Arctic Hiking Mattress from Processed Reindeer Pelt

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Abstract: Quality of clothing and equipment has always been the most important matter when hiking in extreme, arctic conditions. Reindeer (*Rangifer tarandus*) hides were processed with the aid of irreversible tannage and careful hydrophobic treatment. As a result, a processed reindeer-pelt hiking mattress was obtained, superior to the best hiking mattresses on the market made of plastic materials. Its physical properties are: weight 1.7 kg, width 60 cm and length 190 cm. The reindeer pelt has a low initial isothermal compressibility, 0.71 Pa^{-1}, a low thermal conductivity, 0.070 $Wm^{-1}{}^{\circ}C^{-1}$, and an R-value of 0.35 $m^{2}{}^{\circ}CW^{-1}$. The heat-flow experimenrs have been carried our at a pressure of 810 Pa. In addition, the reindeer pelt stays dry in use because of its good ventilation. In these respects the reindeer pelr is superior to plastic mattresses.

Key words: hydrophobic processing, chrome tannage, isothermal compressibility, thermal conductivity.

Rangifer, 16 (3): 103–108

Introduction

The reindeer and caribou (*Rangifer tarandus*) have been the most important resource for survival throughout the human history of the arctic or subarctic parts of the northern hemisphere. The reindeer is thermally well protected against cold. In the living animal, heat dissipation by conduction through the fur is of minor importance, whereas the heat convection is most significant, especially in cold and windy conditions.

Besides outward conditions such as wind and moisture, there are many structural properties which affect the thermal insulation of the reindeer pelt in living animals. However, in this study the reindeer pelt will be considered after flaying, in the skin and leather state.

The reindeer has well-built long and relatively stiff guard hair. The fur consists of thick guard hairs and of thin filled woollen underfur (Bohl & Nikolajewsky, 1931; Kaplan, 1971). The guard hairs contain air-filled cavities separated from each other by thin membranes forming a medullar structure. The woollen hairs consist of thin and filled matrix structure. The surface density of the guard hairs varies from 1000/cm^2 to 2000/cm^2 in different areas of the pelt (Timisjärvi *et al.*, 1984; Nieminen, 1994). For comparison, the birth fur is very dense, 3200/cm^2, and short. The fur thickness has large individual and areal variations. In Finland, the thickness of the fur coat is approximately 30 mm. In the living animal, the skin temperature varies greatly depending on conditions. In addition, the guard hairs are not perpendicular to the skin and the thermoerection of the hairs regulates the heat convection. (Soppela *et al.*, 1986; Nieminen, 1994). The heat flow density through the fur coat in living reindeer varies from 25 to 32 Wdm^{-2} depending on the coat thickness, varying from 30 to 55 mm (Scholander *et al.*, 1950). These values for the heat flow density seem to be rather high and hence extreme temperature differences between skin and air outside the pelt and high heat convections can be expected.

Traditionally, Indians in North America have used brain tanning for buckskins with the hair off and also for beavers with the hair on. They apply mushy cooked brains, actually oils from the brain, several times on the scraped skin for penetration and partially dry and stretch it in the meantime. Thus, while the skin dries, the oils will allow the skin fibres to remain separated and they will swell somewhat, resulting in leather-like behaviour. Finally, they allow smoke to penetrate the tanned leather, waterproofing only the fibres, not the whole leather (Belitz, 1983; McPherson, 1988).

There is no documented information of brain tanning for the caribou and deer. Perhaps it would be too much work to try to brain tan the flesh side of a large rawhide. The only practical use for hair on deer rawhides is for covering the tepee's wall and floor. After the hair has loosened, the softened rawhides are ready for brain tanning and perhaps for smoking. (Belitz, 1983; McPherson, 1988). It is interesting to note that smoking the leather is actually retanning with formaldehyde.

Reindeer herders have traditionally used reindeer rawhides as sleeping mattresses in the Lapp hut. However, rawhides are too heavy because skin membranes and other matter on the hide are left on and should be removed. Also, without any skin opening-up, the proteins which are not suitable for tanning contribute to the hide weight. In this case, the hides with the hair on have been exposed to the attack of bacteria and micro-organisms when they have become moistened in use. Hence, hair loosens rapidly and the hide is unusable for sleeping mattress and sleeping bag.

