NC STATE UNIVERSITY
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JTATM Journal of Textile and Apparel, Technology and Management

Volume 8, Issue 3, Winter2013

A Preliminary Study on the Collection and Detection of Axillary Odor within Textiles

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ABSTRACT

A preliminary study to guide development of a new method to generate and detect axillary odor in vitro was based on the incubation of 'fresh' sweat solution on fabrics and compared to the in vivo wear trial method. Samples of cotton and polyester knit fabrics, untreated and antimicrobial-treated with polyhexamethylene biguanide (PHMB) or zinc pyrithione (ZP), were sewn into the axillary area of T-shirts worn during vigorous exercise or incubated with composite sweat solutions from exercise participants. A trained sensory panel used a 150 mm line scale to measure odor intensity of fabric samples following wear or incubation with sweat solution. Compared with the in vivo wear trial method, the in vitro method allowed a comparison of a greater number of fabrics in a single session and limited intrapersonal and interpersonal variability in human participant odor intensity. Despite some inconsistencies between the methods, the in vitro method has potential applications for screening and evaluating textiles in a controlled laboratory environment. The addition of a trained panel sensory evaluation of odor intensity to the assessment of antimicrobial efficacy was found to be beneficial for the evaluation of antimicrobial treatments designed to reduce malodor within clothing.

Keywords: fabrics, in vitro, in vivo, sensory measurement, antimicrobial, odor intensity

INTRODUCTION

Body odors emanating from a person can be an embarrassing problem in many cultures where natural body odors may be viewed as unpleasant and even considered unhygienic. The axillary region, in particular, is highly odorous due to a high density of sweat glands, as well as bacteria located in this site (Kloos & Musselwhite, 1975; Sato, Kang, Saga, & Sato, 1989). It has long been demonstrated that sterile axillary sweat is initially odorless and much of the malodor arising from this region results from microbial degradation, especially from Gram-positive aerobic bacteria, such as the *Corynebacterium* species (Leyden et al., 1981; Rennie, Gower, Holland, Mallet, & Watkins, 1990; Taylor et al., 2003); although micrococci and some species of staphylococci have also been implicated in odor (Taylor et al., 2003; Troccaz,

Starkenmann, Niclass, van de Waal, & Clark, 2004). Bacteria grow rapidly in the warm, moist, nutrient-rich axilla, which further facilitates odor generation.

Although malodor is first generated and released from the human body, clothing can play a further role in retaining or emanating odor because bodily secretions and skin bacteria may be easily transferred from the body to the adjacent garment. The absorbed sweat retained by textiles may provide further nutrients for bacterial growth (Teufel, Schuster, Merschak, Bechtold, & Redl, 2008) allowing bacteria and odor to persist for many days after removal of the garment from the body (McQueen, Laing, Brooks, & Niven, 2007a). For some textiles, such as polyester, washing may not effectively reduce odor, as researchers have observed that the amounts of odorants remaining in polyester fabrics after 24 hours with or without washing were not significantly different (Munk, Johansen, Stahnke, & Adler-Nissen, 2001).

In the pursuit of healthy lifestyles, participation in sports and other types of exercise has become a part of many people's everyday life. Odor-control textiles are now in high demand in the exercise apparel market (Gao & Cranston, 2008). Currently, there are no standard test methods for estimating the odor reduction efficacy of anti-odor textiles. Typically, methods based on assessing reduction of bacteria have been used (e.g., AATCC 100, AATCC 147, ISO 20743). This assumes that if bacterial populations are reduced so too is odor (e.g., Payne & Kudner, 1996; Scentlok, 2011). Methods used to assess antimicrobial activity of textiles are generally not applicable for odor control assessment within anti-odor textiles, as bacteria used for this purpose are not typically those which produce odor (McQueen, Keelan, & Kannayiram, 2010). Furthermore, evidence of antimicrobial activity *in vitro* does not always correspond to odor reduction *in vivo* (McQueen, Keelan, Xu, & Mah, 2013) and cannot be evaluated in anti-odor textiles that control odor through absorption of odorous molecules (e.g., activated carbon, cyclodextrins). Due to the complexity of human body odor, both the odorous molecules and the bacteria that generate odor must be considered when evaluating odor-control technologies in textiles.

Chemical analysis of odorous compounds through instruments such as gas chromatography-mass spectrometry can be used to quantitatively analyze the chemical structure and concentration of specific odorants (Troccaz et al., 2004; Zeng et al., 1991). These chemical analyses are complicated and expensive, and instrument sensitivity may not be sufficient to detect odors with particularly low human olfactory thresholds. Conversely volatiles may be identified that do not contribute to axillary malodor.

