Received: 9 November 2023 | Accepted: 6 August 2024

DOI: 10.1111/vde.13290

Veterinary Dermatology

ORIGINAL ARTICLE

Ultraviolet radiation protection factors of livestock shade cloths for free-range pigs

A. W. Schmalwieser[1] | L. Bigelbach[1] | S. Helletzgruber[1] | H. Danhel[1] | J. Heydenreich[2]

[1]Unit of Physiology and Biophysics, University of Veterinary Medicine, Vienna, Austria

[2]Department of Dermatology, Bispebjerg Hospital, Copenhagen, Denmark

Correspondence
A. W. Schmalwieser, Unit of Physiology and Biophysics, University of Veterinary Medicine, Veterinaerplatz 1, Vienna 1210, Austria.
Email: alois.schmalwieser@vetmeduni.ac.at

Abstract

Background: Protection from solar ultraviolet radiation (UVR) is paramount in light-skinned pig breeds such as Yorkshire or Landrace to avoid sunburn.

Objectives: Determination of the UVR exposure of a pig and the sun protection abilities of shade cloths with different shade rates.

Animals: Life-sized plastic model of a Landrace pig.

Materials and Methods: The model was equipped with 20 UVR meters at various anatomical positions that recorded the erythemal effective solar irradiance. A turntable enabled irradiation from different directions. Solar irradiance was measured in direct sunlight as well as under three shade cloths with different shade rates (50%, 75% and 90%) and a camouflage net. The sun protection factors (SPF) were determined as the ratio of unshaded-to-shaded measurements at the same solar elevation. The exposure ratio to ambient (ERTA) was calculated for each body site with respect to ambient irradiance. It allows determination of when pigs are at risk of sunburn and protection is needed.

Results: The calculated ERTA values show that some body parts may receive higher values than ambient UVR. Measurements showed that the SPF of shade cloths depends on textile denseness. Selected shade cloths reached values of 3.5 (shade rate 50%), 4.2 (75%) and 5.8 (90%). Protection by the camouflage net was poor. The highest SPF was gained on body sides where ERTA was highest.

Conclusions and Clinical Relevance: Shade cloths can protect all body sites effectively and vulnerable sites in particular. The results of our study enable an estimation of when pigs are at risk of sunburn and provide quantitative metrics for sun protection. This allows effective prevention of UVR-caused skin damage and secondary disorders.

KEYWORDS
free-range, pigs, shade cloths, sun protection

INTRODUCTION

It is well-known that pigs with light skin and without fur are at high risk of developing sunburn.[1–3] Keeping such pigs free-range outdoors therefore requires sun protection. Scant scientific literature is available regarding sun protection for pigs.

Sunburn in mammals is caused by shortwave ultraviolet (UV) radiation (UVR), namely UV-B radiation (280–315 nm),[4] yet as a consequence of the high amount of solar UV-A radiation (315–400 nm) in sunlight, this wavelength range also becomes important outdoors. Solar-induced skin erythema is most pronounced around 24 h after UVR exposure, and fades over several days. The degree of erythema depends on the dose. The dose is the radiation exposure (irradiance over time) which penetrates the skin and becomes absorbed. It is often equated to the radiation exposure striking the skin and therefore expressed in J/m^2.[5] The dose–response relationship for the development of erythema is not linear. It is characterised by a threshold dose below which there is no erythema response (minimal erythema dose [MED]), followed by a range where dose and response are directly proportional to each other, and then a so-called shoulder where the response starts to stagnate despite increasing dose.[6]

In very light-skinned people, the radiation exposure that causes just-noticeable erythema [the MED] is in the order of 100–200 J/m^2 (on previously unexposed skin).[7] It has been reported that in light-skinned pigs, such as Landrace or Yorkshire, the MED is in the same range of approximately 165 J/m^2.[8] This means that these light-skinned breeds are at the same risk of sunburn as very light-skinned people. Sun adaption of the skin increases the MED, mainly as a consequence of thickening of the epidermis; this may increase the MED by a factor of 4 in humans[9] and can be considered to be similar in pigs owing to the similarity of human and porcine skin.[10–12] This increased MED is not sufficient to avoid sunburn or long-term damage,[13] and extrinsic protection is necessary.

Extrinsic protection against solar UVR can be achieved by wallowing or shade. Shade structures may be bushes and trees as well as shade cloths that are permeable to air. The sun protection capabilities of shade cloths depend on the ultraviolet protection factor (UPF) of the textile, the area of the sky which is covered and the position of the receiver (e.g. body site) under the shade cloth. Sun protection capabilities have primarily been estimated relative to humans, for horizontally and vertically orientated static receivers.[14,15] The body geometry of pigs is different and different orientations with respect to the sun occur through movement. In this study we investigated the sun protection capabilities of commercially available shade cloths for agricultural use with respect to the body geometry of pigs, including the simulation of movement.

Additionally, we calculated the exposure ratio to ambient (ERTA) for different body sites. The ERTA is the ratio between the UVR exposure of a certain body site and ambient (horizontally orientated receiver) UVR.[5] Once established, the ERTA allows estimation of the UVR exposure of a certain body site at any time and place from ambient UVR measurements, which are available for many locations.[16] It can therefore be used to estimate when pigs are at risk of UVR exposure and will require sun protection.

MATERIALS AND METHODS

Simulating animal and movement

A true-to-life model (length 1.63 m, height 0.72 m) of glass fibre-reinforced plastic material was used to mimic a Landrace/Yorkshire pig. The model was mounted on a turntable to change the alignment of body sites with respect to the sun as it occurs during natural movement such as walking in a circle.

Instrumentation and body sites

Owing to the similarity of the erythema action spectrum (wavelength dependence of effectiveness in causing erythema) in mammals[4] and the similarity of human and porcine skin,[10,11] we decided to measure the erythemal effective irradiance according to the joint standard from the International Organization for Standardization and the International Commission on Illumination.[17] For measurements, 20 miniature UVR-meters of Sunsaver[18] type were used. This meter can take measurements of the erythemal effective irradiance, which can be expressed in units of mW$_{ery}$/m^2 or in units of the UV index (UVI), whereby 25 mW$_{ery}$/m^2 correspond to 1 UVI.[23,24] With a sampling rate of 1 s, changes in irradiance resulting from movement can be recorded. The measuring positions are depicted in Figure 1. The meters were calibrated under the sun by comparison to a high-grade research instrument (type SL501; Solar Light Inc.), which has been used in the Austrian UVI network[16] since 1996 and is maintained according to international standard procedures.[19] This instrument was also used to measure ambient erythemal effective irradiation in parallel during the experiment.