Eskimos and arctic Indians have used tanned caribou pelts and also reindeer pelts traded from Siberian Eskimos for parkas and sleeping bags. The tanning recipe has been as follows: first the skins were scraped, soaked in urine and softened with boiled salmon roe; then they were worked by rubbing with hands and biting with teeth (Varjola *et al* , 1990). Actually, this is saliva-enzyme dressing.

In this study the physical properties of a hiking mattress made from reindeer hide, with special processing and aimed for extreme arctic conditions, are reported.

Material and methods

Six reindeer hides from the first-year, late-autumn stock were selected. The fur thickness, hair density, hide weight and skin quality were taken into consideration in the selection. The hides were specially processed with the aid of irreversible tannage and careful hydrophobic treatment.

Irreversible tannage. Careful hide opening-up must be done previously to any tannage (Faber, 1985, p. 30). To ensure the best stability against micro-organisms chrome tannage should be applied (Fabet, 1985, pp. 131 - 189). Also chrome-aluminium tannage can be used, owing to its irreversibility. In this work, both tannage methods were used.

Hydrophobic processing. It is twofold: 1. lubrication with a hydrophobic grease and 2. treatment with a fluorochemical substance. The chrome tanning agent is strongly cationic; this must be kept in mind when a water-repellent treatment is applied. There are anionic (Scotchgard™ Leather Protector FX-3573, 3M Belgium NV/SA) and cationic (Cutafob AWO™, Dr. Th. Böhme; Nuva LB™, Hoechst AG) fluorochemical hydrophobic substances. To ensure optimum water-repellency, a right combination of fatliquoring agents and auxiliaries, following recipes supplied by manufacturers of fluorochemical substances, with powerful hydrophobic properties should be used in the latter stage of leathermaking. A hydrophobic fatliquoring and a water-repellent agent can be applied also in the same batch. In this work Nuva LB™ was chosen from several good alternatives and a recipe for sueded woolled sheepskin was followed (Hoechst, 1989). The most durable and the most effective protection with excellent static and dynamic water-resistance properties was obtained by spraying a blend of a selected fluorochemical agent on the flesh-side of the leather and hot ironing with exhaust ventilation after the hydrophobic treatment in the batch. The sprayed blend of Nuva LB™ was applied with a float ratio of 1:2 (3 per cent isopropylalcohol added).

After this treatment the leather finishing is not possible. The batch application results in hydrophobic behaviour also for the hair coat.

As a result, four hiking mattresses for extreme arctic conditions were obtained from six processed reindeer pelts by sewing one and a half pelts together and by cutting off extra width and other unnecessary parts. The mattresses had the following average physical measurements: weight 1.7 kg, width 60 cm, length 190 cm and pelt thickness 30 mm. The mattress thickness depends on the selected reindeer hides. The reindeer from forest areas in Finnish Lappland usually have a pelt thickness of 30 mm.

A high-quality hiking mattress, Therm a Rest, Model LE Camp Rest, made by Cascade Designs Ltd. (1995) from a transverse-foam coring plastic material was selected as a reference. It has the same dimensions as the reindeer hiking mattresses except the nominal inflated thickness is 64 mm.

Results

Measurements were made in laboratoty conditions. The change in thickness measurement under compression forms a basic property of the mattress behaviour. The load was applied on an area of 0.3 m x 1.0 m using a laminated board. The thickness was measured after a settling period. In Fig. 1 the mattress thickness, Mt, versus loading pressure, P, is depicted for the reindeer pelt and for the Therm a Rest. It is natural that the reindeer pelt has a different thickness for the head end and rump end. This is the case also for the Therm a Rest, which has a lower mattress thickness at end 1 opposite to the inflation valve (end 2). This behaviour can cause

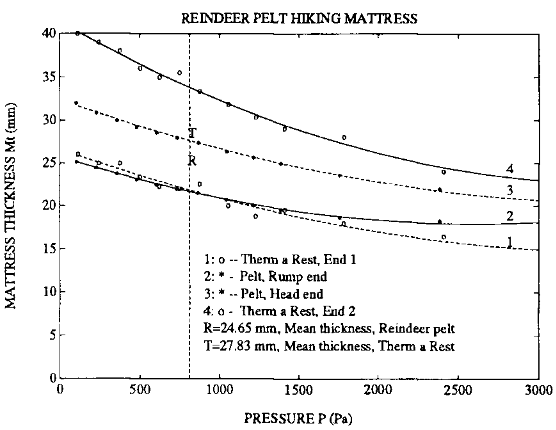

Fig. 1. Mattress thickness, Mt, versus loading pressure, P, for reindeer pelt. Graphs for Therm a Rest are given as reference.

