THE ROLE OF FIBER MOISTURE MANAGEMENT AND SURFACE PROPERTIES IN BACTERIAL GROWTH AND ODOR DEVELOPMENT ON TEXTILES

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ABSTRACT

The aim of this research was to investigate the role of fiber hygroscopic properties in favoring or rather reducing the growth of bacterial types known to be responsible for malodor on human body surface or on the used textiles. Most of odor-generating bacteria require water activity higher than 0.90, i.e. are sensitive to moisture content. In this study, textile surfaces made of cellulosic fibers such as the wood-based fiber lyocell as well as with the non-absorbing polyester were compared. Bacterial growth under different moisture contents was measured by applying bacterial strains of defined number of bacterial colony forming units (CFU) on the textile surface and assessing the count after 24 hours. The tested bacterial types showed lower growth on cellulosic materials than on the non-absorbing polyester. Odor development on the same textile types was investigated. Test persons sweated on textiles under defined conditions, with different fiber types on left and right body sides. The fabrics were incubated for several hours and the odor intensity and hedonics were evaluated by trained personal according to the evaluation scale of VDI3882. High variation within odor degrees among individuals results in high standard deviation of the average degree. The trend is higher odor development on polyester fabrics compared to cellulosics. This trend becomes more conceivable when left-right comparison is made for each participant. Here, the synthetic side showed higher odor development, in terms of intensity as well as in terms of hedonics.

Key Words: CELLULOSE FIBERS, LYOCELL, BACTERIAL GROWTH, HYGIENE, ODOR

1. INTRODUCTION

Odor development on human skin is mostly attributed to volatile metabolites of bacteria located on skin surface having components of human sweat as a source for nutrition [1,2]. A healthy „clean“ skin harbors a complex mixture of microorganisms, counting a typical population of around 100 – 1000 microbes/cm². The population types and quantities vary depending on local skin humidity. Typical humidity-sensitive and odor-generating type is corynebacteria, which is known to be largely responsible for malodor in axilla, feet as well as in intimate areas [3, 4]. A further moisture-sensitive bacterium of interest for this study is the *Pseudomonas aeruginosa*, which forms a hygiene issue, being able to grow under low nutrition and to resist detergents and antibiotics [3, 5]. Moisture sensitivity of bacteria can be also expressed by the water activity value (Aw), meaning the water required for the bacterial type to growth [6]. Available moisture, together with nutrients give an excellent medium for microbial growth. It is already known from food technology [7, 8, 9], that binding the moisture by absorption reduces the moisture content available for the bacteria and hence its growth rate. It is also known, that moisture-absorbing fibers like cotton mostly show less odor development than non-absorbing synthetics [3, 10]. Furthermore, wood-based cellulosics such as lyocell fibers have a distinctively higher moisture sorption capacity than cotton [11, 12] and are therefore expected to bind more moisture, reducing its availability for bacteria and hence offer a less favorable milieu for bacterial growth.

This study combines in vitro assessments of bacterial growth on textiles under moderate humidity conditions and in vivo wear assessing odor formation on textiles after sportive use.

2. MATERIALS

Fabric materials were provided by Lenzing AG. Single jersey fabrics made of

1. 100% lyocell (CLY),
2. 40/60 lyocell/polyester (CLY/PES, 40/60),
3. 20/80 lyocell/polyester (CLY/PES 20/80) and
4. 100% polyester (PES)

were knitted based on NM50/1 ring yarns and with the fabric weight of ~ 120 g/m². All the fabrics have been washed in a household machine at 40°C using an ECE detergent (EN ISO 6330) and line-dried. For bacterial growth assessments the fabrics additionally were autoclaved.

Bacteria types (*Corynebacterium jeikeium*, ATCC43734 and *Pseudomonas aeruginosa*, ATCC 15442) were provided by Hohenstein. Inoculum: 1:20 TS-Bouillon / 0.85% NaCl + 0.05% Tween 80.

Elastane-free commercial polyester and cotton shirts with a fabric weight of approx. 120 g/m² were ordered from Trigema resp. Geldan. Shirts were washed with in a household machine at 40°C using a disinfection detergent with no fragrance, tumbler-dried, and cut into two halves. CLY and PES halves were sewn as shown in figure 1.

3. EXPERIMENTAL

3.1. Assessment of bacterial growth

Of each bacterial type 4 specimen of each fabric qualities were loaded with 100 µL of the suspension (approx. 10^5 colony-forming unit (CFU)/specimen).
The zero value is determined by elution of the bacteria immediately after loading. One of the specimens is washed out by 10 mL of a 0.85% NaCl + 0.05% Tween 80 solution and the number of CFU is determined after cultivation on appropriate nutrition medium.
All other specimens are left to dry in room temperature. Afterwards, each of the sample is wetted with the 85% NaCl solution to reach 15% resp. 30% moisture content. The specimens were incubated in closed tubes at 36°C. After 18 hours they were eluted and the CFU number determined as mentioned above.