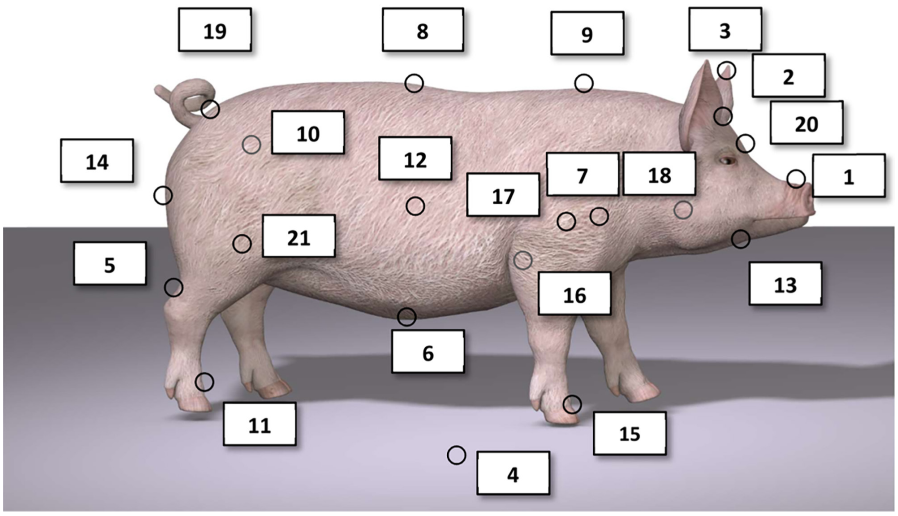

FIGURE 1 Visualisation of measuring positions.

Shade cloths

Woven shade cloths are frequently characterised by the so-called shade rate. This is not a standardised measure and describes the amount of visible light that is absorbed. Camouflage nets are also offered for sun protection as a less eye-catching alternative. Three different commercially available shade cloths (4 × 5 m) with different shade rates were selected, together with a camouflage net:

Mesh 1: 50% shade rate, polyethylene (PE); BeGrit (Figure 2a).
Mesh 2: 75% shade rate, PE; Patura/Galebreaker (Figure 2b).
Mesh 3: 90% shade rate, high density polyethylene (HDPE); Storystore (Figure 2c).
Mesh 4: Camouflage net, polyester (PET); Ouhytck (Figure 2d).

UPF of textiles

As mentioned above, the shade rate refers to visual light and is not applicable in UVR protection. Therefore, the UPF of the respective fabric was determined in the laboratory according to the European guideline EN 13758-1[20,21] by measuring the erythemal-weighted transmittance of simulated solar radiation. The camouflage net is not a woven textile (see Figure 2d); it consists of impermeable polyester straps, which are threaded on a wire net and thus form a patchy structure. Owing to the large holes in between the straps, its UPF was determined for portions of the continuous material only.

Experimental set-up and measurement protocol

The shade cloths were mounted at a height of 2 m, on posts which were wired to the ground to avoid excessive sagging of the cloths. The ground consisted of light pea gravel and sand. The animal model was affixed to the turntable (covered by a piece of plywood) and placed in the deepest shadow to ensure best shading of the whole body. The rotation period of the turntable was set to 2 min and the temporal resolution of the Sunsavers was set to 1 s. This resulted in 120 measurements per turn, or one measurement per 3°. Measurements were taken over five full turns alternately in the direct sun and under the shade cloths. During movement from under a shade cloth to the full sun the model was covered by a blanket. Experimentation was performed in Vienna (48.2° N, 16.4° E, 160 m above sea level), Austria on almost cloud-free days close to the summer solstice between 26 June and 4 July 2023. For these dates, one would expect the highest annual erythemal effective irradiance on cloudless days to be approximately 0.18 mW_{ery}/m^2,[22] or 7.5 UVI, and daily erythemal effective radiant exposure of approximately 4500 J_{ery}/m^2, or 50 UVI/h[25] on cloud-free days on a horizontally orientated receiver.

Measurements started just before solar noon (13:05 Central European summer time [CEST]) and lasted until the evening (12:00–19:00 CEST), covering a range in solar

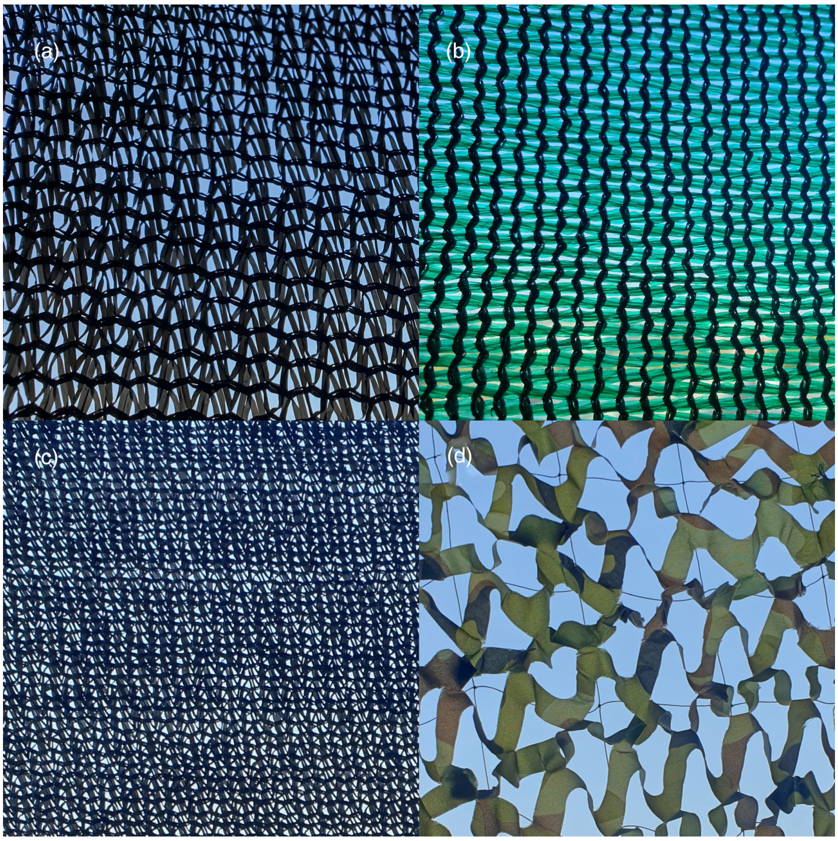

FIGURE 2 Detailed view of textiles: (a) Mesh 1 (50% shade rate, UPF = 5), (b) Mesh 2 (75% shade rate, UPF = 10), (c) Mesh 3 (90% shade rate, UPF = 15) and (d) Mesh 4 (camouflage net, cloth portions UPF = 50+). UPF, ultraviolet protection factor.

height between 65° and 15°. The afternoon was chosen because preparations could be made during daylight hours. The measurement set-up is depicted in Figure 3.

