Journal of Applied Sciences Research, 8(2): 1219-1226, 2012
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

The thermoregulatory responses of adult angora goats (*Capra aegagrus*) to repeated wetting.

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ABSTRACT

Large stock losses of Angora goats (*Capra aegagrus*) occur during cold rainy weather, especially when the conditions prevail for long. The objective of this study was to determine the thermoregulatory responses of adult Angora goats to repeated wetting at 8°C and 20°C. Six adult wethers were used in this study. The goats were obtained from the Karoo in the Eastern Cape of South Africa. The first sets of experiments were conducted on goats wetted with water only at the beginning of the experiment and the second sets conducted on goats wetted hourly from 09h00 to 13h00. One experiment was conducted on one goat per day in an environmentally controlled room set at 20°C. The oxygen consumption (VO_2), rectal temperature (Tr), and skin temperature (Ts) of each experimental goat were measured once at each experimental temperature. Readings of the measured parameters were taken every minute from 09h00 to 13h00. The VO_2 of the repeatedly wetted goats was slightly but not significantly higher than that of the goats wetted only at the beginning of the experiment at 8°C and at 20°C. The Tr and the Ts of the repeatedly wetted goats were not significantly different from that of the once wetted goats at 8°C and at 20°C. The goats maintained a relatively constant Tr throughout the experiments. However, each wetting resulted in a rapid drop followed by an increase in Ts. The drop in the Ts may be attributed to the reduction in the coat insulation by water dislodging the entrapped air, while the increase could have been due to the drying up of the goats. Even though repeatedly wetted goats were able to maintain homeothermy, each successive wetting resulted in cumulative stress to the goats. Farmers should keep their Angora goats in shelters when cold rainy weather persists.

Key words: Oxygen consumption, rainy weather, rectal temperature and skin temperature.

Introduction

There had been several reports of Angora goats being susceptible to cold rainy weather especially after being shorn (Hetem *et al*., 2009; Setlalekgomo, 2002; Anon., 2001; Hobson, 1994; Fourie, 1984; Anon., 1964). Temperature affects many physiological processes necessary for an organism's life; hence a need for animals in their natural habitats to have the ability to thermoregulate effectively to cope since extreme temperatures can result in death. According to Whittow (1971), sheep with long fleece can accommodate up to 2 kg of rainwater in their fleece. The penetration of water into the fleece is dependent on the length of the fleece while the magnitude of the cooling effect of water is dependent on the depth to which water penetrates the hair coat (McDowell, 1972). The Angora goats in the Eastern Cape of South Africa are commonly exposed to a number of showers, which may cause cumulative stress to goats due to cold rain water trapped in their fleece. It is of importance to ascertain whether the effect of repeated wetting is cumulative. The purpose of this study was to determine the effect of repeated wetting on the oxygen consumption (VO_2), rectal temperature (Tr) and skin temperature (Ts) of adult Angora goats.

Materials and methods

Experimental animals:

Six adult Angora wethers aged six years were used in this study. The goats were bought from a farmer in the Karoo in the Eastern Cape province of South Africa. Wethers were used in this study to avoid possible pregnancy in females which could cause some variations in the results obtained from the experiments. Wethers play no role in reproduction so they are easily obtainable from farmers. The goats were previously shorn on the same day and had almost the same fleece length. They had mean mass of 44.5 ± 0.88 (mean ± SE) kg at the

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commencement of the study. It is of importance to use goats of the same fleece length and age as differences in these can cause variations in metabolic rate, which was one of the parameters measured in this work. The goats were housed in the University of Port Elizabeth Animal Unit. Lucerne, commercial pellets and water were given *ad libitum*, except twenty four hours prior to experiment where only water was provided. Neither food nor water was provided during the course of the experiment.

Experimental design:

Wind tunnel:

A metal wind tunnel measuring 0.6 m x 0.9 m x 2.25 m was constructed. The tunnel had a fan at the rear end. The air movement in the tunnel was calibrated using a Miniature Vane anemometer. The air flow in the tunnel was laminar, with a constant speed of 3 m/s. The tunnel was designed in such a way that a goat placed inside could not turn around. This was achieved through the use of two planks, each on one side of the goat and parallel to the walls of the tunnel. The planks were tied to the horizontal metal rods across the tunnel, both at the back and in front of the goat to stop it from moving either forward or backward. There was enough space left between the planks and the walls of the tunnel as well as behind the goat to allow laminar flow.