3.2 Assessment of odor development

Eight athletic persons, who regularly participate in spinning training, wore the shirts with the lyocell and polyester halves during 1.5 hours of intensive spinning program. The participants were instructed not to use deodorant, take nutrition of conspicuous smell on the trial day. After the training unit, the sweated shirts were collected, cut again in two halves, packed in sealed bags as shown in figure 1 and sent for odor evaluation to Hohenstein (Germany). The water content (g water/g textile) of the sweated shirts was measured by weight difference after line drying.

Figure 1: Shirt design (left), spinning trial (middle) and sample collection (right) for the assessment of odor development

The incubation time between sweating and odor evaluation was 36 hours. The sample bags were filled with neutral air 1 hour before odor test and incubated at 37°C for 1 hour. Olfactometric assessment of sweat odor intensity was run by 4 expert panelists, trained according to international standard by Maxeiner et al. [13], using an olfactometric sampling unit. Additionally, odor quality (hedonic pleasantness) was assessed on six samples.
Both parameter were assessed according to the evaluation scale of VDI 3882. For odor intensity it states 0 for none-perceivable to 6 for very strong. For hedonics a scale from -4 to +4 is used, indicating degrees of “less pleasant” resp. “more pleasant”.

4. RESULTS AND DISCUSSION

4.1. Bacterial growth

Bacterial growth on the fabric samples is shown in figure 2. The malodor-generating *Corynebacterium jeikeium* showed at all moisture contents lower growth on lyocell and lyocell-rich fabric than on polyester and polyester-rich fabric.
At low and moderate moisture contents (room moisture, 15% moisture content) *Pseudomonas aeruginosa* showed significantly lower growth on the lyocell fabric than on the polyester-blended and the 100% polyester fabric. At enhanced moisture content (30%) or when the amount of absorbing fiber in the fabric is reduced (polyester blends), enough moisture seems to be available for the bacterium to grow.

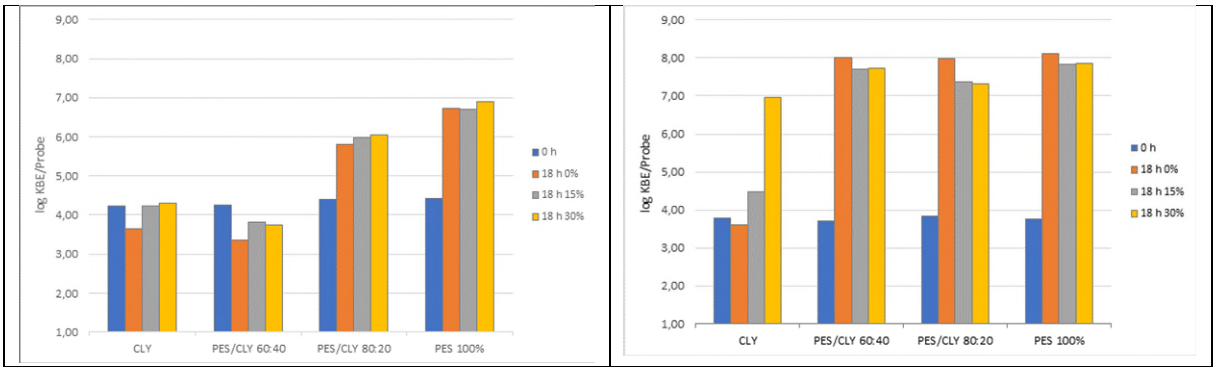

Figure 2: growth of *Corynebacterium jeikeium* (left) and *Pseudomonas aeruginosa* (right) on lyocell and polyester and their intimate blends

4.2. Assessment of odor development

The water content of the sweated shirts is shown in figure 3. Participants showed high variation in sweating rate and consequently in the moisture amount available in the fabric.

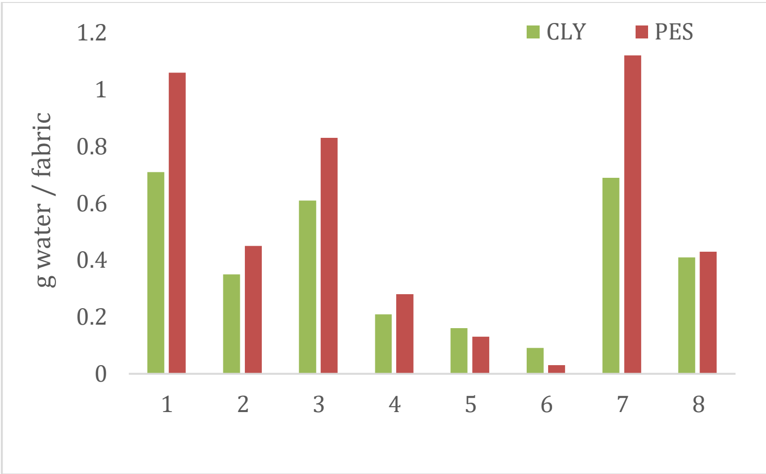

Figure 3: water content [g/g] of the sweated shirts

The average results of odor intensity and hedonic evaluations are shown in figure 4. As individuals vary in sweat quantity (moisture content) as well as in body odor, the "average" results show high variation. The difference is observed in the tendency, showing by trend stronger and more unpleasant odor on the polyester fabric.