SPF and exposure ratio to ambient

The SPF for each body site i was calculated at different solar elevations h as the ratio between the irradiance measured without cloths (unshaded) $E_{i,\mathrm{unshaded}}$ and the irradiance measured with cloths $E_{i,\mathrm{shaded}}$:

$$\text{Sun protection factor }(h)_i = E(h)_{i,\mathrm{unshaded}} / E(h)_{i,\mathrm{shaded}}$$

The ERTA$(h)_i$ of each body site i was calculated at different solar elevations h as the ratio between the irradiance in direct sunlight $E_{i,\mathrm{unshaded}}$ and ambient irradiance E_{ambient} from the SL501.

$$\mathrm{ERTA}(h)_i = E_{i,\mathrm{unshaded}} / E_{\mathrm{ambient}}$$

The higher the ERTA is, the higher the UV exposure of a body site. The ERTA is generally between 0 and 1, and may exceed a value of 1 under certain conditions.[5]

Data analysis and statistical methods

Data analysis and statistics were done using EXCEL (Microsoft 365). Mean values and standard deviation of irradiance, ERTA and SPF were calculated for each of the five full turns separately. The ERTAs were calculated from measurements at all body sites in the direct sun and measurements of ambient UVR, and were derived for different solar elevations between 65° and 15° as mean values over a period of 10 min (five turns).

RESULTS

UPF of textiles

The mean UPFs of Mesh 1 (shade rate 50%), Mesh 2 (shade rate 75%) and Mesh 3 (shade rate 90%) were 5, 9 and 15, respectively. The continuous material portions of the camouflage net had a UPF of 50+ (inbetween these material portions, there is no protection). Figure 4 depicts the shadow pattern produced by uniform net structures (such as Mesh 1, 2 and 3) and by the patchy structure of the camouflage net.

SPFs

The calculated mean SPFs are depicted in Figure 5. It can be seen that the protective effect is highest at locations which are approximately horizontally orientated, such as the back or the nose, and least at locations which are approximately vertically orientated. The camouflage cloth protects least, with an SPF of ≤2.5 (at the back). This was valid for a moving object only; for a static object (standing, lying) the patchy structure allowed unhindered irradiation of small skin patches. The continuously woven cloths provided sun protection for static postures and movement equally. Mesh 1 (UPF=5, shade rate 50%) provided SPF ≤3.5 at the most vulnerable sites such as back or nose. Mesh 2 (UPF=9, shade rate 75%) provided SPF ≤4.2 and the most protective Mesh 3 (UPF=15, shade rate 90%) SPF ≤5.8.

Mean SPF values were calculated from all measurements (solar elevation between 15° and 65°). The SPF showed a slight and complex dependence on solar elevation (see also ERTA below). For approximately horizontally orientated sites (e.g. nose), the influence was largest and within ±13%; at least influenced sites it was within the standard deviation of measurements (±5%).

Mesh 1 reduced the erythemal effective irradiance at noon from 7 UVI to <2 UVI at all body sites. Mesh 2 reduced it to 1.7 UVI and Mesh 3 down to 1.2 UVI. The camouflage net reduced irradiance down to 2.8 UVI on average when the animal was moving, yet did not provide adequate protection on a static animal.

Exposure ratio to ambient

Figure 6 depicts the change in ERTAs during the day. ERTAs showed a slight and complex dependence on solar elevation. For rather horizontally orientated sites,

FIGURE 3 Measurement set-up of life-sized pig model with attached sensors. (a) frontal view, (b) side view and (c) placement under shade cloth.

FIGURE 4 Shadow pattern from (a) a uniform net structure (Mesh 1) and (b) the patchy structure of the camouflage net (Mesh 4).

the ERTA was highest (≤100%) at high solar elevations, while for rather vertically orientated sites the ERTA was highest (≤40%) at low solar elevations. ERTA was highest at sites which are slightly inclined (compared to horizontal), such as parts of the back, and may exceed 100%.

DISCUSSION

It is well-known that erythema occurs in light-skinned pig breeds, yet little research has been done on erythema in pigs. One study[8] estimated the MED of Landrace pigs kept indoors. To the best of our knowledge, behaviour studies of free-range kept pigs and erythema monitoring in conjunction with UVR measurements, have not been done yet, and this is the first study to focus on sun protection in free-range kept pigs, have not been performed previously.

In Europe, free-range husbandry has become more popular during the past decades because quality standards such as 'organic' labeling, demand a certain amount of mobility outdoors. Sun protection in pigs is therefore an important issue because sunburn causes pain. Severe sunburn leads to blisters and further enables secondary bacterial infections such as moist dermatitis in pigs; in piglets heavy sunburn may even be lethal. Furthermore, there have been reports that sunburnt sows do not accept boars for mating and may undergo embryonic reabsorption, or abortion.[2,3,27]

We showed that even light-skinned pig breeds such as Landrace or Yorkshire can be protected well by shade cloths. Depending on the denseness of the textile, SPFs of ≤5.8 were found. Interestingly, even body locations which point downwards, such as the lateral abdomen, were protected by the shade cloth. This can be explained by the fact that the shade cloth blocks direct solar radiation and therefore prevents reflections from the ground.