Sensory measurement is an important tool in the analysis of odorants and is frequently used in product development and quality evaluation in the food industry where consumer satisfaction is critical (Stone & Sidel, 2004). Although visual and tactile sensory measurement is commonly used in textile research, odor assessment on fabrics is an emerging technique (e.g., McQueen et al., 2007a; McQueen, Laing, Wilson, Niven, & Delahunty, 2007b; Munk, Munch, Stahnke, Adler-Nissen, & Schieberle, 2000). A sensory panel can assess malodor in its entirety and compare odor varying in quality, while instrumental analyses result in complex comparisons of individual odorants. In previous studies to evaluate odor on textiles, odor was collected *in vivo* via a wear trial ranging in duration from several hours to several days (McQueen et al., 2007a; Munk et al., 2000). The wear trial method is time consuming as only two fabrics can be compared each time for the one individual acting as the 'odor provider', making the wear trial method impractical for assessing anti-odor treatments on textiles. Therefore, rapid laboratory based *in vitro* test methods are needed to efficiently evaluate odor retention and release from textiles.

The purpose of this preliminary study was to develop an *in vitro* method to collect axillary odor on fabrics and compare this method to the traditional wear trial method. Test fabrics were composed of polyester and cotton, as these fabrics have been shown to have detectable differences in the amount of odor they retain and release following wear next to the axillae (McQueen et al., 2007a; Munk et al., 2000). Both fabrics were treated with selected antimicrobials in order to evaluate the potential effects of odor reduction due to antimicrobial treatments.

Materials and Methods

Materials

Experimental fabrics and selected properties are provided in Table 1. Fabrics used in this study were cotton (Style #460 bleached cotton interlock knit) and polyester (Style #720 texturized Dacron 56T double knit jersey) knit fabrics, which were sourced from Testfabrics Inc (West Pittston, PA, USA). Two antimicrobial finishes polyhexamethylene biguanide (PHMB) and zinc pyrithione (ZP) were added on the test fabrics through padding and drying processes.

Fabric samples were padded in a freshly prepared pad bath containing antimicrobials of 0.3% PHMB active or 0.12% ZP active. The pickup of the padded fabrics were 83% and 86% for cotton fabric treated with PHMB and ZP respectively, and 128% and 121% for polyester fabrics respectively, at a speed of 1 m/min and a pressure of 100 kPa (1 bar). After padding, the fabrics were dried at 130°C for 2 min in a stentor oven.

Table 1. Fabric types and treatment

Fabric code	Fiber content	Antimicrobial treatment	Fabric structure	*S. aureus* reduction[a] (%)	Mass/unit area[b] (g/m^2)	Thickness[c] (mm)
C0	cotton	none	interlock	-	203.7	0.38
CP	cotton	PHMB	interlock	>99.9	218.2	0.49
CZ	cotton	ZP	interlock	>99.9	217.0	0.48
P0	polyester	none	double jersey	-	174.3	0.38
PP	polyester	PHMB	double jersey	>99.9	166.7	0.38
PZ	polyester	ZP	double jersey	>99.9	168.3	0.37

[a]ISO 20743: 2000; [b]CGSB4.2 No. 5.1-M90: 2004; [c]CAN/CGSB-4.2 No.37-2002.

Axillary odor collection

Ethical approval was obtained from the Human Research Ethics Board at the University of Alberta. Three participants (two males and one female, age range 25-40 years) were screened prior to selection to ensure they generated sufficiently high post-exercise odor intensity. For screening, participants wore T-shirts which had polyester fabric swatches sewn into the underarm for one hour of exercise. Following wear, the fabric swatches were removed from the T-shirts and assessed for odor intensity and to ensure there was no right-left arm odor imbalance (American Society for Testing and Materials, 2009). The same three participants were used in both the *in vivo* and *in vitro* parts of the study. They were asked to avoid the use of any perfumed or antimicrobial products (e.g., antiperspirants, deodorants) and consumption of strong tasting/spicy food (i.e., garlic) for the duration of the study. As this was a preliminary study to guide development of a new test method, the number of participants used in the study was

small.

Wear trial (in vivo) study

The *in vivo* odor collection was carried out through a wear trial method following a similar method as conducted by McQueen et al. (2007a; 2007b). Fabric specimens (180 mm x180 mm) were cut from the treated and untreated cotton and polyester fabrics and were hand stitched to the underarm regions of the inside of 100% cotton knitted T-shirts. T-shirts were supplied and pre-laundered by the researchers using a perfume-free detergent (Tide® Free & Gentle, Proctor & Gamble). Participants were asked to wear the T-shirt for 8 hours of their normal daily routine as well as during a 30 min exercise session of their own choosing (e.g., a brisk walk on the treadmill) to generate sweat. The five combinations of matched fabric pairs used in the study were: 1) untreated cotton (C0) matched with untreated polyester (P0); 2) C0 matched with cotton treated with PHMB (CP); 3) C0 matched with cotton treated with ZP (CZ); 4) P0 matched with polyester fabrics treated with PHMB (PP); and 5) P0 matched with polyester treated with ZP (PZ). One fabric of the matched pairs was stitched into the left underarm region of the T-shirt and the matched pair in the right side. These were then swapped to the opposite sides of the body when the same matched pair fabric combinations were worn again for the duplicate trial. Each participant wore all five fabric-pair combinations in duplicate.