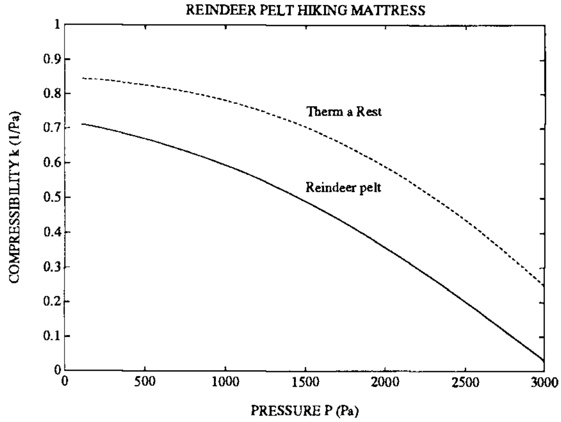

Fig. 2. Mattress isorhermal compressibility, k, versus loading pressure, P, for reindeer pelt and Therm a Rest.

trouble in cold conditions. To achieve an equal thickness quickly the mattress must be over-inflated by mouth. At the same time, moisture is introduced into the mattress and this is an unfavourable phenomenon. From Fig. 1 it can be seen that the guard hair and woollen hair lean toward the horizontal direction under compression more slowly than the Therm a Rest loses its thickness. At a pressure of 810 Pa, marked in the diagram, the mean thickness values, 25 mm (marked R) for the reindeer pelt and 28 mm (marked T) for the Therm a Rest, were calculated for the determination of thermal conductivity and heat flow density.

From these figures the isothermal compressibility, k, can be determined using the expression

(1) $$k = -(1/V)(dV/dP).$$

At a volume, V, the volume difference, dV, is caused by the pressute difference, dP. The compressibility, k, for the reindeer pelt and Therm a Rest is shown in Fig. 2 as a function of pressure. The reindeer pelt has a lower isothermal compressibility than the Therm a Rest. The initial and final isothermal compressibilities are 0.71 Pa^{-1} and 0.020 Pa^{-1} for the reindeer pelt and 0.85 Pa^{-1} and 0.24 Pa^{-1} for the Therm a Rest, respectively. The sleeper's body loads the mattress unequally and the reindeer mattress clearly behaves better because the air flows away from the heaviest loaded areas in the Therm a Rest and at the same time thermal energy flows more easily through these areas.

Thermal conductivity was measured using an arrangement shown in Fig. 3. The reindeer pelt as well as the Therm a Rest (2) were placed on a wide

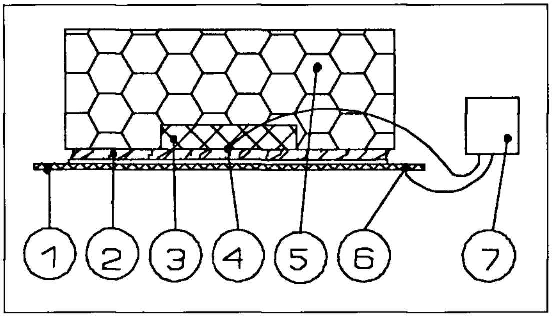

Fig. 3. Arrangement in hear flow and thermal conductivity experiments. 1 aluminium plate as heat sink, 2 reindeer pelt hair-side up or Therm a Resr, 3 aluminium disk as heat supply, 4 and 6 thermocouples, 5 styrofoam insulator and 7 digital thermometer.

aluminium plate (heat sink) (1) hair-side up in the case of the pelt. The aluminium plate which was 6 mm thick, conducted and radiated the heat away and its temperature was maintained at a constant value of 24.0°C during the heat flow measurements. A heated aluminium disk (heat supply) (3) with known mass, area and specific heat was then put in the middle area. Its temperature was monitored at a point (4) with one thermocouple and a digital thermometer (7). The outside temperature was monitored at another point (6) with another thermocouple and also with the thermometer (7). A styrofoam insulator (5), having a thickness of 30 cm, ensured the heat flow only through the pelt or the Therm a Rest. The aluminium disk (3) compressed the pelt and the Therm a Rest at a pressure of 810 Pa as seen in Fig. 1. This simulated well the pressure caused by the sleeper.

