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Comparison between the thermal insulation properties of Huacayo alpaca and Merino sheep fleeces

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ABSTRACT

The aim of the study was to evaluate and compare the fleece thermal insulation of Huacaya alpacas and Merino sheep. The study included 13 clinically healthy Huacaya alpacas and 14 Merino sheep. Fleece samples were taken from the trunk (lateral aspects) of each animal to measure coat fibre length and average fibre diameter. The insulating properties of each sample were determined using a calorimetric method. In addition, infrared thermographic images were taken of the trunk (lateral aspects) for both species in an indoor environment. Four regions of interest (ROIs) were determined from each thermographic image (corresponding to the coat sample sites) and the mean temperature within each ROI was calculated. Merino sheep had significantly ($P<0.001$) longer and thicker fibres than alpacas, but less efficient (by about 20%) insulation at all sample sites. Sheep in similar experimental conditions therefore had significantly higher fleece surface temperature (by 1 - 2 °C) than Huacaya alpacas. Infrared thermography also provides information about fleece surface temperatures *in vivo*, which can be used to validate models of heat exchange in homeotherms.

Key words: Alpacas; fibre diameter; fibre length; fleece; sheep; thermal insulation; infrared thermography

Introduction

Coat insulation plays a major role in body temperature conservation and regulation. Most of the temperature difference between an animal and the air surrounding it is found

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within the coat, which is the layer between the underlying surface of the skin and the atmosphere. Therefore, the coat temperature is influenced by various energy fluxes which contribute to the animal's energy balance, and it depends on the coat structure and the external microclimate (CENA, 1974; McARTHUR and MONTHEIT, 1980; McCAFFERTY, 2007; SOROKO et al., 2015; SOROKO et al., 2017).

Wool is one of the best textile materials due to its characteristics, including good hygroscopic properties and heat insulation, high tensile strength and ease of spinning. The most popular breed of sheep utilised for wool is the Merino. The fibres are devoid of a medulla (REIS and SAHLU, 1994; SHARMA and PANT, 2013) with a diameter from about 12 to 25 microns (REIS and SAHLU, 1994; SHARMA and PANT 2013; SCOBIE et al*.,* 2015).

Alpacas are also becoming popular in fibre production. There are two main breeds of alpacas: Suri and Huacaya. Suri fibres are finer and longer compared to Huacaya fibres, which are more similar to Merino and Corriedale sheep wool. However, unlike sheep wool, only the minority of alpaca fibres are medulla-free. The medulla present in their structure may be continuous or fragmented (GERKEN, 1997; ANTONINI, 2010; CZAPLICKI, 2012). Numerous studies on sheep and alpaca fibres have indicated their efficient insulating and thermo-active properties (SHAKYAWAR et al., 2007; GERKEN, 2010; MOORE et al., 2011). However, no studies have evaluated and compared the fleece thermal insulation of alpacas and sheep using equivalent techniques. Therefore, the aim of our study was to evaluate and compare fleece thermal insulation of Huacaya alpacas and Merino sheep.

Materials and methods

Animals. The study was conducted in October 2015 and included clinically healthy Huacaya alpacas (n = 13) and Polish Merino sheep (n = 14). All the examined animals were females aged between 2-4 years. They were bred and kept on the Sieborowice Farm, Kraków, Poland. Shearing for both species was conducted using a hand clipper or an electric shearing machine, five months prior to examination. Both the Huacaya alpacas and the Merino sheep were kept indoors. Fleece samples were taken for measuring: fibre length, average fibre diameter and thermal insulation. In addition, thermographic examination of both species was performed to estimate the fleece surface temperature. All experimental procedures were approved by the Local Ethical Committee for Experiments on Animals in Wroclaw.

Fleece sampling. Four small fleece samples were taken from each animal at the following sampling sites: left upper trunk (LU), left lower trunk (LL), right upper trunk (RU) and right lower trunk (RL). The fleece was cut about 2 mm above the base of the skin using scissors.