Natural sun protection

Shade cloth should be seen as an additional tool for sun protection. The opportunity to wallow should be provided regardless of additional shade, not only for sun protection, but also for cooling and skin care (e.g. antiparasitic and insecticidal effect). Sun protection by soil is poorly investigated, yet even a thin layer of ochre was shown to deliver a SPF between 2 and 13.[28]

Natural shade can be provided by trees. Little is known about the shading properties of trees, as geometry is rather complex and depends on many factors such as type, size and season. Estimates for tree shading range from SPF 2 to 10.[29,30] By contrast, the effects of shade cloths are easier to estimate because of their simple and uniform geometry.

Textiles and SPF

For each of the textiles, a shade rate is provided by the manufacturer. We found that a shade rate of 50% corresponds to UPF 5, 75% to UPF 9 and 90% to UPF 15; these UPFs provide SPFs of 3.5, 4.2 and 5.8, respectively, at the most vulnerable sites. Neither the shade rate nor the UPF describe the SPF in a satisfactory way. The shade rate is not a standardised measure and was not investigated before this, yet it is a well-known factor determining UPF.[14] Besides the UPF, SPF depends on the size and height of the shade cloth as well as on solar elevation.

Size and height

The larger the size of the shade cloths, the more sky is covered, allowing less diffuse UVR to reach beneath the cloth (the shadow becomes deeper/darker), leading to an increase in the SPF.[14,15] The shade cloths used for this study had a size of 4 × 5 m, which are typical dimensions

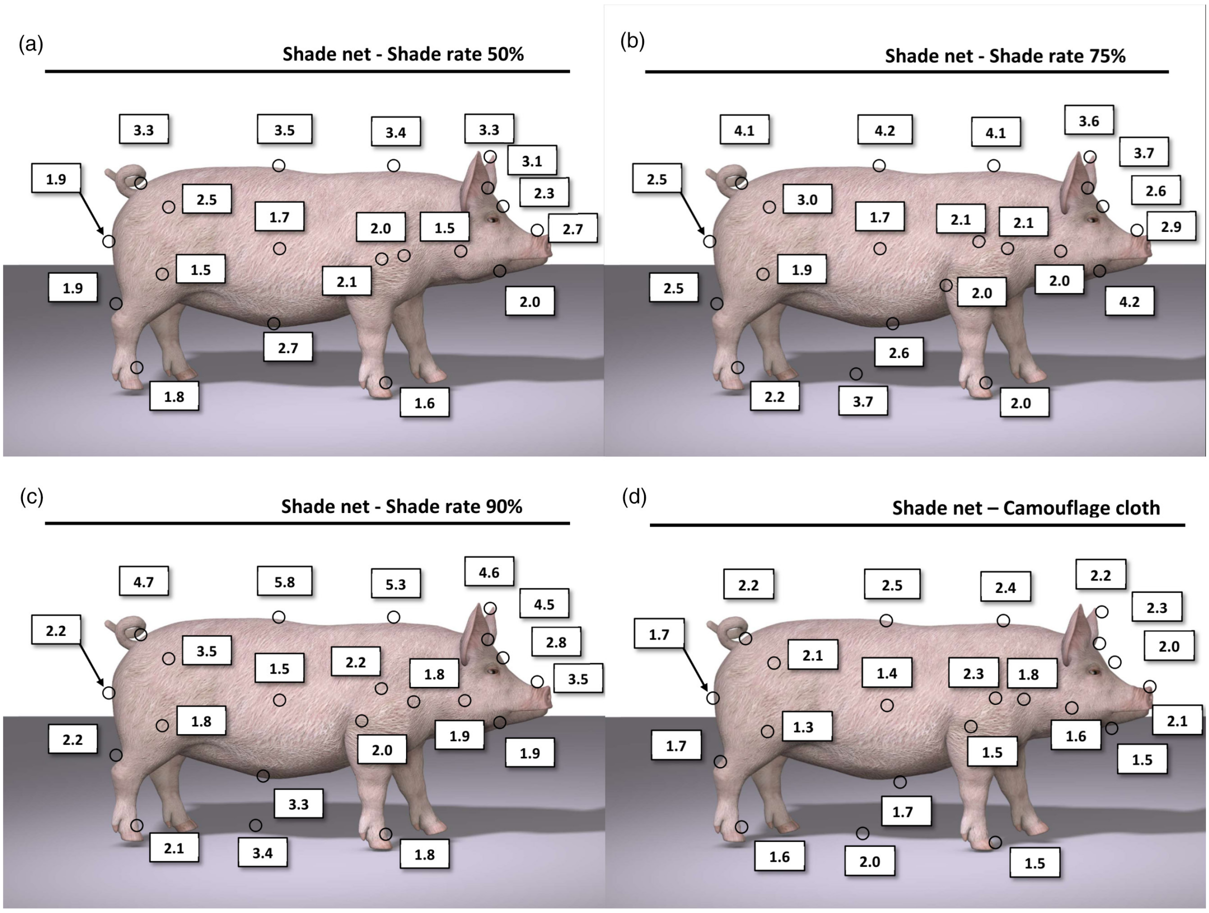

FIGURE 5 Mean sun protection factors at all measuring positions for the woven shade cloths with (a) 50% (UPF=5), (b) 75% (UPF=9) and (c) 90% (UPF=15) shade rate as well as (d) for the camouflage net (Mesh 4). UPF, ultraviolet protection factor.

of ready-to-use cloths and provide full shade for a few animals. Larger shade cloths than these would provide higher SPF.

The higher the cloth is mounted, the more diffuse the available irradiance[14,15] reaching the animal laterally. Therefore, shade cloths which are mounted lower than these in our study would gain higher SPF.

At a solar elevation of 90°, the shadow of the cloth is located directly under it. At lower solar elevations, the shadow moves out from underneath the cloth. For a cloth of 4×5m at 2m height, the shadow on the ground lies completely outside the cloth at solar elevations <20°. Even when an animal is inside this shadow, the SPF is noticeably lower, as a much smaller part of the sky is covered by the cloth. Larger size lowers the solar elevation at which this effect occurs. The lower the solar elevation is, the lower the ambient erythemal effective irradiance. At solar elevations <20°, the UVI is <2 in any case.

Application for shade structures

The higher the ERTA is, the higher the UVR exposure of a body site. This allows for identification of the most vulnerable body sites. The ERTA can be used to estimate the UVR body exposure of a pig at any time and place, by simply multiplying the ERTA with the ambient erythemal effective irradiance at a certain time and location. Using this method, one can determine when animals are at risk and define those time periods when sun protection is necessary.

