SUPPRESSION EFFECT OF WEAK-ACIDIC POLYESTER ON BODY ODOR

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ABSTRACT

Body odor is promoted by perspiration as sebum and other secretory substances in sweat are decomposed into odorous substances by residence bacteria such as *Staphylococcus aureus* on the skin surface. *Staphylococcus aureus* grows when the skin pH increases above 5.5 and stimulates skin, resulting the generation of strong body odor and causing skin itching and/or reddening. In order to suppress the growth of *Staphylococcus aureus* on the skin, weak-acid polyester was prepared by introducing acid groups onto polyester fabric and evaluated its antibacterial /deodorant effect on human subjects. The results confirmed that the growth of *Staphylococcus aureus* on the skin was suppressed and in consequence less body odor was generated after perspiration.

Key Words: Staphylococcus aureus, weak-acid polyester, antibacterial /deodorant properties, body odor

1. INTRODUCTION

Body odor is one of unpleasant odors generated commonly in our life. Body odor is considered as a kind of a social harassment referred to as smell-harassment which makes the surrounding people uncomfortable, and, in severe cases, might destroy the human relations in the society. Body odor can be roughly classified in two categories: (1) the odor due to sebum and other secretory substances in sweat being decomposed by bacteria on skin, and (2) the odor caused by the metabolic secretion from the body due to aging, fatigue, stress, and diseases[1]. The bacteria such as *Staphylococcus aureus* and *Staphylococcus epidermidis* are present on human skin as resident microbiota, and the skin pH of healthy state is weakly acidic (pH4.5-6.0) by being covered with a weakly acidic sebaceous membrane [2-3]. However, when the skin pH increases by sweating, *Staphylococcus aureus* grows, and sebum and and other secretory substances in sweat would be decomposed into odorous substances such as ammonia, causing the generation of unplesant odor from the body. In addtion, the skin problems such as itching and reddening could be caused by *Staphylococcus aureus.* In fact, the atopic dermatitis has a higher skin pH and the population of *Staphylococcus aureus* is higher [4-5]. *Staphylococcus aureus* is so-called bad bacteria causing both odor generation and skin irritation.
Although polyester is the most frequently used synthetic fiber for clothing, it is said to cause skin allergy despite that no allergen was found in polyester. Polyester is hydrophobic and absorbs no water but sebum might be absorbed and could not be washed out. Hydrophilic cotton on the other hand is considered as a safe material. In this study, we prepared the weak-acidic polyetster by introducing acidic groups to make polyester less hydrophobic and keep the skin pH in its healthy state in order to suppress bacteria. The wear test was conducted with this weak-acidic polyetster fabric and its effect was examined in terms of the suppression of the growth of *Staphylococcus aureus*.

2. EXPERIMENTAL

2.1 Samples

Wearing test samples were prepared from the knitted fabrics of the weight 150g/m^2, composed of 84 dtex, 72 filaments. The weak-acidic polyester produced from the copolymer of ethylene diol, terephthalic acid and a small amount of ester-forming sulfonium metal salt compound (cation-dyeable polyester) was immersed in acetic acid or malic acid aqueous solution adjusted to pH=5 at 70^{o}C for 20 - 40min. It is partially hydrolyzed by weak-acidic groups after alkaline reduction, and free weak-acidic groups are thought to localize in the vicinity of the sulfonium metal salts in the amorphous region of polyester. Weak-acidic polyester processed with maleic acid was used in the present wearing test. The sample fabric was provided by TEIJIN FRONTIER CO., LTD) [6].

2.2 Antibacterial property

The antibacterial property was evaluated according to JIS L1902; the method of fungus liquid absorption. *Staphylococcus aureus* (ATCC 6538P) was used as a source stain. The bacteria were mixed with agar and the mixture was poured onto a sample fabric previously set in a laboratory dish. The dish was held at 36 ^{o}C for 18 hours in an incubator. The amounts of living bacteria were evaluated immediately after incubation.