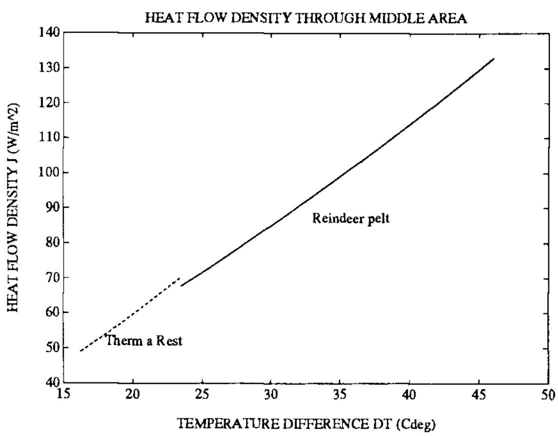

Fig. 4. Heat flow density, J, versus temperature difference, DT.

The heat flow density, J, is defined by the expression

(2) $J = -(1/A)(dQ/dt)$,

where A is the area of the aluminium disk (3) and dQ/dt the thermal energy flow rate measured at point 4. Fig. 4 shows the heat flow density, J, as a function of the temperature difference, DT, between points 4 and 6. As can be seen, the Therm a Rest has a little higher tendency to conduct heat energy than the reindeer pelt has because of its higher compressibility in dynamic conditions. This behaviour would become more clear if the heat flow density curve for the Term a Rest were extrapolated for higher temperature differences. In practice, it is not

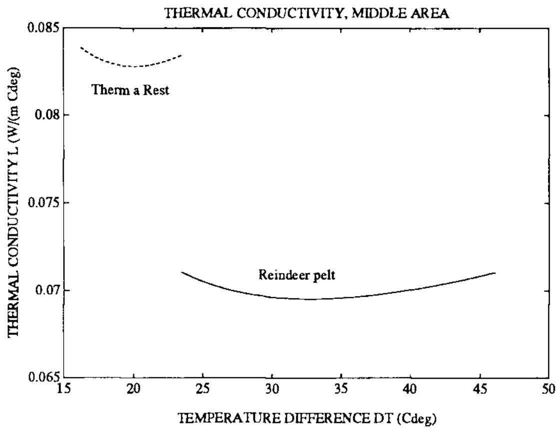

Fig. 5. Thermal conductivity, L, versus temperature difference, DT.

possible to use as high temperatures for the Therm a Rest as for the reindeer pelt in the heat flow measurements because the Therm a Rest would melt.

The thermal conductivity, L, can be defined with the expression

(3) $L = -J / grad_X(T)$.

Here T is the temperature and the x-axis is directed from the hair-side towards the leather-side. Using the data derived from Figs. 1 and 4 the thetmal conductivity, L, was evaluated as indicated by the graphs in Fig. 5. The mean values of the thermal conductivity for the reindeer pelt and for the Therm a Rest are 0.070 $Wm^{-1}°C^{-1}$ and 0.083 $Wm^{-1}°C^{-1}$. Loaded with a pressure of 810 Pa, the corresponding insulator thicknesses, Mt, are 25 mm and 28

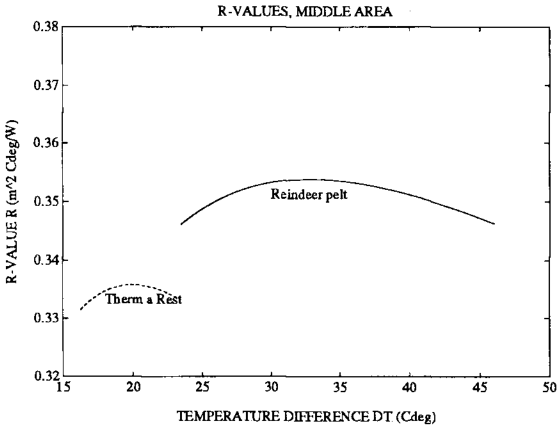

Fig. 6. R-value, R, versus temperature difference, DT.

mm, respectively. For comparison the thermal conductivity of air is 0.02 $Wm^{-1}{}^{\circ}C^{-1}$.

Quite often insulation properties are expressed in terms of R-values

(4) $R = Mt/L$.