Mask:

A head of a slaughtered adult Angora goat was bought from an abattoir, and was used to create a plaster of Paris mold. The mold was used for the construction of a flexible mask using nylon stockings and latex. Six additional masks were made for familiarisation purposes. Two one-way valves, enclosed in a plastic tube, were stitched and sealed with latex and nylon stockings to a hole cut on the mouth and nostrils positions on the experimental mask. The collective mass of the valves and the mask was 198g.

To familiarise the goats to the experimental mask, each goat was fitted with a mask cut at the mouth and nostrils positions to allow breathing, and then placed inside the wind tunnel for one hour. The wind speed was set at 3 m/s and the experimental temperature set at 20 ± 1°C. This was repeated once a day for each goat, for four days.

Experimental procedure:

The protocols used in this study were non-invasive and were approved by the University of Port Elizabeth Animal Ethics Committee. One goat at a time had all food, except water, withheld for twenty-four hours prior to experiment. The experimental goat was weighed before and after each experiment. The goat was wetted by dipping it in water for at least three minutes to ensure saturation of the fleece then given 15 minutes for the excess water to drip off. The experimental goat was then taken into an environmentally controlled room where a pre-calibrated Tr probe was inserted 15 cm beyond its anal verge, and a small portion on its flank shaved for attachment of a pre-calibrated Ts probe with the help of an adhesive tape (Andersson, 1958). The Tr and the Ts readings were recorded by a Mini-Mitter mini-logger. The goat was then put inside the wind tunnel and a mask fitted to its snout. The mask was connected to a flexible pipe, which was tied to the roof of the tunnel above the head of the goat to take off extra weight from the goat. As the goat breathed, ambient air moved in via one one-way valve, and exhaled air passed through the second one-way valve into the flexible tube. The exhaled air passed through two condensation traps for removal of moisture, and a Miniature Vane anemometer which measured the flow rate. A sample of the exhaled air was pumped into the pre-calibrated Applied Electrochemistry Ametek Oxygen Analyser on continuous basis, for the measurement of the amount of oxygen consumed by the goat. The readings were logged into a computer connected to the oxygen analyser. Humidity was constant at 30% for all the experiments. The experimental temperatures used were 8°C and 20°C. The experimental exposure period was four hours, from 09h00 to 13h00. For each experiment, the goat was allowed the first 30 minutes settling period in the wind tunnel. The readings for all the measured parameters were taken every minute. Each goat was used at all experimental temperatures, but only once per temperature. Each goat was given at least one week's rest before being used in any other experiment.

Data handling:

All data logged into the mini-logger were imported into a spreadsheet (Quattro-Pro Version 8). The Tr and the Ts readings from the logger were corrected using a calibration curve derived using a calibrated thermometer. The values of the difference in oxygen content between ambient air and exhaled air recorded in the computer were used together with the flow rate readings and the mass of the goat taken before experiment to calculate the specific metabolic rate (lO_2/kg/hr) of the goat. Oxygen consumption was used for the estimation of metabolic rate in this study because according to Schmidt-Nielsen (1997), the amount of heat produced per litre of oxygen used in metabolism remains constant irrespective of what food nutrient is oxidised.

Data analysis:

The experiments were divided into two sections; the once wetted (SW) and the repeatedly wetted (SWW) goats at 8°C and 20°C. For each section, the means of the VO_2, the Tr and the Ts for at least five goats at a given temperature were used for statistical analysis. The abbreviations used in this document are defined in Table 1.

Table 1: Definitions of the abbreviations used in the text.

Abbreviation	Definition
SW08	Once wetted shorn goats at 8°C
SW20	Once wetted shorn goats at 20°C
SWW08	Repeatedly wetted shorn goats at 8°C
SWW20	Repeatedly wetted shorn goats 20°C
C1	Condition 1
C2	Condition 2

One-tailed Student t-tests were done on hypotheses concerning the VO_2 and the Ts in that it was anticipated that short fleece, wet and low temperature conditions would increase metabolic rates and related parameters. Two-tailed hypotheses were used for Tr (as representing core temperature) as it was thought these would remain constant within the time frame of the experiments. Multiple pair-wise contrasts were used as opposed to analysis of variance (ANOVA) to allow the testing of one-tailed hypotheses. ANOVA was used to compare the minimum as well as the maximum values of the measured parameters reached per hour. For all statistical tests, the level of significance was taken at 95% (Zar, 1998).

