

A note on integumental (1→3)(1→6) β -D-glucan permeation, using the porcine ear skin model

Wilfried Meyer, MD,¹ Britta Schönagel, MD¹ & Lutz-Günther Fleischer, MD²

¹Anatomical Institute, School of Veterinary Medicine, Hannover, Germany

²Institute of Food Technology and Center of Biotechnology, Technical University, Berlin, Germany

Summary

Based on carbohydrate histochemical methods and the porcine ear skin model, the study demonstrates the rapid permeation of (1→3)(1→6) β -D-glucans from a cosmetic formulation into the mammalian epidermis.

Keywords: glucan, model system, porcine ear

Introduction

Bioartificial skin and artificial dermis, in particular, for wound dressing to mimic the normal human dermal skin is mainly composed of gelatin and polysaccharides such as hyaluronic acid and (1→3)(1→6) β -D-glucans.^{1,2} The latter glycoconjugate group of multibranched glucose polymers is a nonallergenic structural cell wall component of most fungi or plant storage substances, and, concerning the skin, seems of great importance with regard to the water storing and rheological properties of artificial dermis.³ It has also been reported that β -glucans, which have β (1→3) linkages in the main chain with additional β (1→6) branches, possess antimicrobial and antitumor activities by enhancing the most immune functions.⁴ In our study, β -glucans represented one part of a cosmetic formulation, and we were interested in their permeation abilities, especially into and through the epidermis, as documented by our carbohydrate histochemical approach.

The experimental basis was porcine skin that has been of interest as a model for the human integument for more than 20 years, whereby the epidermis and the dermis show several structural and functional similarities to human skin as useful for the testing of transdermal

systems, or the control of skin permeability.^{5–10} Regarding the integument of the porcine auricle, it has been demonstrated that one region of the outer side can be of value in this connection.^{11–13} Considering that pig keeping and handling is time-consuming and very expensive for routine testing, the use of porcine auricles from freshly dead animals for experimental purposes was recommended. If handled correctly, relevant scientific results can be achieved without difficulties.¹⁰ This is, additionally, cost-efficient and saves laboratory animals.

Materials and methods

The auricles of five pigs (German Landrace/German Yorkshire; females, 6 months old, weight 110–120 kg) were obtained immediately after the animals had been sacrificed in the slaughterhouse, whereby the ears had not been scalded or flamed because such a pretreatment completely destroys the epidermis. One half of the marked part of the outer region (Fig. 1) of eight auricles was carefully covered for 30, 60, 120, and 300 min each with a cosmetic formulation [Pro-Cell³ Night Care, with Active Carrier System, containing 25–30% (1→3)(1→6) β -D-glucans (MW 110,000 daltons, β -glucans of lower MW have not been found until now as far as we know) (Glucaferm®) and Na-hyaluronate (Hyaferm®); Fibona Health Products GmbH, Wiesbaden, Germany] without, and the other half with a surplus addition of 10% Glucaferm® ($n = 4$ for each time period, $n = 16$ for total formulation penetration); the latter aspect served as a

Correspondence: W. Meyer, Anatomical Institute, School of Veterinary Medicine Hannover, Bischofsholer Damm 15, 30173 Hannover, Germany, E-mail: Wilfried.Meyer@tiho-hannover.de