The World Health Organization (WHO) recommends the application of sun protection at UVI 3 for melano-compromised skin types to avoid damage from UVR. As the skin of these rather light-skinned humans and that of light-skinned pig breeds is quite similar,[11] this threshold limit lends itself to the application of sun protection in pigs as well. The ERTAs in conjunction with ambient measurements of the erythemal effective irradiance at a certain location enable identification of those periods when UVI ≥3. Vice versa, the SPF of a sun protection tool should reduce exposure of body sites to a UVI ≤3 to avoid sun damage.

Figure 6b depicts the ambient erythemal effective irradiance measured at solar noon at the location of Vienna, Austria, with horizontal lines to indicate the risk level as defined by WHO for light-skinned people. Despite sun protection being recommended from UVI 3 onwards, the threshold limit is 2.5, as the UVI is published as an integer. It can be seen from the graph that UVI 3 can be expected in Vienna from early March until early October. Therefore, sun protection cloths should be available during this time of the year. The highest values reach up to 7.5. Meshes 1, 2 and 3 reduced UVR exposure to <3 and are therefore appropriate for the location of Vienna, or 48°N.

Mesh 1 reduces the UVR exposure below UVI 3 from an ambient UVI ≤8.8, Mesh 2 from ≤10.5 and

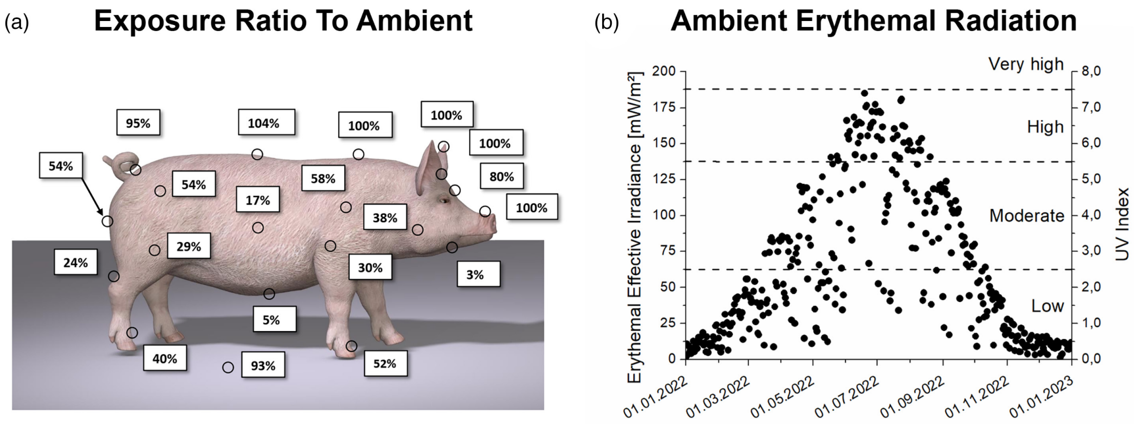

FIGURE 6 (a) Exposure ratio to ambient (ERTA) at all measuring positions. (b) Ambient erythemal effective irradiance at solar noon in Vienna (48.2° N, 16.4° E, 160 m above sea level), Austria in 2022 (horizontal lines indicate the risk levels as defined by the WHO[24] for light-skinned humans).

Mesh 3 from ≤14.5. Mesh 1 is therefore appropriate for latitudes >45°N/S, Mesh 2 for >30°N/S and Mesh 3 even for tropical regions or high alpine altitudes.[23] Knowing the annual cycle of the UVI at a certain location, allows the period for sun protection to be planned in advance; such U I monitoring is carried out at many locations around the world.[16]

For practical applications it should also be considered that the denser the woven material is, the lower the permeability for air and the effect on heat protection (heat build-up) and the higher the load from wind, which affects mounting needs and life span.

Unknown factors

The sun adaption abilities of light-skinned pigs with respect to erythema have not been investigated yet. As practitioners report erythema especially in piglets and new free-rangers (previously kept indoors),[2] it is likely that the porcine skin adapts to the sun and provides a certain SPF. In humans, skin adaption may provide a SPF of 4 rather easily, mainly by epidermal thickening.

Limitations of our study

The results of our study are restricted to the geometry of the shade cloths and are valid for solar elevations up to 65° and a standing pig with no fixed orientation with respect to the sun. SPFs of a pig lying down (different posture and no movement) or a pig with significantly different body shape (e.g. piglets) may differ. For higher solar elevations, SPFs increase because the shadow becomes deeper and the contribution of albedo decreases. For a lying pig or a piglet, the distance between the cloth and the body is larger which lowers the SPFs. For static postures, vertically orientated body parts which are directed towards the sun would get lower protection, those directed away from it would get higher protection. These differences vanish with increasing solar elevation. The experiment was performed on a substrate of pea gravel and sand, which has relatively high albedo (reflection from the ground), and other artificial materials (e.g. concrete) may have even higher albedo.[26]

CONCLUSIONS

Our experiments made evident that furless free-range pigs are at high risk for sunburn because parts of the porcine body receive erythemal effective UV irradiance that is comparable to ambient or even higher for short periods. Our experiments also demonstrated that woven shade cloths can protect pigs very well from sunburn, while camouflage nets are inappropriate. Our results enable estimation of the time of the year when shade cloth should be applied. The establishment of shade cloth ensures welfare of animals, and prevents secondary disorders and failures in breeding. However, we recommend shade structures only in addition to wallowing.

Further studies are needed to estimate the MED in other breeds as well as to estimate the self-protection abilities of porcine skin as a result of sun adaption. Basic sun protection by wallowing should also be investigated. For shade cloths, larger sizes and other heights should be investigated.

AUTHOR CONTRIBUTIONS

A. W. Schmalwieser: Conceptualization; methodology; investigation; visualization; validation; writing – original draft; supervision; resources. **L. Bigelbach:** Investigation; formal analysis; methodology; writing – original draft; data curation; validation; visualization. **S. Helletzgruber:** Methodology; validation; writing – original draft; investigation. **H. Danhel:** Writing – review and editing; methodology; data curation; software; validation; resources. **J. Heydenreich:** Writing – review and editing; supervision; resources; software; methodology.