2.3 Deodorant property

The deodorant effect was evaluated by means of the detector tube method using a vacuum type gas sampling device (Gas Tec Co., Ltd. GV-100S type) and a detector tube. Two pure chemical odor substances, acetic acid as a model of sebum and ammonia as a model of sweat were used as standard sample odors. After the sample fabric (weak-acidic and untreated polyester) (1g) was placed in a bag (2L) made of vinyl fluoride, odor gas (1L) was injected and the bag was sealed tightly. After one hour, the gas in the bag was sampled with a gas sampling device and the concentration of the sample odor was measured by the detector tube. The deodorant effect was evaluated from the following equation from the measured concentration of odor gas.

$$Deodorant\ effect\ = \frac{Y(0)-Y(t)}{Y(0)}\ \text{X}\ 100$$

Here Y (0) and Y (t) are the concentrations of odor gas without sample fabric (the initial odor gas concentration) and that of the sampled odor gas from the Tedlar bag sealed with the sample fabric for the time t, respectively.

2.4 Human subject test

The wearing tests were performed with the wear of two kinds of polyester (weak-acidic and untreated polyester). The subjects were constituted of 11healthy women who belong to the badminton club. The subjects performed badminton exercise for 3 hours at gymnasium. The subjects took a shower in prior the exercise, and the skin pH's at two places on the back were measured with a pH meter (HORIBA pHMETER F-52), and the bacteria on the skin of two places on the back were observed using a Lumitester (Kidkoman Biochemifa Lumitester PD-30). The *Staphylococcus aureus* count on the skin surface at one place on the back was evaluated according to a food stamp method (Nissui Pharmaceutical Co., Ltd. TGSE agar: *Staphylococcus aureus*) before and after exercise. The body odor intensity was classified in 6 grades and the degree of comfort /discomfort after exercise were evaluated in 9 grades subjectively by smelling.

3. RESULTS AND DISCUSSION

3.1 Characteristics of weak-acid polyester

The pH of the cloth is closely related to the antibacterial characteristics. The pH value of the sample polyester fabrics ranged from 6.0 to 6.5. The pH value of 6.7 is a threshold for the growth of bad bacteria **[7]**, where the number of living bacteria increases at the pH value over 6.7 but decreases below this value. The antibacterial property of weak-acid polyester was confirmed as shown in Table 1. After incubation of 18 hrs, the number of living bacteria on untreated polyester increased, whereas the number decreased for weak-acidic polyester. According to the JIS L 1902, the antibacterial property appears when the bacteriostatic activity value exceeds 2.2. The bacteriostatic activity value of two kinds of polyester were also calculated as shown in Table 1, where the values of 4.9 for weak-acidic polyester was classified to antibacterial fabrics. That is, the weak-acidic fabrics suppress the growth of bacteria.

Table 1 The Antibacterial property of various sample fabrics against *Staphylococcus aureus*

Sample	Logarithmic value of number of living bacteria(number)		Bacteriostatic activity value *
	Before incubation	After Incubation for 18hrs	
Weak-acidic polyester	4.3	2.0	4.9
Untreated polyester	4.2	6.3	0.5
Standard cotton fabrics	4.3	6.9	-

＊Bacteriostatic activity value ＝(Mb-Ma) –(Mc-Mo)
Mb-Ma ： Difference of logarithmic values of the number of living bacteria of the standard fabric before and after incubation, Mc- Mo ： Difference of logarithmic values of the number of living bacteria of the sample fabric before and after incubation

The deodorant effects of weak-acid polyester were calculated according to the formula as shown in Figure 1. Since the weak-acidic polyester is acidic in nature, it shows a deodorant effect on alkaline odor of ammonia by neutralization. However, hardly any deodorant effect was observed on acetic acid, since weak-acidic polyester and odor substance are acidic and no reaction is expected between them.

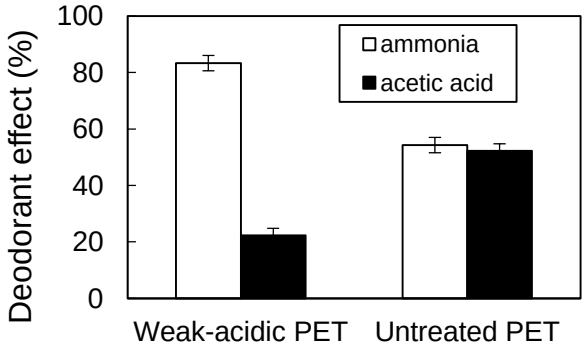

Figure 1. Deodorant effect of weak-acidic polyestyer for two kinds of odors

3.2 Evaluation of suppression effect of weak-acidic polyester by human subject test

We examined the influence of weak-acidic polyester on the skin. Various bacteria such as *Staphylococcus epidermidis*, *corynebacterium* and *Staphylococcus aureus* are present on the skin surface [8]. The skin pH, count of bacteria and *Staphylococcus aureus* before and after exercise when wearing weak-acidic polyester wear are summarized in the Table2.