Accepted for publication October 30, 2005

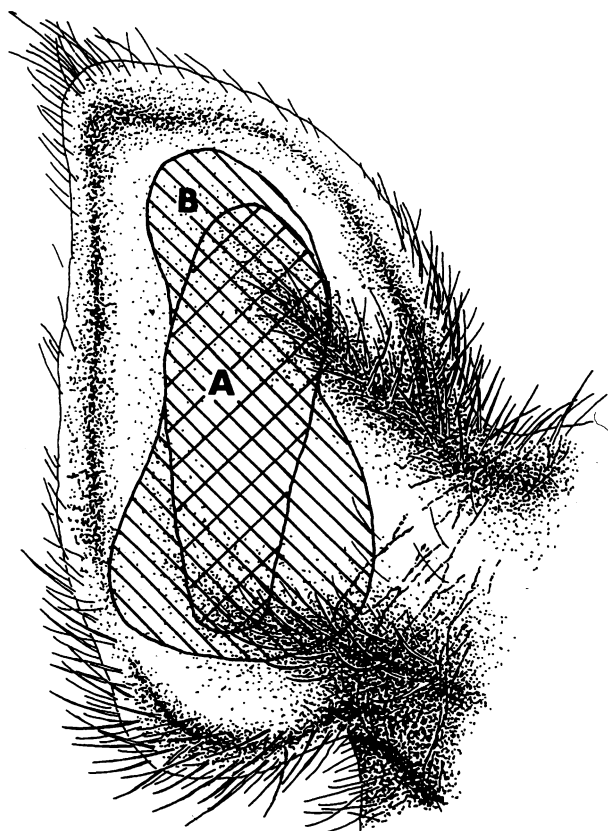


Figure 1 Region of the outer side of the porcine auricle recommended for use as a model system in human dermatological research with regard to the skin layers (epidermis and dermis), central part A: optimal, peripheral part B: suboptimal; from Meyer and Zschemisch.¹³

further control. Two auricles were used as basic control and remained uncovered. After each sampling time, skin specimens were directly immersed in Bouin's solution for 48 h, dehydrated, and routinely embedded in paraffin. As we know from long experience, Bouin's solution ensures a rapid and homogeneous fixation process without severe shrinkage artefacts, and good histochemical results.¹⁴ The use of frozen sections was avoided because it is not possible to get an intact stratum corneum with such an approach, and considering that by such an approach there would be the possibility that parts of the topical treatment could be dragged along with the knife into the skin, whereas this problem is completely avoided by paraffin embedding. Additionally, the frozen ear cartilage can impair section quality.

The following histological and carbohydrate histochemical procedures were applied to 8- μ m paraffin sections that were obtained by a cutting direction tangentially to the skin layers: (a) HE-staining for the control of tissue integrity; (b) alcian blue – periodic acid Schiff

(AB-PAS) staining (alcian blue 8GX purchased from Sigma, Schiff's reagent after Barger and DeLamater) for the specific demonstration of β -glucans and hyaluronic acid. Alcian blue (pH 2.5) stains acid glycoconjugates, and especially hyaluronic acid, whereas the PAS reaction produces a red or pink staining of neutral glycoconjugates, including glucans and glycogen, and still is the histochemical method of choice for high molecular weight carbohydrates^{14,15}; (c) Con A (EY Laboratories/Sanbio) staining for the demonstration of α -D-mannose and α -D-glucose, visualization with PO/DAB;¹⁶ (d) for the control of the carbohydrate histochemical reactions, digestion with hyaluronidase (Sigma) for acid glycoconjugates, and with α - and β -amylases (Sigma) for neutral glycoconjugates was used prior to the PAS reaction procedure.^{15,17} In this connection it has to be explained that glucans like amylose or amylopectin, rather unbranched carbohydrate polymers from bacteria and plants, are digested completely by both α - and β -amylase, whereas glycogen, a strongly branched carbohydrate polymer and the energy storage substance of animals, is completely digested by α -amylase, but resists β -amylase.

Results and discussion

When analysing the epidermis of the outer region of the porcine auricle, the different carbohydrate histochemical procedures applied (AB-PAS, Con A, untreated skin control and digestion controls, especially α - and β -amylases) clearly demonstrated that the (1→3)(1→6) β -D-glucans (Glucaferm®) of the cosmetic formulation used had already penetrated into the cells of the vital epidermis after 60–120 min. This was true of the normal formulation and the formulation with additional β -glucans. The distinct medium-red to dark-red or violet coloring of the cytoplasm of the epidermal keratinocytes (Figs 2–4; for untreated control see Fig. 5) was not based on the presence of glycogen, because this animal energy storage substance normally cannot be found, or if only in very small amounts in the vital epidermis of the hairy skin of pigs.¹⁶ Glycogen is likewise only present in small and/or varying amounts in the vital epidermis of the porcine ear skin, whereby it diminishes in cellular contents with increasing storage time of the detached porcine auricle (30–240 min; independent of storage at room temperature or cooled), so that is no longer demonstrable after 300 min of storage.¹⁸ In our preparations, however, PAS reaction staining was still very obvious after 300 min of penetration time.