In total each participant carried out ten 8-hour day wear trials. To reduce the likelihood of an antimicrobial treatment influencing skin microflora, participants waited at least one day after wearing an antimicrobial treated fabric in an axilla before again wearing test fabrics.

Following wear, fabric swatches from each underarm were removed from the T-shirts and prepared for sensory and microbiological analysis. The method of cutting and assigning fabric specimens to each group was similar to the procedure described in previous research (McQueen et al., 2007a). In the current study, however, fabric swatches were divided into a 4x4 grid and cut into 16 small fabric specimens (30 mm x 30 mm) and then pooled into two groups of 8 specimens. Eight specimens from either group were randomly selected for sensory measurement to assess odor intensity followed by microbiological analysis to quantify bacterial populations.

Laboratory (in vitro) study

For the second odor collection method, test fabric samples were incubated with a fresh axillary sweat solution following a process similar to that for collecting axillary microflora (Jackman & Noble, 1983; Taylor et al., 2003). Participants were asked to undergo at least 30 min of physical activity of the participants own choosing to facilitate sweating in the axillary region. This exercise session occurred toward the end of the day. Following this 30 min period of activity participants then lay down on a table with their hands behind their heads to ensure the axilla was in a flat position for scrubbing the axilla. A Teflon cylinder (4.9 cm^2) was then held firmly against the center area of the axilla, and 2 mL of phosphate buffer solution (PBS) with 0.05% Tween 80 were pipetted to the cylinder. The skin was then scrubbed with a skin cell scraper for 1 min and the solution was removed into a 40 mL sterile glass beaker. The cylinder was shifted to cover an adjacent area of the underarm which had not previously been scrubbed so that the procedure was repeated twice for each axilla. The sweat/PBS solution for the two underarms was pooled (to make 8 mL solution in total). Following collection, 1.2 mL of solution were pipetted onto the prepared fabrics (four layers of 30 mm x 30 mm specimens). The inoculated fabric specimens were then incubated at 37°C for three days prior to sensory measurement and microbiological analysis.

Sensory measurement

The same sensory measurement procedure was used to assess odor intensity of samples collected via the *in vivo* and the *in vitro* method. Each participant's specimens of the same fabric type were placed in separate

sterile Petri dishes and left overnight at 20±2°C and 65±5% R.H. for at least 8 h, and then transferred to sterile 60 mL amber glass bottles with screw lids before sensory measurement. Control test samples (i.e., non-worn cotton and non-worn polyester for the *in vivo* method and cotton and polyester inoculated with PBS solution only for *in vitro* method) were also placed into test bottles.

The trained sensory panel was comprised of 11 people (9 females and 2 males – all non-smokers) aged from 18-39 years. They were selected from an initial pool of 28 people based on their olfactory sensitivity and acuity. Screening tests involved a two-alternative forced choice threshold test using isovaleric acid and a triangle test using androstenone (American Society for Testing and Materials, 2009). Training sessions were carried out over two days to familiarize panelists with the reference/test samples, olfactory assessment techniques, and use of the line scale to record odor intensity. To verify panelist reliability after training, test results from each assessor on two different days were evaluated for their consistency over time. Assessors were asked not to wear perfumed substances, consume spicy food or alcohol or carry out strong physical activities at least on the test day.

Sensory tests were conducted in individual sensory testing booths free from environmental odors and distractions (International Organization for Standardization, 2007). Fabric samples in glass bottles were each assigned a random three digit number and placed in a water bath at 37±2°C. Seven samples as a group (control sample included and always presented as the first) were presented to each assessor with a different order following the 6-treatment design (MacFie, Bratchell, Greenhoff, & Vallis, 1989) to avoid order effects. Intensity of odor was rated on a 150 mm line scale with "extremely low" odor intensity on the left of the scale and "extremely high" on the right. The line scale was also differentiated into thirds to facilitate placement of low, medium and high odor intensity samples, a technique generated during the training session.

Microbiological analysis

After each sensory assessment, fabric specimens were transferred to 50 mL Corning tubes for microbiological analysis. Bacterial populations were extracted by vortexing fabric specimens with sterile glass beads in 20 mL of PBS amended with 0.05% Tween 80 for 1 minute. Ten-fold dilutions were made in PBS-Tween 80 solution and 20 µL of each dilution were plated in triplicate onto the culture media of a non-selective blood agar media (Taylor et al., 2003) and then incubated at 37°C for 48 h. Viable bacteria were counted and expresses in colony forming units per milliliter (CFU/mL). The detection limit was 17 CFU/mL.