Results and Discussion

Oxygen consumption:

The VO_2 of the once and the repeatedly wetted goats at experimental temperatures of 8°C and 20°C is represented in Figures 1 and 2. The results of statistical comparisons are listed in Tables 2 and 3 respectively. The results show very low VO_2 values which could be attributed to a possible technical error in the anemometer during the measurement of the breathing rate of the goats. However, there is a clear pattern of the effect of repeated wetting on the VO_2 of the goats.

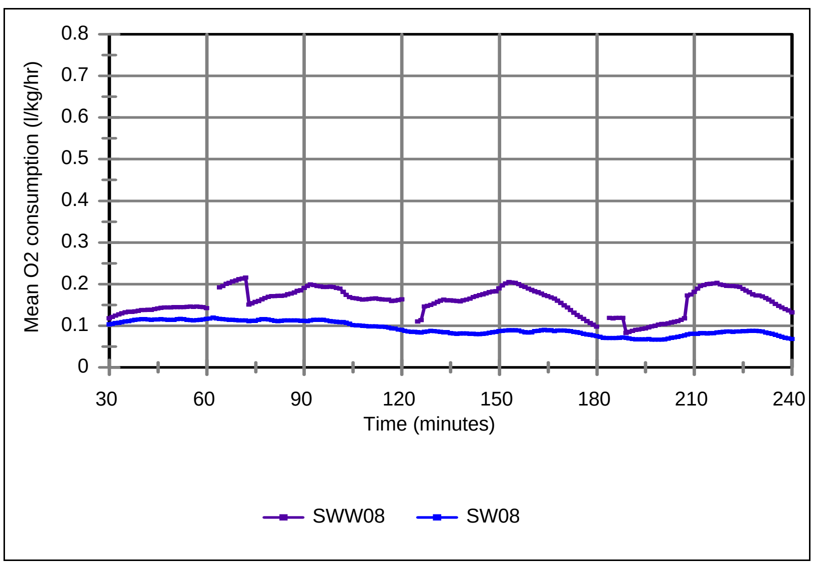

Fig. 1: The oxygen consumption of the once and the repeatedly wetted goats at an experimental temperature of 8°C as per legend. SWW08 stands for repeatedly wetted goats at 8°C while SW08 stands for once wetted goats at 8°C.

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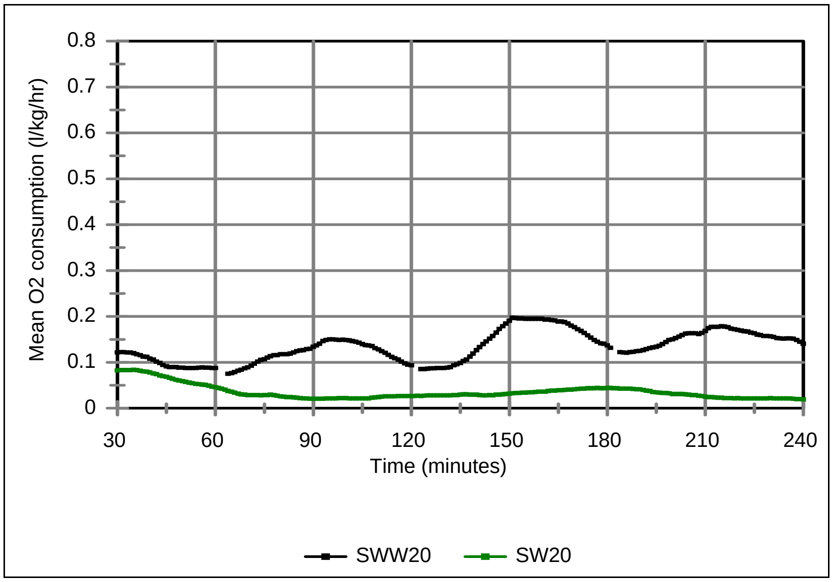

Fig. 2: The oxygen consumption of the once and the repeatedly wetted goats at an experimental temperature of 20°C. SWW20 stands for repeatedly wetted goats at 20°C while SW20 stands for once wetted goats at 20°C.

Table 2: Summary of the results of the one-tailed Student t-test of the oxygen consumption of once and repeatedly wetted adult Angora goats at different experimental temperatures.