Additionally, the idea of demonstrating β -glucans is supported by the results of the digestion experiments with both amylase types, i.e. any remarkable red staining was

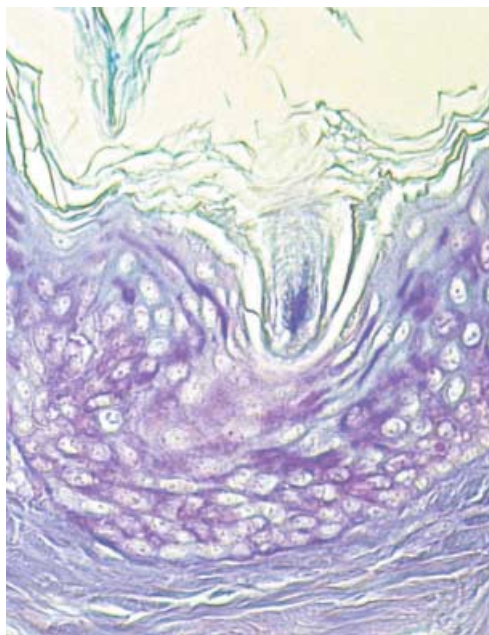


Figure 2 AB-PAS staining; distinct intracellular red tinging of keratinocytes as reaction of the vital epidermis after 300 min of incubation with the cosmetic formulation with 10% addition of Glucaferm®; thickness of stratum corneum: 18–20 μ m, thickness of vital epidermis: 45–50 μ m.

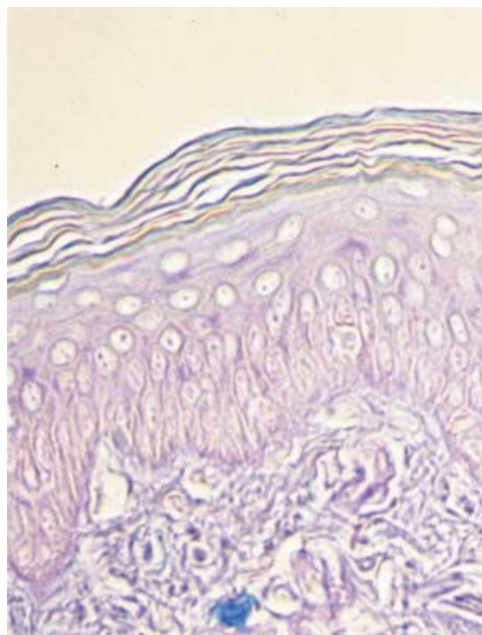


Figure 4 AB-PAS staining; negative or weak reaction staining of the vital epidermis in the untreated control; thickness of the stratum corneum: 19–21 μ m, thickness of vital epidermis: 48–51 μ m.

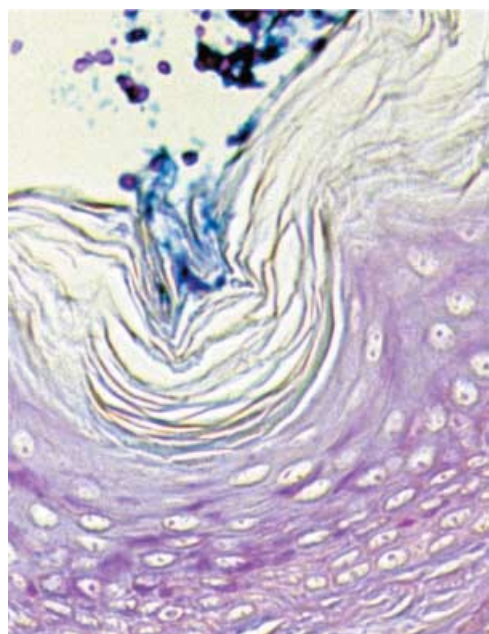


Figure 3 AB-PAS staining; distinct intracellular red tinging of keratinocytes as reaction of the vital epidermis after 300 min of incubation with the cosmetic formulation without 10% addition of Glucaferm®; remarkable is the blue staining of remnants of the cosmetic formulation on the corneal layer marking the vehicle Hyaferm®; thickness of stratum corneum: 18–22 μ m, thickness of vital epidermis: 45–52 μ m.