Statistical analysis

Panel mean scores of odor intensity were calculated and CFU/mL was $\log_{10}$ transformed before data analysis. For the *in vivo* method paired t-tests were carried out for the data of each matched pair collected. For the *in vitro* method a multiple analysis of variance was performed on the data with factors of fiber, treatment, and participant. Tukey's HSD tests were used as the post-hoc difference test. All analyses were performed using IBM SPSS Statistics version 19 (SPSS Inc, 2010) with a significance level of 0.05.

Results and discussion

Findings from in vivo and in vitro methods of odor collection

Wear trial method (in vivo)

Overall odor intensity ratings for matched fabric pairs following wear next to the axillae are shown in Figure 1. Odor intensity was slightly lower on antimicrobial-treated fabrics compared to their matched untreated control fabrics ($p>0.05$). Untreated cotton fabrics were also slightly lower in odor intensity compared to the matched untreated polyester fabrics ($p>0.05$). Results for each replicate for each participant and for all matched pairs are shown in Figure 2(a-e).

Although all wear trial participants were screened prior to the study for sufficient odor intensity, differences in odor intensity were still strongly linked to the individual, with Participant 1 having the most intense odor and Participant 3 having the least.

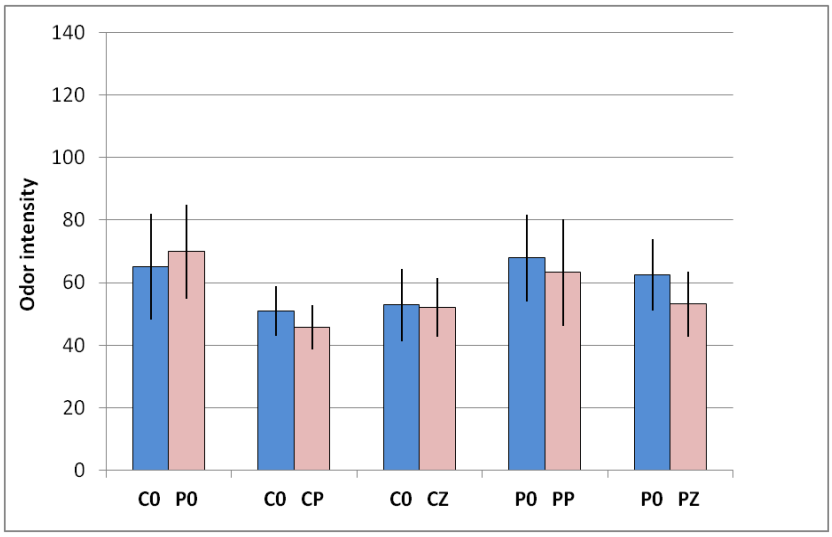
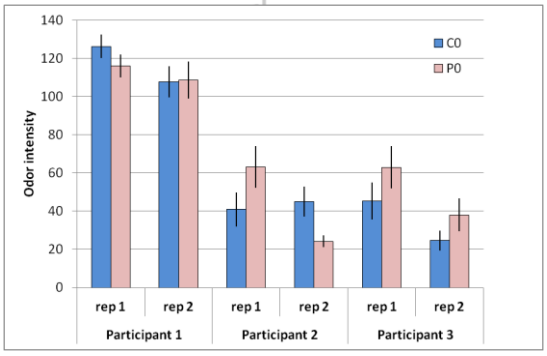


Figure 1. Overall mean of odor intensity (mean ± s.e.m) for the matched pairs in vivo (odor intensity was rated on a 0-150 mm line scale)

a)



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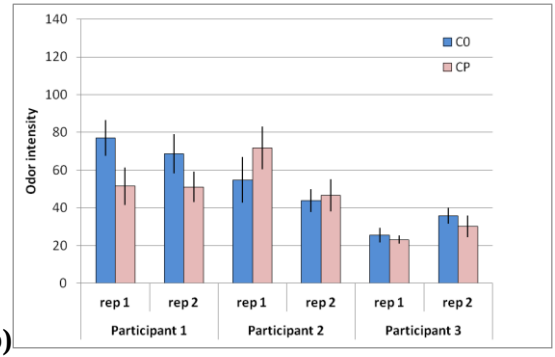