C1	C2	t	P	df	Conclusion
SWW08	SW08	0.66	0.27	6	SWW08 not greater than SW08
SWW20	SW20	1.03	0.18	5	SWW20 not greater than SW20

The VO_2 of the repeatedly wetted goats was not significantly higher than that of the goats wetted only at the beginning of the experiment at both 8°C and 20°C (Table 2). However, Figures 1 and 2 show that the VO_2 of the repeatedly wetted goats at 8°C and 20°C was slightly higher than that of goats wetted only at the beginning of the experiment at both 8°C and 20°C. Repeated wetting seems to cause more stress than single wetting. The increase in the VO_2 and the observed shivering were indicative of a raised metabolic rate to counteract a drop in the Tr (Bianca and Kunz, 1978).

Table 3: Summary of the results of the ANOVA of the minimum and the maximum values of the oxygen consumption of adult Angora goats after each wetting hour at different experimental temperatures.

Experimental temperature (°C)	Min/Max values reached	Wetting hours	df	F-calculated	P	Conclusion
8	Min	1,2,3	35	127.21	<0.001	1 ≠ 2 ≠ 3
	Max	1,2,3	30	0.76	0.48	1 = 2 = 3
20	Min	1,2,3	33	110.70	<0.001	1 = 2 ≠ 3
	Max	1,2,3	40	665.95	<0.001	1 ≠ 2 ≠ 3

Table 3 shows that at 8°C, the lowest VO_2 values reached after each successive wetting were significantly different from each other. The values increased from the first to the third wetting hour (0.10, 0.15, 0.17 l/kg/hr). The highest VO_2 values were all the same. At 20°C, the lowest VO_2 value reached after the first wetting hour was equal to that of the second but different from the third one (0.09, 0.09, 0.13 l/kg/hr). The highest values were all different from each other (0.15, 0.19, 0.18 l/kg/hr). The goats responded to the wettings by raising their VO_2. This has implications to the farmers that the goats were becoming more stressed with every wetting especially at a lower experimental temperature.

Rectal temperature:

The rectal temperature (Tr) of the once and the repeatedly wetted goats at experimental temperatures of 8°C and 20°C is represented in Figures 3 and 4. The results of statistical comparisons are listed in Table 3.

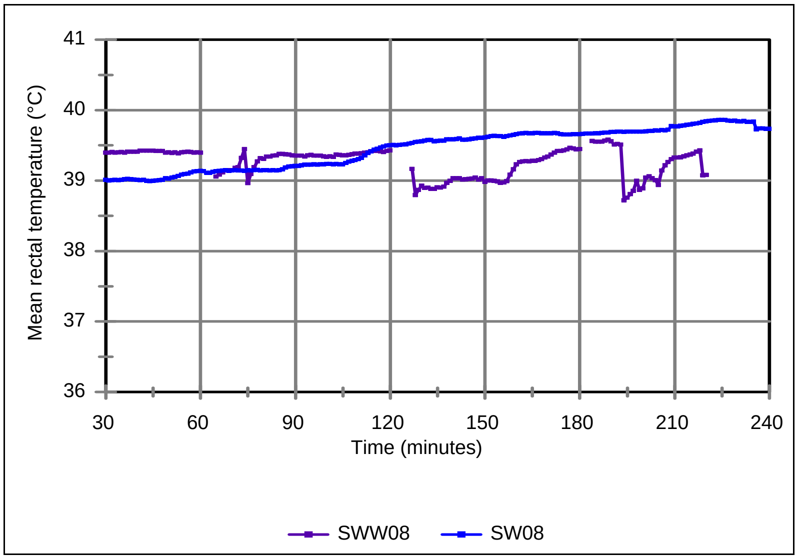

Fig. 3: The rectal temperature of the once and the repeatedly wetted goats at an experimental temperature of 8°C.