Table 2 Change of skin pH, the count of bacteria and *S.aureus* before and after exercise

	Sample	Before(B)	After(A)	Difference (A)-(B)
Skin pH	Weak-acid	5.09	4.61	-0.48**
	Untreated	4.70	5.00	0.29**
Bacteria count (number)	Weak-acid	1442	4323	2880**
	Untreated	2664	10322	7658**
Count of *S. aureus* (number)	Weak-acid	75	102	27**
	Untreated	94	184	90**

**: $p<0.01$

The skin pH of the subjects before exercise was slightly acidic in the pH range of 4.8- 5.2. When comparing the differences in the skin pH for 11 subjects before and after exercise, the skin pH while wearing weak-acidic polyester does not increase much after sweating even after exercise, whereas the skin pH increased after excise when untreated polyester was worn. The comparison among the individual results of the skin pH of 11 subjects are shown in Figure 2. When the skin pH of all 11 subjects wearing weak-acidic polyester, the skin pH was lower compared with those wearing the untreated polyester. The weak-acidic polyester can suppress the increase of the skin pH after perspiration and keep the skin pH weakly acidic.

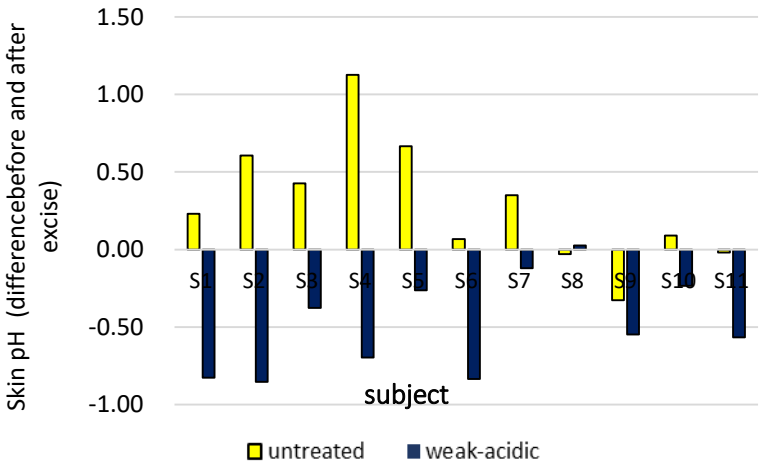

Figure 2 The comparison on individual result of skin pH of 11 subjects when wearing weak-acid and untreated polyester.

Various bacteria such as *Staphylococcus epidermidis*, *corynebacterium* and *Staphylococcus aureus* are present on the skin surface. The Lumitester detected these bacteria. As shown in Figure 3, the individual results of the measured number of these bacteria on skin, shows that a smaller number of bacteria was detected when the weak-acidic polyester was worn, in

comparison with the case of untreated polyester. When wearing weak-acidic polyester, the number of bacteria on the skin was suppressed in all 11 subjects, confirming that weak- acid polyester has a suppressing effect on these bacteria. *Staphylococcus aureus* not only degrades sweat and sebum into malodorous substances, but also causes skin disorders. The weak-acidic polyester was found effective to suppress the growth of *Staphylococcus aureus.*