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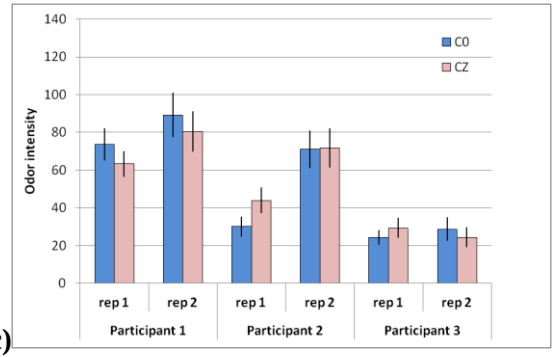
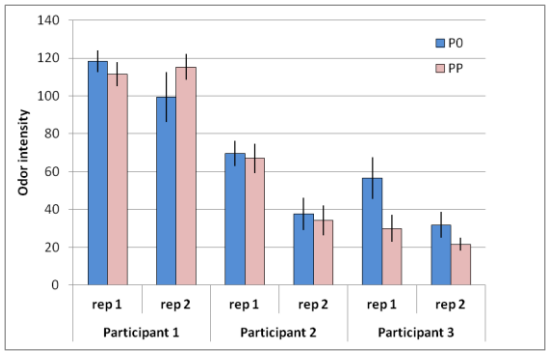
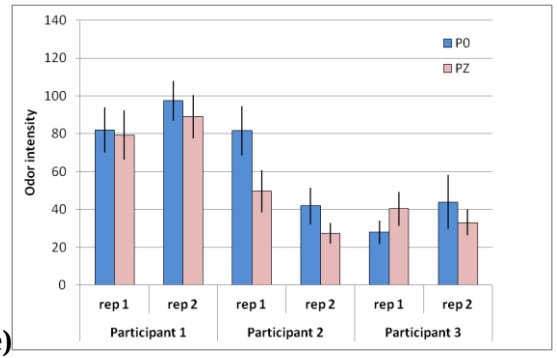




d)



e)

Figure 2. Mean (± s.e.m) ratings of odor intensity on a 0-150mm line scale of each matched pair of fabrics for each participant a) C0/P0; b) C0/CP; c)C0/CZ; d) P0/PP; e)P0/PZ

Overall bacterial counts (log transformed) of fabrics following wear next to the axillary region are shown in Figure 3. Bacterial counts obtained for each replicate for each participant are shown in Figure 4(a-e). The antimicrobial treatment was effective in reducing bacterial populations, as all treated fabrics had significantly lower bacterial counts than the matched control fabrics. PHMB was particularly effective in reducing bacterial counts (cotton: t_5=7.44, p≤0.001; polyester: t_5=11.97, p≤0.001), with counts for most trials being well below the limit of detection (i.e., <17 CFU/mL) (Figures 4(b) and 4(d)). The fabrics treated with ZP also showed significant reductions (cotton: t_5=5.33, p≤0.01; polyester: t_5=4.96, p≤0.01); however, more typically only a 1-1.5 log reduction was observed and bacterial populations were never below the limit of detection (Figures 4(c) and 4(e)).

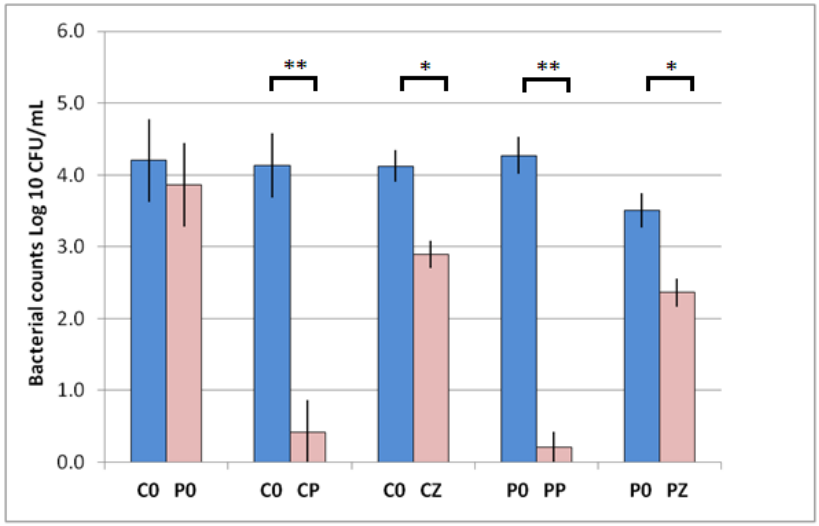


Figure 3. Overall bacterial counts (Log_{10} transformed) for each matched pair of fabrics in vivo (*p<0.01; ** p<0.001)