Examination of fleece length. The natural length of fibre from Huacaya alpacas and Merino sheep was measured without stretch, using a ruler and a magnifying glass. Fleece length was determined by measuring 10 bundles of fibres per sample with a precision of 0.1 cm.

Examination of fleece diameter. To estimate the diameter of the fibres, 4000 hairs were measured from each animal, 1000 from each sampling site. Fibres were cleaned in lukewarm water with detergent to free them of grease, and were then mounted on slides and immersed in paraffin oil. The measurement of fibre diameter was performed according to Polish Standard PN-72/P04900 using an MP3 lanameter, with magnification of ×500.

Measurement of fleece insulation properties. The measurement of thermal insulation was performed using equipment for the evaluation of insulating materials exposed to thermal radiation produced by Lodz University of Technology (Poland) (Fig. 1).

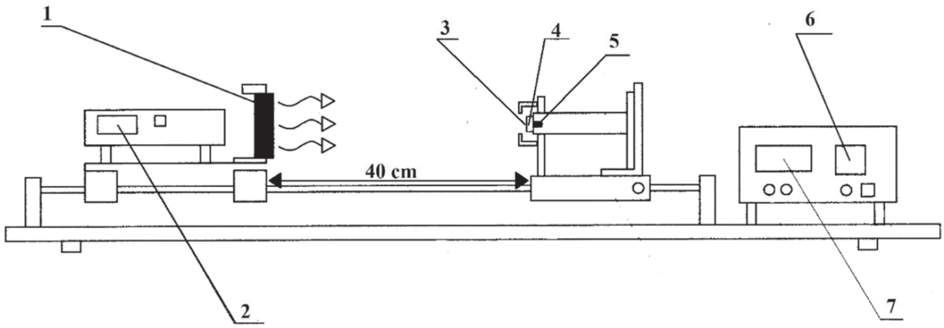

Fig. 1. The scheme of the equipment for the measurement of thermal insulation in materials exposed to thermal radiation produced by Lodz University of Technology (Poland) (1- infrared heater; 2- infrared heater temperature meter; 3- measuring sample; 4- aluminium calorimeter; 5- temperature indicator; 6- temperature meter; 7- time measurement meter).

To evaluate the heat insulation of Huacaya alpaca and Merino sheep fleeces, a 0.3 g sample from each animal was weighed and placed in a holder so that it covered the aluminium calorimeter without squeezing. The sample was placed 40 cm away from the heat source at a temperature of 680 ºC. The measurement time was 5 minutes for each sample. For each sample, the factor Rp (°C/s) was determined, expressing the rate of temperature rise of the calorimeter.

$Rp = \Delta T/\Delta t$

where:

Rp - rate of temperature rise of the calorimeter with the sample, °C/s

ΔT - temperature rise

Δt - heating time

Subsequently the factor qs (kW/m^2) was calculated - the density of heat flux penetrating the sample.

$qs = (m \times cp \times R)/A \times \alpha$

where:

qs - density of heat flux penetrating the sample, (kW/m^2)

m - the mass of aluminium sample of the calorimeter, 0.00716 kg

cp - specific heat of aluminium, 900 J/kg °C

A - surface area of the calorimeter, 0.00049 m^2

α - absorption coefficient of the blackened surface of the calorimeter, 0.95

Measurements were also made for the empty calorimeter to indicate R0 (the rate of temperature rise of the calorimeter without the sample) and q0 (the density of heat flux acting on the sample), to calculate the heat transfer rate (HTR). HTR is a measurement of the heat penetrating through a sample subjected to the thermal radiation. It is equal to the ratio of the density of heat flux that has passed through the sample (qs) to the density of heat flux acting on the sample (q0). The lower the HTR, the better the heat insulation. The measurements carried out on the test bench complied with the requirements of Polish Standard PN-EN ISO 6942.

