experiments 9, 10 and 11 clearly showed that the Anglo Nubian had a lower RR than both the Saanen and Toggenburg, and this was associated with a lower RML (Experiment 12). The possibility that the most tolerant breed, the Anglo Nubian, has a superior sweating ability will be investigated in Chapter 8, Experiment 16. The present findings support those of APPLEMAN and DELOUCHE (1958), who demonstrated the superiority of the Anglo Nubian over the Swiss breeds of goat in environments of 35 to 40°C. In such circumstances, profuse sweating would tend to depress RR, both by reducing the stimulii received from the skin (which would be cooler as a consequence of evaporation), and by body cooling and a reduction in the need to dissipate heat through panting.

Despite their relatively low RR, the Anglo Nubians had the highest RT among breeds in the experiment, a fact which clearly indicates that total heat dissipation was not sufficient to remove from the body all the heat produced during exercise. In other words, heat was stored in the body and caused an increase in RT, but the Anglo Nubian as a breed was apparently able to tolerate this higher RT without corresponding increases in RR. The Toggenburg, on the contrary, had the lowest RT and thus the lowest, amount of heat stored amongst those 3 breeds; the increased RR in Toggenburgs is an indication that most heat was dissipated through panting. Saanens, on the other hand, can be classified as an "intermediate" breed in terms of heat storage ability. They maintained both RR and RT at levels between the Toggenburg and Anglo Nubian. It can thus be concluded that the Anglo Nubian has not developed evaporative cooling mechanisms sufficient for maintaining a constant body temperature during exercise and instead stores heat ("heat storer"), while the Saanen and Toggenburg breeds have developed the opposite strategy. For the Anglo Nubian, this strategy to store heat and minimize evaporation is consistent with their evolution (the Nubian) in a desert environment (DEVENDRA and McLEROY, 1972).

The current results are also in general agreement with JOHNSON (1971), who reported that neither the sheep nor goats studied by him exhibited passive body temperature lability as an adaptation to thermal stress. TAYLOR and ROWNTREE (1973) subsequently concluded that animals of different breeds and species have different ways to maintain heat balance, and that these vary to a considerable degree with body size, environmental conditions and sweat gland output.

Differences in stride length could also explain part of the differences in response observed between the different breeds. For example, the mean stride lengths of the Anglo Nubian, Saanen and Toggenburg animals used in this study were 65, 61 and 58 cm respectively. Their corresponding leg lengths were 54 ± 1.2, 53 ± 2.3 and 48 ± 1.5 cm and step numbers/minute were 77 ± 2.9, 82 ± 0.2 and 86 ± 1.1 respectively when walking at 3km/h. The longer the step, the lower the number of steps taken per minute, and presumably the lower the heat production and thus the lower the level of heat stress experienced. In this regard the current findings support the suggestion of YEATES and MURRAY (1966) that Santa Gertrudis cattle responded less than Herefords during walking at least partly because the Santa Gertrudis had longer legs in proportion to body size, and therefore a longer stride. Within breeds, YEATES and MURRAY observed that individuals with the smallest steps also displayed the greatest increase in RT and RR.

The length and depth of the hair coat could also contribute to differences in heat tolerance between animals. Measurements of hair length and depth of the Toggenburg, Saanen and Anglo Nubian animals used here revealed values (mean ± sd) of 6.4 ± 1.7, 2.3 ± 0.4 and 2.2 ± 0.6 cm and 2.8 ± 0.3, 1.8 ± 0.5 and 1.9 ± 0.6 cm respectively. In the indoor environment used in the current experiments (no solar radiation), a long, deep coat could be expected to reduce the efficiency of evaporation of sweat and to thus increase (as in Toggenburg) the stress experience. In cattle, such effects of a long furry coat are well known (eg. BONSMA, 1949; YEATES and PARTRIDGE, 1975). The above explanations for the differences observed between the breeds appear likely to be genetically determined, since, in cattle at least, the heritability of RT has been shown to be as high as 0.5-0.6C (KNAPP and CLARK, 1951; GARCIA and RODRIGUEZ, 1976).

Results from Experiment 11 showed that the higher the level of feed intake, the greater the reaction to exercise (higher RR, RT and ST). Such differences are again in line with the results of MURRAY *et al.*, (1981) who found in cattle that the RT response to exercise was greater in a high than in a low plane group. The work of GRAHAM *et al.* (1959), who found in sheep that low (600 g), medium (1200 g) and high (1800 g) levels of feeding were associated with rates of heat production of 0.23, 0.35 and 0.42 KJ/h respectively, suggests that the differences observed in the current work were largely a reflection of differences in heat production between feeding levels. The opportunity to examine this possibility experimentally did not exist for the author, but this is an area in which further study is required.

The fact that PCV increased after 30 minutes, exercise (from 32.7 to 35.2%; Experiment 12) is in general agreement with ACHARYA *et al.* (1979) who found in cattle that there was an increase in haemoglobin %, PCV, total RBC and WBC counts after work; trends which they suggested could have resulted from loss of body water by such means as urination, defaecation and evaporation (sweating and respiratory) during work. Another reason for the increase in PCV could have been sympathetic neural activation during exercise (DETWEILER, 1984), which causes the spleen to contract and discharge erythrocytes into the circulation. BIRD *et al.* (1981) and KUHLMANN *et al.* (1985) agree that the spleen is an important reservoir of erythrocytes, called upon when the body has a greater need for oxygen in the tissues, and that increases in PCV and hemoglobin concentration are critical mechanisms which enable ruminants to increase oxygen transportation to exercising muscle. Those conclusions have been supported by MUNDIE *et al.* (1991) and APPLE *et al.* (1994).

The results of Experiment 12 clearly showed that the stress experienced by the goats increased (higher RR, RT and RML) as the environmental temperature experienced during exercise increased from 20 to 40°C. The current results are in general agreement with SIQUEIRA *et al.* (1993) who reported that amongst unshorn sheep kept in the sun or the shade (at temperatures of 46°C or 31°C respectively), ewes exposed to sunlight had a significantly higher RT (40.6 vs 40.1°C) and RR (191/min vs 129.5/min) than those in

the shade. The increase in RR could be due to the animal's need for more oxygen to activate carbohydrate oxidation and provide more energy during exercise as well as for cooling processes. HARMAN and PETHIC (1994) have reported that during exercise in sheep the absolute rate of glucose oxidation increases by between 5 and 9-fold when walking below and above the anaerobic threshold respectively. These findings support those of FUKURA *et al.* (1986), who observed in goats that oxygen consumption increased to 1.1 and 1.4 litre/kg$^{0.75}$/h during walking at 1.5 or 3.7 km/h respectively, compared to 0.7 litre/kg$^{0.75}$/h while resting.

The overall conclusion to be reached from the work reported in this chapter is that of the 3 breeds studied, the Toggenburg was the most stressed (highest RR), the Saanen was "intermediate" and the Anglo Nubian was least stressed and behaved as a "heat-storer" during exercise. Animals at the highest feeding level were more stressed than those fed at a lower rate. Higher RR could possibly be associated with higher RML and further experiments were thus undertaken in different breeds and sexes to examine this phenomenon (Chapter 7).