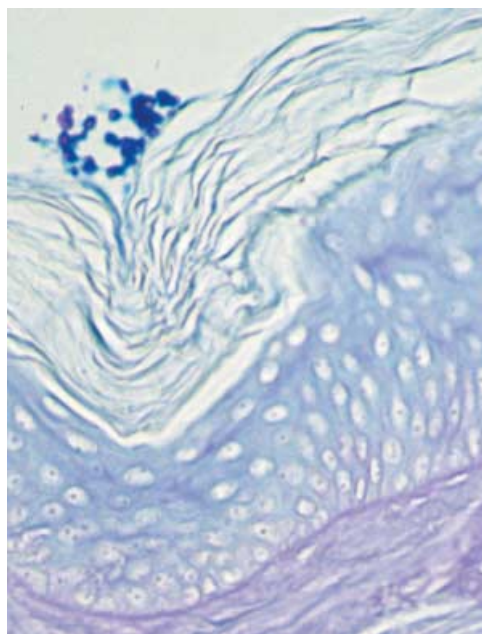


Figure 5 AB-PAS staining; positive alcian blue reaction of the vital epidermis after 120 min of treatment with the cosmetic formulation without addition of 10% addition of Glucaferm®, the latter feature has caused a more rapid development of epidermal staining by the vehicle Hyaferm®; thickness of stratum corneum: 18–20 μ m, thickness of the vital epidermis: 45–52 μ m.

not visible after digestion with β-amylase so that, if at all, only very few glycogen granules were present,¹⁷ and the rather strong reaction intensities originated from β-glucan penetration into the cells. This finding was corroborated by the negative or weak intracellular reaction for the lectin Con A, that in the hairy skin seems more prominent.¹⁶ It should also be mentioned that, even considering the fact that the skin of the freshly obtained porcine auricle remains rather intact or vital for a certain time,¹⁰ there are no enzymes present in the stratum corneum that could hydrolyse high molecular glycoconjugates,^{6,8,9,19} and thus alter the standard treatment conditions before and during substance penetration.

The hyaluronic acid (Hyaferm®) as part of the cosmetic formulation used was stained by the AB (pH 2.5; no positive staining after hyaluronidase control^{15,16,20}) and could be confirmed in its function as vehicle for the β-glucans, whereby this view is corroborated by the observation that, independent of a strong blue to violet color of remnants of the formulation lying on the stratum corneum of the porcine ear skin, after 30–60 min the vital epidermis and the dermis were distinctly tinged stronger blue (Fig. 5) than normally detectable for the different skin layers of the pig.^{16,18}

Conclusions

The specific carbohydrate histochemical methods used in the course of this study have demonstrated that (1→3)(1→6)β-D-glucans penetrated from a cosmetic formulation into the cells of the vital epidermis of porcine ear skin, obviously with the help of hyaluronic acid as vehicle. Such β-glucans may be important for the stabilization of osmotic conditions in the keratinocytes. Independent of this finding, the study has confirmed that the skin of freshly obtained detached porcine auricles can be helpful as a model for the human integument when permeation experiments are concerned.

Acknowledgements

The skillful technical assistance of Miss Marion Gähle is gratefully acknowledged.