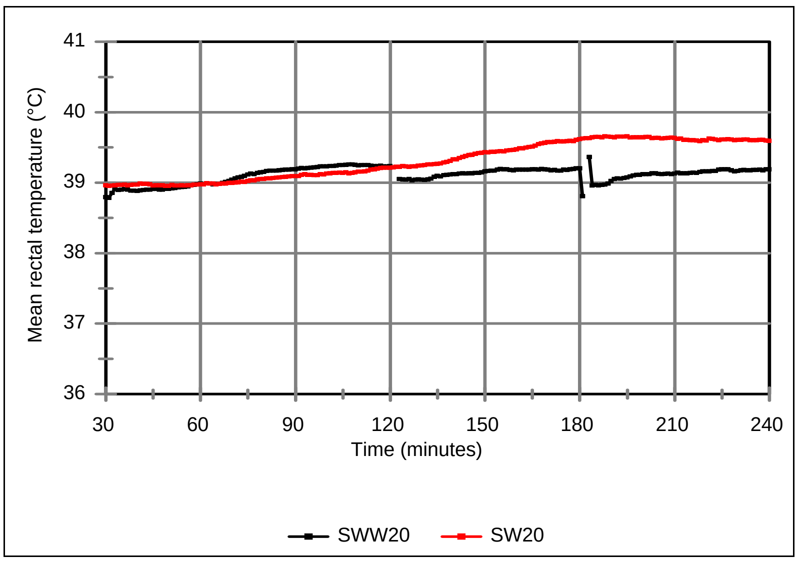

Fig. 4: The rectal temperature of the once and the repeatedly wetted goats at an experimental temperature of 20°C.

From Figures 3 and 4, the Tr of the repeatedly wetted goats appeared slightly lower than that of the goats wetted only at the beginning of the experiment. However, the statistical results in Table 4 indicate no significant difference in the rectal temperature of the once and the repeatedly wetted goats.

Table 4: Summary of the results of the two-tailed Student t-test of the rectal temperature (Tr) of the once and the repeatedly wetted adult Angora goats.

C1	C2	t	P	df	Conclusion
SWW08	SW08	0.01	0.99	6	SWW08 = SW08
SWW20	SW20	0.01	0.99	6	SWW20 = SW20

The Tr of the repeatedly wetted goats was not significantly different from that of the once wetted goats at experimental temperatures of 8°C and 20°C (Table 4). The goats were able to maintain their body temperature within the normal body temperature range (Anderson, 1970). This was achieved through complementary physiological reactions like shivering, which generated heat to limit downward deviations of body temperature (Kuhnen and Jessen, 1990). The results are in good agreement with those of Wentzel *et al*. (1979) who reported

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a relatively constant Tr (38.9 °C) of pregnant mature Angora goats that survived 48 hours exposure to low ambient temperatures (0°C – 5°C).

Skin temperature:

The skin temperature (Ts) of the once and the repeatedly wetted goats at experimental temperatures of 8°C and 20°C is represented in Figures 5 and 6 respectively. The results of statistical comparisons are listed in Tables 5 and 6.

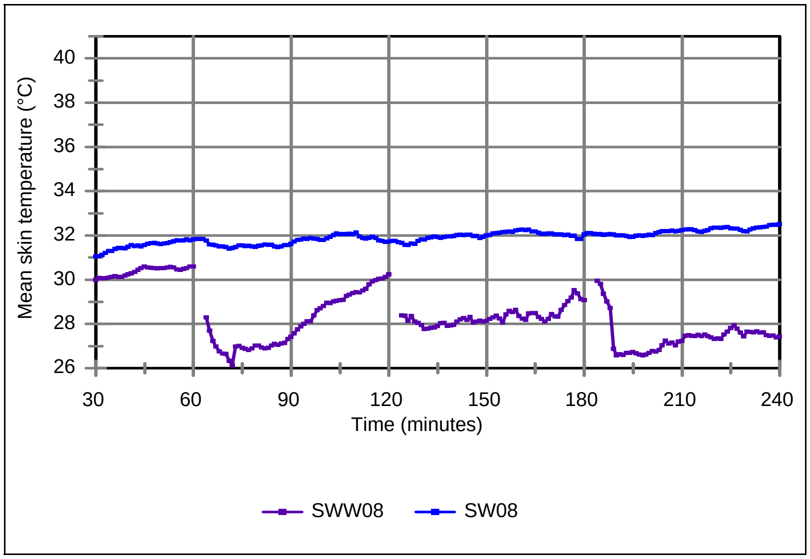

Fig. 5: The skin temperature of the once and the repeatedly wetted goats at an experimental temperature of 8°C.