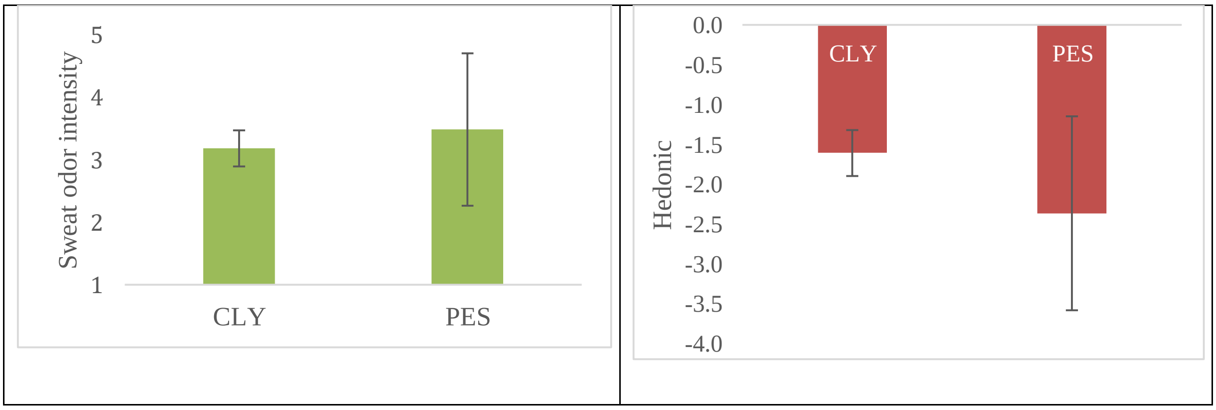

Figure 4: Average odor intensity and hedonics for sweated lyocell and polyester shirts

A better resolution was obtained when both shirt halves are compared for each participant as shown in figure 5. The evident difference between both shirt sides emphasizes the role of textile fiber material in odor development. No connection between the odor intensity and the sweat quantity produced by the participants was found. Participants 2 and 8, who showed different results than the rest of the group in term of odor intensity didn't conspicuously differ from other participants in sweating behavior. On the other hand, it can be stated that persons who produced high sweat amounts (Participants 1, 3 and 7) showed also higher differences in odor intensity or unpleasantness values on both shirt sides.

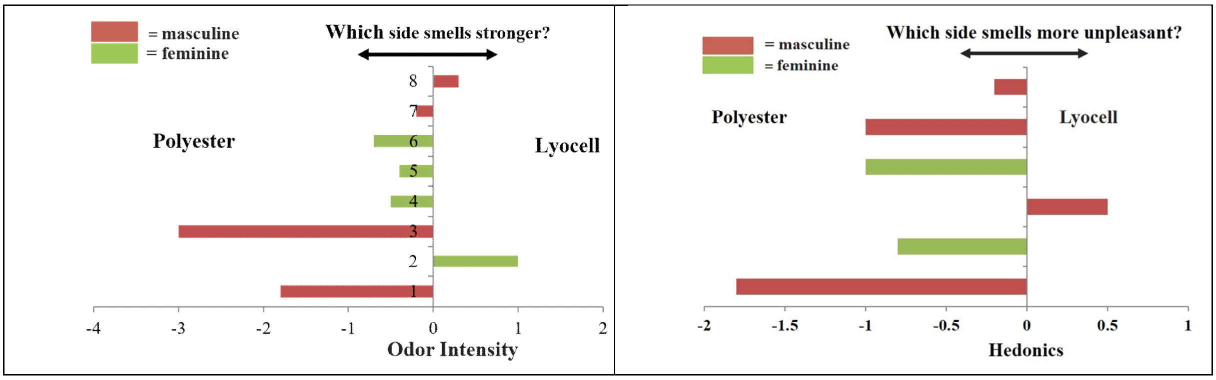

Figure 5: Odor intensity (left) and hedonics (right) difference between both shirt halves for each participant

The odor development was tested under extreme sport conditions, where maximal amounts of human sweat were produced by the participants and the fabrics were almost at saturation level or at least significantly wet. These conditions usually offer enough moisture for all bacterial types to grow. Nevertheless, the difference between the absorbing lyocell and the non-absorbing polyester was still perceivable.
For 6 of 8 participants, the smell on the polyester side was evaluated as "stronger". From 6 on hedonics tested fabrics, 5 fabrics showed significantly more unpleasant odor on the polyester side.

5. CONCLUSION

The study confirms by using a different method earlier findings of Teufel [3] and McQueen [1] regarding the role of the moisture absorption of the textile in providing a favorable or non-favorable medium for bacterial growth. Further work is needed to test other bacterial types under the same growth conditions. A further aspect to be investigated is the adhesion of the different bacterial types to the textile surfaces. One practical result was demonstrated in the odor assessment, where on the majority of the sweated shirts a stronger and more unpleasant odor was observed for polyester, compared with lyocell. Changing the working (and sweating) conditions could lead to a different odor quality as well as different sweating behavior. Testing the fabric set under different working conditions would show the influence of moisture absorption in reality-near conditions and could help in finding optimal fiber blends for the different applications.

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