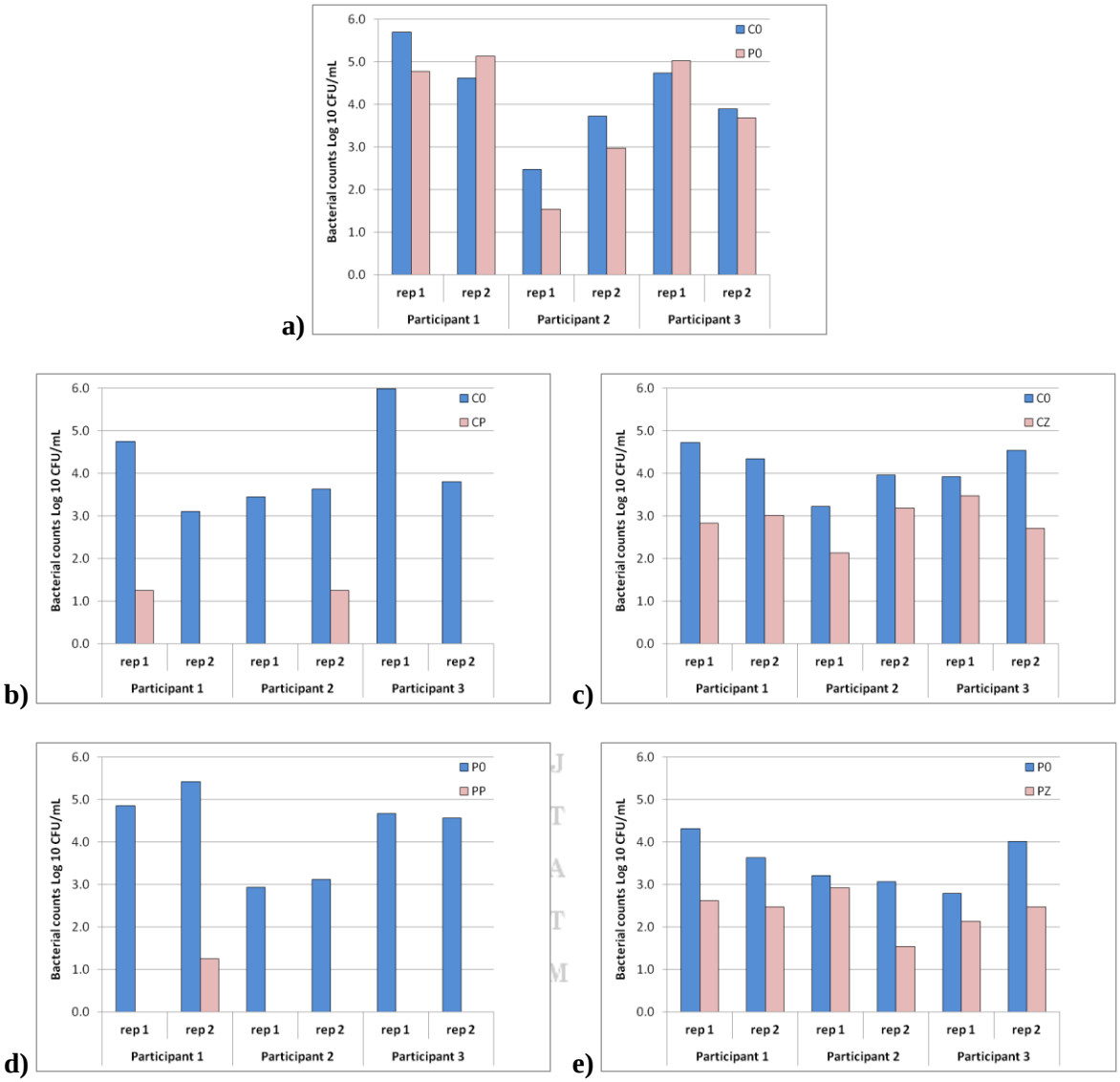


Figure 4. Bacterial counts (Log_{10} transformed) of each matched pair of fabrics for each participant a) C0/P0; b) C0/CP; c)C0/CZ; d) P0/PP; e)P0/PZ

Laboratory-based method (in vitro)

Mean odor intensity values for each fabric, treatment type and participant are shown in Figure 5. Differences in odor intensity were strongly influenced by fiber type ($F_{1,18}$=132.61, p≤0.001);cotton fabrics were perceived to have lower odor intensity than polyester fabrics. Differences in odor intensity ($F_{2,18}$=11.91, p≤0.001) were also observed for antimicrobial treatment, as fabrics treated with PHMB were perceived to be lower in odor than the untreated and ZP-treated fabrics. A difference was also found in odor intensity due to participant who provided the sweat for the *in vitro* study ($F_{2,18}$=3.88, p≤0.05), but to a much lesser extent than their effect in the *in vivo* study.

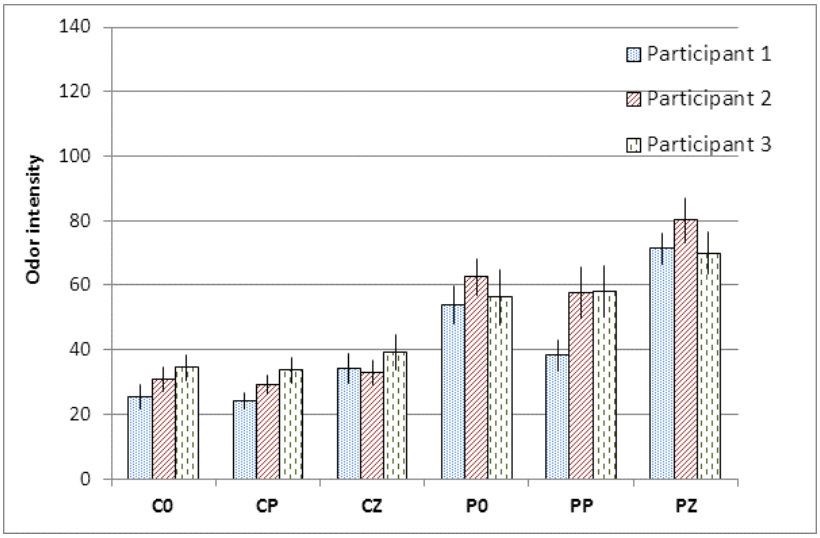


Figure 5. Mean (± s.e.m) odor intensity of fabric in vitro rated on a 0-150 mm line scale