References

- Lee SB, Jeon HW, Lee YW, et al. Bio-artificial skin composed of gelatin and (1→3),(1→6)-β-glucan. *Biomaterials* 2003; **24**: 2503–11.
- Lee SB, Jeon HW, Lee YW, et al. Artificial dermis composed of gelatin, hyaluronic acid and (1→3),(1→6)-β-glucan. *Macromol Res* 2003; **11**: 368–74.
- Colleoni-Sirghie M, Kovalenko IV, Briggs JL, Fulton B, White PJ. Rheological and molecular properties of water soluble (1,3),(1,4)-β-glucans from high-β-glucan and traditional oat lines. *Carbohydr Polymers* 2003; **52**: 439–47.
- Pang Z, Otaka K, Maoka T, et al. Structure of β-glucan oligomer from laminarin and its effect on human monocytes to inhibit the proliferation of U937 cells. *Biosci Biotechnol Biochem* 2005; **69**: 553–8.
- 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. *Curr Probl Dermatol* 1978; **7**: 39–52.
- Meyer W. *Die Haut des Schweines (The Porcine Integument)*. Hannover: Schlütersche Verlagsanstalt; 1986.
- Meyer W. Bemerkungen zur Eignung der Schweinehaut als biologisches Modell für die Haut des Menschen. *Hautarzt* 1996; **47**: 178–82.
- Archambeau JO, Bennett GW. Quantification of morphologic, cytologic, and kinetic parameters of unirradiated swine skin: a histologic model. *Radiat Res* 1984; **98**: 254–73.
- Bouclier M, Cavey D, Kail N, Hensby C. Experimental models in skin pharmacology. *Pharmacol Rev* 1992; **42**: 127–53.
- Meyer W, Zschemisch NH, Godynicki S. The porcine ear skin as a model system for the human integument: influence of storage conditions on basic features of epidermis structure and function – a histological and histochemical study. *Pol J Vet Sci* 2003; **6**: 17–28.
- Meyer W, Zschemisch NH, Neurand K. Untersuchungen zur Struktur der Ohrhaut beim Hausschwein, unter Besonderer Berücksichtigung einer Verwendung in der Humandermatologischen Forschung: 1. Makroskopische Aspekte und Haarkleid. *Berl Münch Tierärztl Wschr* 2001; **114**: 92–9.
- Meyer W, Zschemisch NH, Godynicki S, Neurand K. Untersuchungen zur Struktur der Ohrhaut beim Hausschwein, unter Besonderer Berücksichtigung einer Verwendung in der Humandermatologischen Forschung: 2. Spezielle Histologie des Integuments. *Berl Münch Tierärztl Wschr* 2001; **114**: 100–11.
- Meyer W, Zschemisch NH. Die Hautschichtendicke am Ohr des Hausschweines, mit Besonderer Berücksichtigung der Nutzung des Ohrinteguments in der Humandermatologischen Forschung. *Berl Münch Tierärztl Wschr* 2002; **115**: 401–6.
- Pearse AGE. *Histochemistry. Theoretical and Applied*. Vol. 2: *Analytical Technology*, 4th edn. Edinburgh, London, Melbourne, New York: Churchill Livingstone; 1985.
- Culling CEA. *Handbook of Histopathological and Histochemical Techniques*, 3rd edn. London, Boston: Butterworth; 1974.
- Tsukise A, Meyer W. Histochemistry of complex carbohydrates in the hairy skin of the domestic pig. *Histochem J* 1983; **15**: 845–60.

- 17 Lillie RD, Fullmer HM. *Histopathologic Technique and Practical Histochemistry*. New York, Toronto: McGraw-Hill; 1976.
- 18 Zschemisch NH. *Untersuchungen zur Verwendbarkeit der Haut des Schweineohres in der dermatologischen Forschung*. Diploma Thesis Biology, University of Hannover / School of Veterinary Medicine Hannover; 1998.
- 19 Meyer W, Neurand K. The distribution of enzymes in the skin of the domestic pig. *Lab Animals* 1976; **10**: 237–47.
- 20 Yasui T, Tsukise A, Meyer W. Localization of epidermal hyaluronan in the foot pads of the North American raccoon (*Procyon lotor*). *Arch Histol Cytol* 2004; **67**: 219–26.