FUNDING INFORMATION

Self-funded.

CONFLICT OF INTEREST STATEMENT

No conflicts of interest have been declared.

ORCID

A. W. Schmalwieser https://orcid.org/0000-0003-0719-391X

REFERENCES

1. Sambuco CP. Miniature swine as an animal model in photodermatology: factors influencing sunburn cell formation. Photo-Dermatology. 1985;2:144.
2. Potter R. Clinical conditions of pigs in outdoor breeding herds. In Practice. 1998;20:3–14.
3. Carr J, Wilbers A. Pet pig medicine: 2. The sick pig. In Practice. 2008;30:214–21.
4. Schmalwieser AW, Wallisch S, Diffey B. A library of action spectra for erythema and pigmentation. Photochemical & Photobiological Sciences. 2012;11:251–68.
5. Schmalwieser AW. Possibilities to estimate the personal UV radiation exposure from ambient UV radiation measurements. Photochemical & Photobiological Sciences. 2020;19:1249–61.
6. Weihs P, Schmalwieser AW, Schauberger G. UV effects on living organisms. In: Meyers RA, editor. Encyclopedia of sustainability science and technology. New York: Springer; 2018. https://doi.org/10.1007/978-1-4939-2493-6_454-3
7. European Commission Scientific Committee on Consumer Products. "Opinion on biological effects of ultraviolet radiation relevant to health with particular reference to sunbeds for cosmetic purposes". European Commission, Health and Consumer Protection Directorate-General; Report no. SCCP/0949/05 2006.
8. Reischl S, Henrich J, Schauberger G. Time course and dose-response-relationship of erythema of the pigs induced by UVB- and UVC-radiation. *13th international congress on photobiology 2000; San Francisco, CA, USA*: p. 136. 2000.
9. De Winter S, Vink AA, Roza L, Pavel S. Solar-simulated skin adaptation and its effect on subsequent UV-induced epidermal DNA damage. The Journal of Investigative Dermatology. 2001;117:678–82.
10. Meyer W, Schwarz R, Neurand K. The skin of domestic mammals as a model for the human skin, with special reference to the domestic pig. Current Problems in Dermatology. 1978;7:39–52.
11. Branski LK, Mittermayr R, Herndon DN, Norbury WB, Masters OE, Hofmann M, et al. A porcine model of full-thickness burn, excision and skin autografting. Burns. 2008;34:1119–27.
12. Jung EC, Maibach HI. Animal models for percutaneous absorption. Journal of Applied Toxicology. 2014;35:1–10.
13. Geffrotin C, Crechet F, Le Roy P, Le Chalony C, Leplat J-J, Iannuccelli N, et al. Identification of five chromosomal regions involved in predisposition to melanoma by genome-wide scan in the MeLiM swine model. International Journal of Cancer. 2004;110:39–50.
14. Kudish AI, Harari M, Evseev EG. The solar ultraviolet B radiation protection provided by shading devices with regard to its diffuse component. Photodermatology, Photoimmunology & Photomedicine. 2011;27:236–44.
15. Turnbull DJ, Parisi AV, Sabburg J. Scattered UV beneath public shade structures during winter. Photochemistry and Photobiology. 2003;78:180–3.
16. Schmalwieser AW, Gröbner J, Blumthaler M, Klotz B, De Backer H, Bolsée D, et al. UV index monitoring in europe. Photochemical & Photobiological Sciences. 2017;16:1349–70.
17. International Organization for Standardization, International Commission on Illumination. ISO/CIE 17166:2019: Erythema reference action spectrum and standard erythema dose. 2019 Available from: https://www.iso.org/standard/74167.html
18. Heydenreich J, Wulf HC. Personal electronic UVR dosimeter measurements: specific and general uncertainties. Photochemical & Photobiological Sciences. 2019;18:1461–70.
19. Webb A, Gröbner J, Blumthaler M. A practical guide to operating broadband instruments measuring erythemally weighted irradiance. Brussels: COST (European Cooperation in Science and Technology), Publications Office; 2006 Available at: https://op.europa.eu/en/publication-detail/-/publication/aa7c45a2-aba9-4e3f-a5b7-5d0d05c5fca9
20. European Standards. CEN EN 13758-1:2007 – textiles – solar UV protective properties – part 1: method of test for apparel fabrics. Brussels: European Committee for Standardization; 2007.
21. Gambichler T, Laperre J, Hoffmann K. The european standard for sun-protective clothing: EN 13758. Journal of the European Academy of Dermatology and Venereology. 2006;20:125–30.
22. Schmalwieser AW, Schauberger G, Janouch M, Núñez M, Koskela T, Berger D, et al. Global validation of a forecast model for irradiance of solar, erythemally effective ultraviolet radiation. Optical Engineering. 2002;41:3040–50.
23. Vanicek K, Frei T, Litynska Z, Schmalwieser A. UV-index for the public. Brussels: European Union; 2000.
24. WHO, WMO, UNEP, ICNIRP. Global solar UV index: a practical guide. Report no. 9241590076. 2002 Available from: https://www.who.int/publications/i/item/9241590076
25. Schmalwieser AW, Schauberger G, Janouch M, Nunez M, Koskela T, Berger D, et al. Global forecast model to predict the daily dose of the solar erythemally effective UV radiation. Photochemistry and Photobiology. 2005;81:154–62.
26. Turner J, Parisi AV. Ultraviolet radiation albedo and reflectance in review: the influence to ultraviolet exposure in occupational settings. International Journal of Environmental Research and Public Health. 2018;15:1507.
27. Mullowney PC, Hall RF. Skin diseases of swine. The Veterinary Clinics of North America. Large Animal Practice. 1984;6:107–29.
28. Rifkin RF, Dayet L, Queffelec A, Summers B, Lategan M, d'Errico F. Evaluating the photoprotective effects of ochre on human skin by in vivo SPF assessment: implications for human evolution, adaptation and dispersal. PLoS One. 2015;10:e0136090.
29. Diffey BL, Diffey JL. Sun protection with trees. The British Journal of Dermatology. 2002;147:397–9.
30. Parisi AV, Kimlin MG, Wong JCF, Wilson M. Diffuse component of solar ultraviolet radiation in tree shade. Journal of Photochemistry and Photobiology. B. 2000;54:116–20.