Fleece surface temperature. The thermographic examination was performed indoors using a high resolution VarioCam infrared camera 640×480 (InfraTec, Dresden, Germany) at an ambient temperature of between 5.2 - 7.6 ºC for Huacaya alpacas and 7.9 - 9.6 ºC for Merino sheep. The emissivity (ε) was set to 1 for all readings. The animals were studied at rest before daily turnout for grazing, and moved to a separate box to avoid close contact 10 minutes prior to imaging. Images were recorded while the animals were standing and were held by the head area to maintain the same position. Any straw or mud present in the imaging field of view was removed before the thermographic examination, and wet or torn fleece, or scars, inflamed or swollen areas were recorded for each examined animal. All thermographic images were taken perpendicular to each subject to avoid any possible errors due to angle. Each animal had two thermographic images recorded to include both lateral aspects of the trunk from a distance of 2.5 m (Figs. 2, 3). Regions of interests (ROIs), with a size of 200 × 300 pixels, were determined for each thermographic image of both species. On each image 2 ROIs were defined at the sites where fleece samples were taken later. The temperatures were determined by IRBIS 3 Professional software (InfraTec, Dresden, Germany) using the mean pixel value in the rectangular ROI. Statistical analysis was conducted with STATISTICA 10 software (StatSoft, Inc., Tulsa, Ok., USA). The statistical characteristics of the quantitative variables were presented as arithmetic means (M) and their standard deviations (SD). The normality of the variable distribution was verified by Shapiro-Wilk tests. The Student *t*-test for independent variables was used to compare the statistical characteristics of normally-distributed quantitative independent variables. The significance of differences between mean values of variables with nonhomogeneous variances was verified using the Student *t*-test with independent estimation of variance. The homogeneity of variance was examined with the Levene and Brown-Forsyth tests. A P value of <0.05 was considered statistically significant.

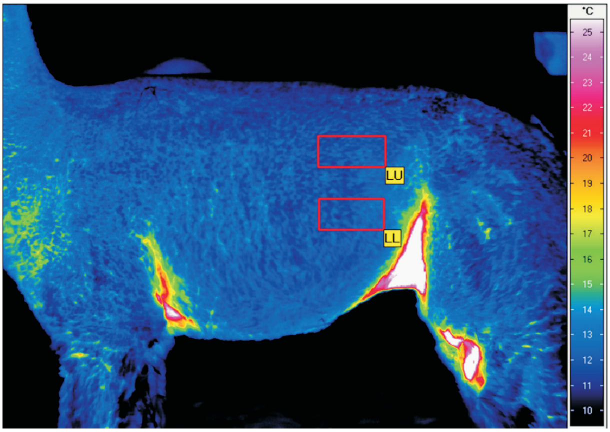

Fig. 2. Thermogram of the left lateral aspect of the Huacaya alpaca's trunk. Measured Regions of Interest (ROI): LU - left upper trunk, LL - left lower trunk.

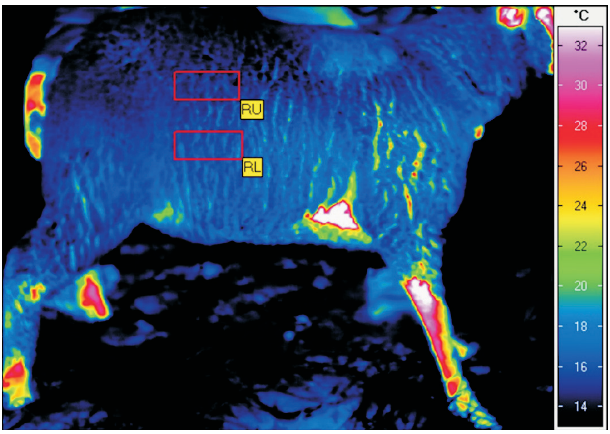

Fig. 3. Thermogram of the right lateral aspect of the Merino sheep's trunk. Measured Region of Interest (ROI): RU - right upper trunk, RL - right lower trunk.