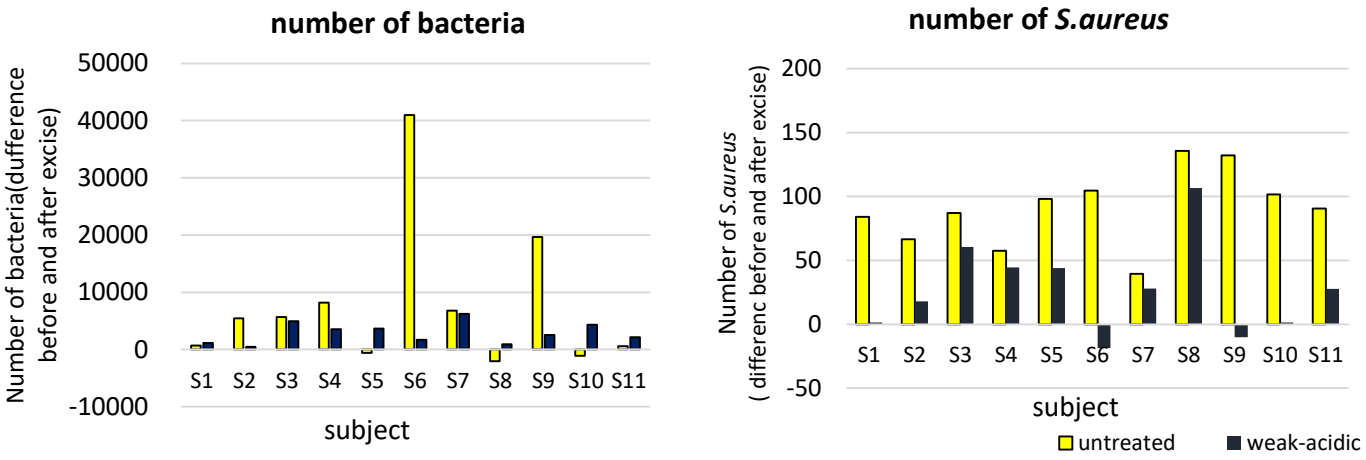

Figure 3 The comparison on individual result of bacteria or S.aureus of 11 subjects when wearing weak-acid and untreated polyester.

As mentioned above, when malic acid was introduced onto cation-dyeable polyester, the resulted weak-acidic polyester exhibited an excellent antibacterial property, as confirmed as the growth suppression of Staphylococcus *aureus* on the skin of healthy people. Body odor will be generated because sweat and sebum are degraded by *Staphylococcus aureus* to malodorous substances. Sweat is odorless in the sweat glands. The odor intensity and degree of comfort/discomfort of body odor were subjectively examined when wearing weak-acidic polyester or untreated polyester. Figure 4 shows the human sensory evaluation of the body odor intensity. The odor intensity of body odor is low when wearing weak-acidic polyester as the odor is ranked between 1 and 2 where the number of 1 denotes the threshold odor that can be perceived as there is (Detection threshold concentration) and 2 denotes the weak odor which can be understood the nature of odor (Cognitive threshold concentration). According to our previous research results, body odor malodorants are mainly composed of fatty acids

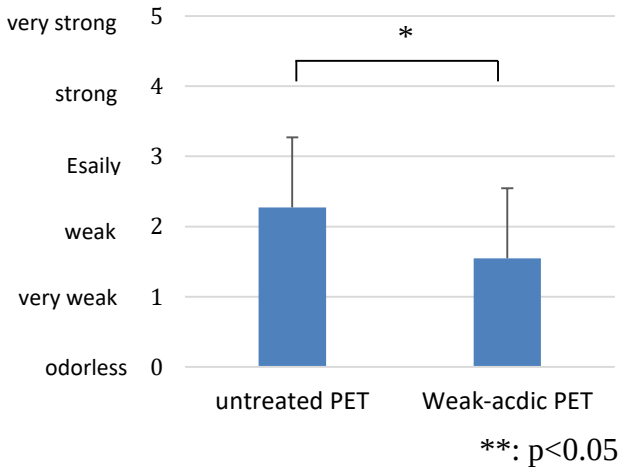

Figure 4. Comparison of odor intensity of body odor when wearing weak acid polyester and untreted polyester.

such as capric acid and pelargonic acid. Although these malodorous substances could not be directly deodorizing by the weak-acidic polyester, it is considered that its antibacterial effect prevents the decomposition of the sweat and sebum into the malodorous substances in this context, the suppression effect of the weak-acidic polyester on the growth of Staphylococcus aureus is an important factor for the decrease of the generation of malodorants.

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