How to cite this article: Schmalwieser AW, Bigelbach L, Helletzgruber S, Danhel H, Heydenreich J. Ultraviolet radiation protection factors of livestock shade cloths for free-range pigs. Vet Dermatol. 2024;35:641–651. https://doi.org/10.1111/vde.13290

Zusammenfassung

Hintergrund: Bei hellhäutigen Schweinerassen wie dem Yorkshire oder der Landrasse ist ein Sonnenschutz gegen ultraviolettes Licht (UVR) von höchster Bedeutung, um einen Sonnenbrand zu verhindern.
Ziele: Feststellung der UVR Exponierung eines Schweins und die Möglichkeiten des Sonnenschutzes mittels Schatten-spendenden Stoffen mit unterschiedlicher Schattenstärke.
Tiere: Ein Plastikmodell eines Landrasse Schweins in Lebensgröße.
Materialien und Methoden: Das Modell war ausgestattet mit 20 UVR-Metern in unterschiedlichen anatomischen Positionen, welche die tatsächliche erythemwirksame Sonneneinstrahlung festhielten. Ein Drehtisch ermöglichte eine Bestrahlung aus verschiedenen Richtungen. Die Bestrahlungsstärke der Sonne wurde in direktem Sonnenlicht sowie unter drei Schichten des Schattenstoffs (50%, 75% und 90%) sowie unter einem Camouflage Netz gemessen. Die Sonnenschutzfaktoren (SPF) wurden bestimmt als das Verhältnis der Messungen zwischen schattenlos und Schatten bei gleicher Erhöhung der Sonneneinstrahlung. Die Exponierungsrate auf die Umgebung (ERTA) wurde für jede Körperstelle in Bezug auf die Umgebungsstrahlung kalkuliert. Das erlaubt eine Bestimmung ab wann das Schwein dem Risiko eines Sonnenbrands ausgesetzt und ein Sonnenschutz nötig ist.
Ergebnisse: Die kalkulierten ERTA-Werte zeigen, dass einzelne Körperstellen höhere Werte an Umgebungs-UVR erhalten. Die Messungen zeigen, dass der SPF von schattenspenden Stoffen von der Dichte der Textilien abhängt. Ausgewählte Schatten-spendende Stoffe erreichten Werte von 3,5 (Schattenrate bei 50%), 4,2 (75%) und 5,8 (90%). Der Schutz durch das Camouflage Netz war gering. Die höchsten SPF wurden an Körperstellen erzielt, wo die ERTA am höchsten war.
Schlussfolgerungen und klinische Bedeutung: Schattenspendende Stoffe können alle und vor allem empfindliche Körperstellen effektiv schützen. Die Ergebnisse unserer Studie erlauben eine Abschätzung ab wann Schweine dem Risiko eines Sonnenbrands ausgesetzt sind, und stellen quantitative metrische Daten für den Sonnenschutz zur Verfügung. Das erlaubt eine wirksame Verhinderung von UVR-verursachtem Hautschaden und sekundären Veränderungen.

摘要

背景: 对于浅色皮肤的猪品种，如约克夏猪或长白猪，保护它们免受太阳紫外线 (UVR) 的照射以避免晒伤。
目标: 确定猪的 UVR 暴露量以及不同遮光率的遮阳布的防晒能力。
动物: 长白猪的真人大小塑料模型。
材料和方法: 该模型在不同的解剖位置配备了 20 个 UVR 测量仪，用于记录红斑有效太阳辐照度。转盘可以从不同方向进行照射。在直射阳光下以及三种不同遮光率(50%、75% 和 90%)的遮阳布和迷彩网下测量太阳辐照度。防晒系数 (SPF) 确定为相同太阳高度下无遮光与有遮光测量值的比率。根据环境辐照度计算每个身体部位的环境暴露比 (ERTA)。它可以确定猪何时有晒伤风险并需要保护。
结果: 计算出的 ERTA 值表明，某些身体部位可能比环境 UVR 受到更高的照射。测量结果表明，遮阳布的 SPF 取决于纺织品的密度。选定的遮阳布达到 3.5(遮阳率为 50%)、4.2(75%)和 5.8(90%)的值。迷彩网的防护效果不佳。身体侧面的 SPF 最高，而 ERTA 最高。
结论和临床意义: 遮阳布可以有效保护身体的所有部位，尤其是脆弱部位。我们的研究结果可以估计猪何时有晒伤的风险，并提供防晒的定量指标。这可以有效预防 UVR 引起的皮肤病变和继发性疾病。

Résumé

Contexte: La protection contre le rayonnement solaire ultraviolet (UVR) est primordiale pour les races de porcs à peau claire telles que le Yorkshire ou le Landrace afin d'éviter les coups de soleil.
Objectifs: Détermination de l'exposition d'un porc aux rayons UV et des capacités de protection solaire des toiles d'ombrage avec différents taux d'ombrage.
Animaux: Modèle en plastique grandeur nature d'un porc Landrace.
Matériels et méthodes: Le modèle était équipé de 20 UVR-mètres placés à différentes positions anatomiques qui enregistraient l'irradiation solaire effective érythémale. Un plateau tournant permettait une irradiation dans différentes directions. L'irradiation solaire a été mesurée en plein soleil ainsi que sous trois toiles d'ombrage avec différents taux d'ombrage (50 %, 75 % et 90 %) et un filet de camouflage. Les facteurs de protection solaire (FPS) ont été déterminés comme le rapport entre les mesures à l'ombre et sans ombre à la même hauteur d'ensoleillement. Le rapport d'exposition à l'air ambiant (ERTA) a été calculé pour chaque site corporel par rapport à l'irradiation ambiante. Il permet de déterminer quand les porcs sont exposés au risque de coup de soleil et quand une protection est nécessaire.
Résultats: Les valeurs ERTA calculées montrent que certaines parties du corps peuvent recevoir des valeurs plus élevées que le rayonnement UV ambiant. Les mesures ont montré que le FPS des toiles d'ombrage dépend de la densité du textile. Les tissus d'ombrage sélectionnés ont atteint des valeurs de 3,5 (taux d'ombrage de 50 %), 4,2 (75 %) et 5,8 (90 %). La protection offerte par le filet de camouflage était médiocre. Le FPS le plus élevé a été obtenu sur les côtés du corps où l'ERTA était le plus élevé.
Conclusions et pertinence clinique: Les toiles d'ombrage peuvent protéger efficacement toutes les parties du corps et les parties vulnérables en particulier. Les résultats de notre étude permettent d'estimer à quel moment les

porcs risquent d'attraper un coup de soleil et fournissent des paramètres quantitatifs pour la protection solaire. Cela permet une prévention efficace des dommages cutanés causés par les UV et des troubles secondaires.