Results

The results for Huacaya alpaca and Merino sheep fleece samples are presented in Table 1. In all measuring areas, Merino sheep had significantly (P<0.001) longer (on average by 23%) and thicker (by 17%) fibres, but poorer insulation (a higher value of HTR) by as much as 20%. Summary statistics for Huacaya alpaca and Merino sheep fleece surface temperatures are presented in Table 2. The Huacaya alpaca fleece temperature was significantly (P<0.001) cooler (by 1 to 2 °C) compared to Merino sheep at all ROIs.

Table 1. Characteristics of Huacaya and Merino sheep fleece samples, by sampling site (Means ± SD)

Fleece parameters	Sampling sites			
	LU	LL	RU	RL
Length (cm)				
Huacaya alpacas	3.18 ± 0.52	3.24 ± 0.54	3.25 ± 0.64	3.29 ± 0.67
Merino sheep	3.99 ± 0.40	3.99 ± 0.40	4.08 ± 0.45	4.08 ± 0.45
	P<0.001	P<0.001	P<0.001	P<0.001
Diameter (μm)				
Huacaya alpacas	18.9 ± 2.8	20.4 ± 3.7	18.7 ± 3.1	20.7 ± 3.1
Merino sheep	23.3 ± 3.3	23.8 ± 3.0	23.2 ± 2.8	24.1 ± 3.0
	P<0.001	P = 0.007	P<0.001	P = 0.003
Heat insulation, HTR				
Huacaya alpacas	0.67 ± 0.10	0.71 ± 0.07	0.67 ± 0.11	0.72 ± 0.10
Merino sheep	0.81 ± 0.08	0.85 ± 0.04	0.87 ± 0.06	0.87 ± 0.06
	P<0.001	P<0.001	P<0.001	P<0.001

M - arithmetic mean, SD - standard deviation, P - the level of significance, LU - left upper trunk, LL - left lower trunk, RU - right upper trunk, RL - right lower trunk, HTR - the ratio of the density of heat flux that has passed through the sample (qs) to the density of heat flux acting on the sample (q0). Higher values indicate lower insulation.

Table 2. Coat surface temperatures for alpacas and sheep taken by infrared thermography, averaged for the ROIs (Regions of interest); (Means ± SD)

Temperature (°C)	ROI			
	LU	LL	RU	RL
Huacaya alpacas	13.2 ± 1.2	13.9 ± 1.5	13.3 ± 1.2	14.0 ± 1.2
Merino sheep	14.8 ± 0.8	15.6 ± 1.1	14.9 ± 0.8	15.6 ± 0.9
	P<0.001	P<0.001	P<0.001	P<0.001

LU - left upper trunk, LL - left lower trunk, RU - right upper trunk, RL - right lower trunk

Discussion

Animal coats are one of the most efficient insulating materials. The thermal insulation of the coat varies between individual animals due to factors such as differences in coat length, thickness, and the density of the hair (MOORE et al., 2011). GERKEN (1997) found that a minimum fibre length seems to be necessary to benefit from the insulation properties of the fibre. Annual regrowth of fleece ranges from 7.7 to 12.6 cm for Huacaya alpacas (FRANK et al., 2006) and 8.4 cm for Merino sheep (SHARMA and PANT, 2013). In our study the fleece had grown for 5 months since shearing, and the fleece length of approximately 3.2 cm for alpacas and 4 cm for Merino sheep is consistent with other studies.

CZAPLICKI (2012) reported alpaca fibre diameter in a range from 20.6 to 35.4 μm in Poland. In our study the average diameter was 19.7 μm, which lies outside the range quoted by CZAPLICKI (2012). For comparison, in Australia, the alpaca fibre diameter was reported to range from 17.7 to 46.6 μm (McGREGOR and BUTLER, 2004). According to WULIJI et al. (2000) the average thickness of fibres is lower on the alpaca's back than on the side of the trunk. The same results were found in our study, where alpacas had thinner fibres on the upper parts of the trunk compared to the lower.