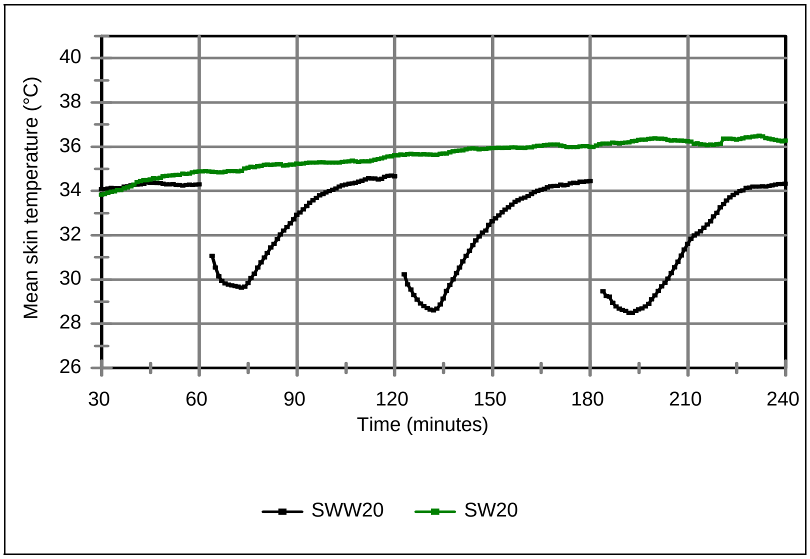

Fig. 6: The skin temperature of the once and the repeatedly wetted goats at an experimental temperature of 20°C.

Table 5: Summary of the results of the one-tailed Student t-test of the skin temperature (Ts) of the once and the repeatedly wetted adult Angora goats.

C1	C2	t	P	df	Conclusion
SW08	SWW08	0.29	0.39	6	SW08 not greater than SWW08
SW20	SWW20	0.22	0.42	6	SW20 not greater than SWW20

The Ts of the once wetted goats was not significantly greater than that of the repeatedly wetted goats at 8°C and at 20°C (Table 5). Each wetting resulted in a rapid drop followed by an increase of the Ts (Figure 6). The drop in the Ts can be attributed to the reduction in the coat insulation by water dislodging the entrapped air (Schmidt-Nielsen, 1997), while the increase could have been due to the drying up of the goats. The Ts returned to the original level faster after every wetting at 20°C than at 8°C (Figures 5 and 6) even though the cooling rates were not calculated.

Table 6: Summary of the results of the analysis of variance (ANOVA) of the minimum and the maximum values of the skin temperature (Ts) of the adult Angora goats after each wetting hour at different experimental temperatures.

Experimental temperature (°C)	Min/Max values	Wetting hours	df	F-calculated	P	Conclusions
8	Min	1,2,3	48	18.45	<0.001	1≠2≠3
	Max	1,2,3	25	103.30	<0.001	1≠2≠3
20	Min	1,2,3	45	30.36	<0.001	1≠2=3
	Max	1,2,3	55	9.69	<0.001	1≠2=3

The Ts of the goats after the first wetting hour was lower than that after the second wetting hour, and equal to that after the third wetting hour at 8°C. However, the highest values of the Ts reached after each hour were significantly different from each other (Table 6). The Ts decreased from the first to the third wetting hour (29.84, 28.91, 27.49°C). The lowest Ts values of the goats at 20°C after each wetting hour were significantly different from each other, and decreased from the first to the third wetting hour (30.07, 29.28 and 28.82°C). The highest values reached after the first hour was significantly different from that of the second hour, which was equal to that of the third hour (Table 6). The goats got colder with each wetting and reduced their Ts to decrease the temperature gradient between the skin and the surroundings, hence reducing heat loss. The decline of the Ts of the goats with every wetting has the implication to farmers that exposure of goats to a number of showers especially at lower ambient temperature induces more stress that can result in stock loss due to hypothermia.

Conclusion:

The repeatedly wetted goats were able to maintain their Tr at a relatively constant level throughout the experimental period. This was achieved through several physiological processes like shivering which was observed but not quantified. The slightly higher VO_2 of the repeatedly wetted goats than that of the once wetted goats was indicative of an increased metabolic rate (Bianca and Kunz, 1978), which helped in preventing deviations in the Tr (Kuhnen and Jessen, 1990). The slight decline in the Ts of the repeatedly wetted goats was to reduce temperature gradient between the skin and the environment so as to reduce heat loss, which could lead to hypothermia. From the results of the VO_2 and Ts of the repeatedly wetted goats, it can be concluded that each successive wetting resulted in cumulative stress to the goats.

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