要約
背景: ヨークシャー種やランドレース種のような皮膚の薄い豚種では、日焼けを避けるために、太陽紫外線(UVR)からの保護が最も重要である。
目的: 本研究の目的は、豚のUVR曝露量および遮光率の異なる遮光布の日焼け防止能力を測定することであった。
供試動物: ランドレース豚の等身大プラスチックモデル。
材料と方法: モデルに様々な解剖学的位置に20台のUVR計を設置し、紅斑有効日射量を記録した。ターンテーブルにより、様々な方向からの照射が可能であった。日射量は、直射日光下と、遮光率の異なる3種類の遮光布(50%、75%、90%)およびカモフラージュネットの下で測定された。日射防御係数(SPF)は、同じ太陽高度における非日陰と日陰の測定値の比として求めた。周囲に対する暴露比(ERTA)は、周囲放射照度に対する各部位の暴露比を算出した。これにより、ブタが日焼けの危険にさらされ、保護が必要な時期を判断することができる。
結果: 算出されたERTA値から、体の部位によっては周囲の紫外線量よりも高い値を受ける可能性があることがわかった。測定により、遮光布のSPFは繊維の密度に依存することが示された。選択した遮光布の値は3.5(遮光率50%)、4.2(75%)、5.8(90%)であった。カモフラージュネットによる保護効果は低かった。最もSPFが高かったのは、ERTAが最も高かった体側であった。
結論と臨床的意義: 遮光布は、すべての身体部位を効果的に保護することができ、特に傷つきやすい部位を保護することができた。本研究の結果は、ブタが日焼けの危険にさらされる時期を推定することを可能にし、日焼け防止のための定量的指標を提供する。これにより、UVRによる皮膚障害や二次障害を効果的に予防することができる。

Resumo
Contexto: A proteção solar da radiação ultravioleta (UVR) é essencial para raças suínas como Yorkshire ou Landrace para evitar queimaduras solares.
Objetivos: Determinação da exposição solar a UVR de um porco e a capacidade de proteção solar de telas com diferentes taxas de sombreamento.
Animais: Um modelo plástico de porco Landrace de tamanho real.
Materiais e métodos: O modelo foi equipado com 20 medidores de UVR em várias posições anatômicas que registraram a irradiação solar efetiva eritêmica. Uma plataforma giratória permitiu a irradiação de diferentes direções. A irradiação solar foi medida sob luz solar direta, bem como sob três telas de sombra com diferentes taxas de sombra (50%, 75% e 90%) e uma rede de camuflagem. Os fatores de proteção solar (FPS) foram determinados como a proporção de medições sem sombra para sombreadas na mesma elevação solar. A taxa de exposição ao ambiente (ERTA) foi calculada para cada local do corpo em relação à irradiação ambiente. Ela permite a determinação de quando os porcos estão em risco de queimaduras solares e a proteção é necessária.
Resultados: Os valores de ERTA calculados mostram que algumas partes do corpo podem receber valores mais altos do que a UVR ambiente. As medições mostraram que o FPS das telas de sombreamento depende da densidade têxtil. As telas selecionadas atingiram valores de 3,5 (taxa de sombra de 50%), 4,2 (75%) e 5,8 (90%). A proteção pela rede de camuflagem foi ruim. O FPS mais alto foi obtido nos lados do corpo onde o ERTA foi mais alto.
Conclusões e relevância clínica: As telas de sombreamento podem proteger todos os locais do corpo de forma eficaz e os locais vulneráveis em particular. Os resultados do nosso estudo permitem uma estimativa de quando os porcos correm risco de queimaduras solares e fornecem métricas quantitativas para proteção solar. Isso permite a prevenção eficaz de danos à pele causados por UVR e distúrbios secundários.

RESUMEN
Introducción: La protección contra la radiación ultravioleta (UVR) solar es primordial en las razas de cerdos de piel clara, como Yorkshire o Landrace, para evitar las quemaduras solares.
Objetivos: Determinación de la exposición a la UVR de un cerdo y la capacidad de protección solar de las mallas de sombra con diferentes índices de sombra.
Animales: Modelo de plástico de tamaño natural de un cerdo Landrace.
Materiales y métodos: El modelo estaba equipado con 20 medidores de UVR en varias posiciones anatómicas que registraban la irradiancia solar efectiva eritematosa. Una plataforma giratoria permitía la irradiación desde diferentes direcciones. La irradiancia solar se midió bajo la luz solar directa, así como bajo tres mallas de sombra con diferentes índices de sombra (50 %, 75 % y 90 %) y una red de camuflaje. Los factores de protección solar (SPF) se determinaron como la relación entre las mediciones sin sombra y con sombra a la misma elevación solar. La relación de exposición a la radiación ambiental (ERTA) se calculó para cada sitio del cuerpo con respecto a la irradiancia ambiental. Permite determinar cuándo los cerdos corren riesgo de sufrir quemaduras solares y es necesario protegerlos.
Resultados: los valores de ERTA calculados muestran que algunas partes del cuerpo pueden recibir valores más altos que la radiación ultravioleta ambiental. Las mediciones mostraron que el SPF de las mallas de sombra depende de la densidad del tejido. Las mallas de sombra seleccionadas alcanzaron valores de 3,5 (tasa de sombra del 50 %), 4,2 (75 %) y 5,8 (90 %). La protección de la red de camuflaje fue deficiente. El SPF más alto se obtuvo en los lados del cuerpo donde la ERTA fue más alta.

Conclusiones y relevancia clínica: Las mallas de sombra pueden proteger eficazmente todas las zonas del cuerpo y, en particular, las zonas vulnerables. Los resultados de nuestro estudio permiten estimar cuándo los cerdos corren riesgo de sufrir quemaduras solares y proporcionan métricas cuantitativas para la protección solar. Esto permite una prevención eficaz del daño cutáneo causado por la radiación ultravioleta y los trastornos secundarios.