Overall bacterial counts from fabrics incubated with sweat solution are shown in Figure 6. Although fabrics made from cotton had higher bacterial counts compared with polyester ($F_{1,18}$=7.37, p≤0.05), the antimicrobial treatment had the greatest impact on bacterial counts ($F_{2,18}$=146.06, p≤0.001) as both the PHMB and ZP treatments were effective in reducing bacterial populations significantly. Bacterial counts were not different among participants.

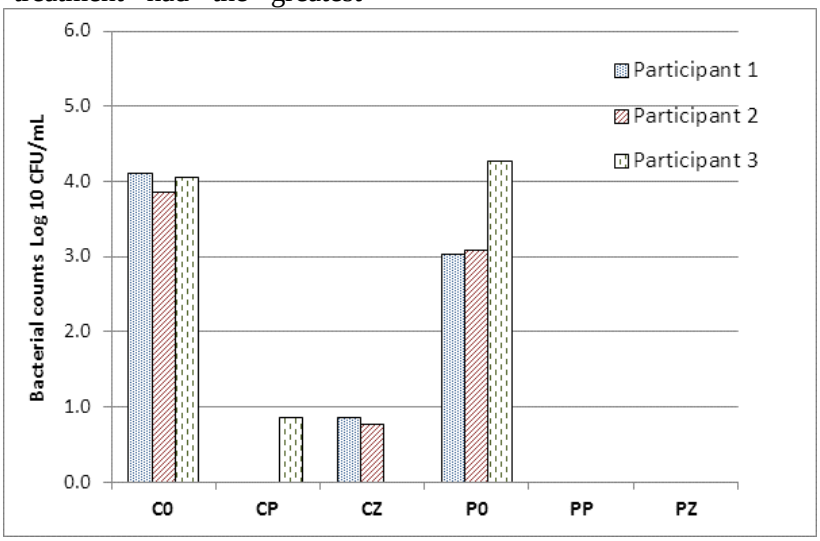


Figure 6. Overall bacterial counts (Log_{10} transformed) in vitro (Note: where no columns are present (e.g., PP & PZ) bacterial counts were below the limit of detection of 17 CFU/mL)

Comparison of the in vivo and in vitro odor collection methods

Differences in odor intensity due to fiber content found in the *in vitro* trial were unexpectedly not detected in the *in vivo* trial. In other research, odor intensity from cotton has been perceived to be much lower than in polyester fabrics after wear next to the axillary region (McQueen et al., 2007a; Munk et al., 2001), with one exception. In one study cotton fabrics worn against the axillae that were laundered then dried slowly

were rated by a sensory panel as more intensely odorous than polyester (Munk et al., 2000). The authors attributed this to one particularly pungent 'fecal' odorant (skatole) present in cotton, but they also found that polyester fabrics had a greater number of high odor impact volatiles overall (Munk et al., 2000).

Despite the lack of apparent differences between cotton and polyester in the *in vivo* study, cotton fabrics were perceived to be less odorous compared to polyester in the *in vitro* study, regardless of whether they had been treated with an antimicrobial or not. This suggests that for the odor arising in fabrics, during the incubation of sweat solution on textiles the chemical-physical properties of the fiber play a significant role in odor absorption and release.

In both the odor-collection methods, bacterial populations were reduced as a result of the antimicrobial treatment, with the PHMB being more effective for the *in vivo* study compared to the ZP. However, there was no difference in the efficacy of the two antimicrobials when fabrics were inoculated with sweat solution in the *in vitro* study. A notable outcome of the *in vivo* trial was the lack of obvious reduction in odor intensity as a result of the antimicrobial treatments, despite the significant reduction of bacterial populations within the fabrics, and only a small effect in odor for PHMB-treated textiles in the *in vitro* study. In the *in vitro* study ZP-treated fabrics were found to be even more odorous than the untreated fabrics. This suggests that antimicrobials may not be sufficient to completely control odor developing within fabrics.