In Fig. 6 R-values for the reindeer pelt and Term a Rest are shown as a function of the temperature difference, DT. Thus, the calculated mean R-values are 0.35 $m^{2}{}^{\circ}CW^{-1}$ for the reindeer pelt and 0.33 $m^{2}{}^{\circ}CW^{-1}$ for the Therm a Rest.

Discussion

R-values of 0.24 - 0.32 $m^{2}{}^{\circ}CW^{-1}$ for reindeer pelt in the skin state determined by Scholander *et al.* (1950) are slightly smaller than the R-values in the leather state determined in the present work. Scholander *et al.* have conducted the heat flow measurements in the opposite direction, from the skin-side through the hair coat, because they have tried to simulate the heat flow in living reindeer. The heat convection can explain the difference. Cascade Designs Ltd. (1995) gives R-values of 4.7 - 6.2 (unit unknown) for the Therm a Rest, Model LE Camp Rest. The lower value is based on self-inflated mattresses and the higher value on mattresses which are over-inflated. These R-values are static, for unloaded mattresses, and do not exist in use, while all the R-values determined in this report are dynamic, determined for loaded mattresses.

The reindeer hides researched were selected based on their good quality. The reference hiking mattress, Therm a Rest Model LE Camp Rest, was selected randomly. Thus, the measured and calculated values are not statistically valid. The termal properties are almost similar for both types of mattresses and both of them are excellent. However, the compressibility, wetting and ventilation behaviour of the reindeer pelt is clearly more suitable for mattress purposes than the Term a Rest.

Guard hairs of the reindeer pelt are somewhat brone to break off in bending. However, this is not a serious problem because the dense and thick underfur is durable and this is the most important feature of the reindeer pelt as hiking mattress.

Experiences in arctic conditions

The Therm a Rest has a lower mattress thickness at end 1 (Fig. 1) opposite to the inflation valve (end 2). To achieve an equal thickness more quickly in cold conditions this mattress must be over-inflated by mouth. At the same time, moisture is introduced into the mattress and this is an unfavourable phenomenon causing trouble when hiking for many days. It is natural that the reindeer pelt has also different thicknesses for the head end and rump end. In this case, this behaviour cannot cause any noticeable trouble.

Snow melts if the flesh-side of the reindeer pelt hiking mattress is in contact with the snow because of the temperature rise on the boundary between the snow and leather. Then, water might diffuse into the leather as a result of capillarity and hydration. If the leather-side gets wet the weight of the mattress increases and the mattress might then freeze. Then, it becomes difficult to roll up for carrying. However, the leather getting wet has a minor effect on the thermal conductivity of the mattress. Neither can water molecules diffuse through the grain layer into the fur coat. A reindeer pelt without effective hydrophobic treatment has this kind of behavior.

It is possible to protect the leather-side against short-term and long-term wetting. The right combination of a hydrophobic fluoride compound with a hydrophobic fatliquor can result in water-repellent fibre bundles and prevent wetting at least for short-term. When sleeping outside with the mattress directly on snow, extreme care must be taken in consideration of water-repellent properties. An additional water-repellent layer on the leather-side must be employed using a spraying method with a concentrated hydrophobic fluoride substance. Then, Greenland wax (a mixtute of paraffin and beeswax) can be applied using an air blower at a temperature range of 55-60°C. These applications together ensure extreme protection against long-term wetting. The tent floor also provides a good short-term protection against leather-side wetting.

The sleeper is always sweating, even when sleeping in the cold. The sweat diffuses through the sleeping bag and hence also into the hair layer. When water vapour molecules enter the condensation zone in the hair layer, wetting happens followed by freezing. However, this behaviour is of minor importance because the sleeper turns around and the hair layer gets ventilated because of the air convection. This behaviour of the reindeer pelt as a hiking mattress is important. The surface of the Therm a Rest is watertight and thus its surface gets wet. Wetting of the sleeping bag also follows.

Summary

As a summary, the hydrophobically processed reindeer pelt is a superior arctic hiking mattress to plastic mattresses with excellent compressibility, thermal insulation, sweat ventilation and water-repellency properties.

Acknowledgements

The authors are grateful to the referees, Professor, Dr. G.E. Attenburrow and Dr. Paul Kronick, for their valuable criticism and positive recommendations. Thanks are also due to Mr. Pekka Tenkilä, M.A., who has revised the English in this report.

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Manuscript received 20 May, 1996
accepted 16 September, 1996