The average fibre diameter of the Merino sheep was about 23.6 μm in our study and was similar to that obtained by REIS and SAHLU (1994), who indicated 20 - 30 μm, and SHARMA and PANT (2013), who found an average fibre diameter of 23 μm.

We found that Merino sheep had longer and thicker fleeces, but less efficient thermal insulation compared to Huacaya alpacas. Differences in thermal insulation between the fleeces of two species may be associated with variations in the internal structure of the individual fibres (WANG et al., 2005; MOORE et al. 2011; CZAPLICKI, 2012). Merino sheep fleece consists of one type of fibre without a medulla, whereas only the minority of alpaca fibres are medulla-free. In alpacas medullae may be continuous or fragmented (ANTONINI, 2010; GERKEN 2010; CZAPLICKI, 2012).

According to CENA and CLARK (1973), coat structure has an important influence on the radiative energy balance of an animal. Coat surface temperature will be a function of a temperature profile within the coat, and of the coat structure. In this study we found that Huacaya alpacas had a lower fleece surface temperature compared to Merino sheep. The lower surface temperature indicates that animals conserve their body temperature better than sheep. However, the rectal temperature was not measured.

Our study has a number of limitations. We used a lanameter to measure fibre diameter, which CZAPLICKI (2012) has criticised for its limited accuracy, in comparison to laser and scanning electron microscopy techniques. Our simple method of fleece sampling using scissors may have also introduced a source of error in the fibre length measurement. Fleece temperature measurements were taken in slightly different ambient temperature conditions for the two species: this is likely to contribute significantly to the differences in fleece temperature observed, and would need to be better controlled for the development of a complete model of heat transfer in the species. Nonetheless, these initial measurements demonstrate that infrared thermography is a practical and viable technique to collect temperature data for small ruminant research.

Conclusions

It was found that Huacaya alpacas have greater thermal insulation properties than Merino sheep (by about 20%). This difference between the species appears to be associated with variations in the individual construction of the fibres rather than differences in the fibre length and diameter. Infrared thermography also provides valuable information about fleece surface temperatures *in vivo*, which can be used to validate models of heat exchange in homeotherms. Environmental conditions must be controlled rigorously to enable those models to be applied.

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SOROKO, M., A. WYROSTEK, K. HOWELL, K. DUDEK: Usporedba izolacijskih svojstava vune alpaka (*Huacayo alpaca*) i merino ovaca. Vet. arhiv 89, 519-528, 2019.

SAŽETAK

Cilj ovoga istraživanja jest procjena i usporedba vune alpaka (*Huacayo alpaca*) i merino ovaca kao toplinskog izolatora. Istraživanje je obuhvatilo 13 klinički zdravih alpaka i 14 merino ovaca. Uzorci vune uzeti su s lateralnog dijela trupa svake životinje kako bi se izmjerili dužina i promjer vlakana. Izolacijska svojstva svakoga uzorka određena su kalorimetrijskom metodom. Također su učinjene infracrvene termografske snimke lateralnog dijela trupa s kojega su uzeti uzorci u obje skupine u zatvorenom prostoru. Na svakoj su snimci određene četiri regije (na temelju mjesta uzorkovanja) te je izračunata prosječna temperatura. Vuna merino ovaca imala je znakovito duža i deblja vlakna od vune alpaka (P<0,001), ali manje učinkovitu izolaciju (oko 20 %) u svim uzorcima. Ovce u sličnim pokusnim uvjetima imale su znakovito višu temperaturu površine vune (1-2 ºC) od alpaka. Infracrvena termografija pruža podatke i o temperaturi površine vlakana *in vivo*, što se može upotrijebiti za vrednovanje modela u izmjeni temperature toplokrvnih životinja.

Ključne riječi: alpaka; promjer vlakna; dužina vlakna; vuna; ovca; toplinska izolacija; infracrvena termografija

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