Axillary odor is a result of bacterial metabolism of human sweat, yet there is surprisingly little evidence that antimicrobials have been effective in reducing odor within textiles. One recent study investigating the effect of a silver-chloride based antimicrobial in the reduction of axillary odor in polyester fabrics found that *in vivo* bacterial populations were not reduced despite *in vitro* antimicrobial efficacy; subsequently, odor was not reduced (McQueen et al., 2013). Conversely, it was observed that the odorous compound 5α-androst-2-en-17-one was reduced when androsterone sulphate was placed on polyester fabrics treated with silver zirconium phosphate (Obendorf, Kim, & Koniz, 2007). This research was conducted in a laboratory environment with only one odorant measured and is not reflective of the complexity of odor in real life. In a wear trial carried out by another group (Mao & Murphy, 2001), fabrics treated with a triclosan-based antimicrobial were compared against an untreated control fabric worn by participants against the axillary region (Mao & Murphy, 2001). However, as a full independent sensory evaluation was not carried out (as odor was only rated by the T-shirt wearer) nor was the intensity of odor quantified, it is not possible to quantify the significance of the odor reduction. The current study shows the value of including trained sensory panel evaluations of odor intensity with assessments of antimicrobial efficacy for the evaluation of antimicrobial treatments designed to reduce malodor within clothing. The *in vitro* method explored in the current study has the potential to be applied for this purpose.

The purpose of this preliminary study was to explore a more convenient laboratory-based method that could be used instead of the wear-trial method for collecting and evaluating odor on textiles. A comparison of the *in vivo* and *in vitro* methods is shown in Table 2. The *in vitro* method allows for evaluation of more than two fabrics at one time, and reduces the variability due to the intrapersonal and interpersonal variation of the individuals who act as odor providers. In this respect, the *in vitro* method was successful in achieving its outcome. Sweat, bacteria and skin cells could be collected using a PBS solution from both the right and left axillae and the fabric inoculated with the same sweat solution, accounting for any variation that may naturally occur between the left and right axilla. This method also can address the deficiency in the wear-trial method of day-to-day fluctuations in odor

intensity that may occur due to changes in a person's diet, physical activities or other physiological factors. Although human derived sweat solutions could vary in odor intensity when collected on different days, in the current study this variability in odor intensity was low compared with the *in vivo* method.

Due to large variability associated with the small number of participants in this preliminary study, a subsequent study with a larger group of participants is necessary. A standardized exercise procedure and standardized bathing protocol could be adopted in the larger follow-up study in order to minimize some of the intrapersonal variation experienced in the current study. Further modifications could be made to the *in vitro* method to reduce the effect of interpersonal variability by pooling sweat collected from multiple participants. A larger number, than just three participants, should be used in pooled sweat to provide a sample that represents the diversity of sweat and bacteria found in the general population. Future research studies may determine the optimum number of participants to generate pooled samples. It was necessary to incubate the sweat on the fabric for three days to develop sufficient body odor for sensory and microbial analyses. Use of a more concentrated sweat solution, such as pooled sweat from multiple people, may intensify odor more quickly. Troccaz et al. (2004), collected concentrated sweat by taking samples of fresh sweat from participants in a sauna following exercise on a stationary bicycle; however not all laboratories may have easy access to saunas. The method developed for the current study was simpler and could be more easily adopted by other research and testing facilities.

Table 2. Comparison of the in vivo and in vitro methods

	In the current study		*Summary*	
	Wear trial in vivo	*Incubation in vitro*	*Wear trial in vivo*	*Incubation in vitro*
Time efficiency	20 days in total	12 days in total	Time-consuming	Time efficient
Exhibit in-use situation	Replicates real-life situation	Does not replicate what happens in real-life	Replicates real-life situation	Does not replicate what happens in real-life
Number of samples obtained each day of testing	6 fabrics at most	6-12 fabrics	Limited	More
Influence of individual participant on odor intensity	Greatest effect compared to others	Small effect compared to others or no effect	Large	Small
Number of participants required	3 used in the study with results varying widely	3 used in the study with relatively consistent results	Large	Small
Right/left arm imbalance	Exists as one fabric only worn under one arm each time	Does not exist by pooling the sweat from the right and left arm	Inevitable	Removed

Conclusions

A new method was explored in order to generate and detect axillary *in vitro* odor based on the incubation of 'fresh' sweat solution on fabrics. Compared with the *in vivo* wear trial method, the *in vitro* method was more time efficient and simpler, allowing a comparison of a greater number of fabrics at the one time. In this preliminary study the *in vitro* method appears to also limit the variability due to intrapersonal and interpersonal differences in odor intensity associated with human participants, although the method should be applied to include a larger number of participants. The new method was not always consistent with findings from the *in vivo* method, as polyester and cotton fabrics did not noticeably differ in odor intensity *in vivo* while they did *in vitro*. These results also highlight the challenge of developing a laboratory-based method that replicates human axillary odor development and transfer to fabrics during wear. The findings in the current study also provide evidence that antimicrobial treatments may not be the complete answer for control of axillary odor development within fabrics. Therefore, when evaluating anti-odor technologies for textiles it is important to incorporate human trained panel sensory evaluation to assess odor reduction.

Acknowledgements

We gratefully acknowledge the assistance of Dr. Monika Keelan, Susan Gibson and Dr. Jane Batcheller for their support in this study. We wish to thank all the participants and assessors who participated in the study. We also acknowledge the Faculty of Agricultural and Life and Environmental Sciences and VP Research at the University of Alberta for financial support in this research.

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