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Fabric detergents for body-odor reduction

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Abstract

This research targets to prepare detergents containing β-cyclodextrin and to use them for fabric laundry in order to improve the body-odor removability of detergents. Three local detergents consisting of two powder detergents (diluted and concentrated) and one liquid detergent (concentrated) were mixed well with various amounts of cyclodextrin powder and they were used for laundering microfiber polyester fabric containing body-odor, compared with using detergents without cyclodextrin. Results from electronic nose analysis indicated that detergents with cyclodextrin provided better body-odor removability than detergents without cyclodextrin. Lower level of body-odor was found on fabric and lower washing cycle was needed when laundering fabric with detergents containing cyclodextrin. Some fabrics showed odorless with only one washing cycle using these high performance detergents. FTIR and SEM analyses indicated that there were cyclodextrin particles left on fabric after washing with detergents containing high content of cyclodextrin.

Keywords: detergents, β-cyclodextrin, microfiber polyester, body odor, electronic nose,

1. Introduction

At present, most sportswears are made of microfiber polyester woven fabrics due to their softness and lightness. However during or after wearing, they often show bad smell from body and bacterial sources. A major component of body-odor is isovaleric acid (Medical News Today, 2012) and generally it can't be removed completely from fabric with only one laundering cycle. This research aims to improve the body-odor removability of local detergents via an application of cyclodextrin into the detergents, to act as a body-odor absorber or remover. Cyclodextrin (CD), a cyclic oligosaccharide, contains 6; 7; or 8 glucose units linking into rings of α; β; or γ-cyclodextrin respectively (Grigoriu et al., 2008; Bhaskara-Armit et al., 2011). It is known that an empty space within the ring shows a hydrophobic property and can be used for storing nonpolar substances,

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and then releasing them at specific conditions. In addition, cyclodextrin can also be used for absorbing cigarette smoke as well as malodor (Angell et al., 2005). In this research, β-cyclodextrin was used to added into the detergents for body-odor reduction because of the most widely used applications, inexpensive and simple process.

2. Materials and Methods

2.1 Materials

Fabric used in this research was microfiber polyester woven fabric (weight per square meter: 240 g/m^2), supplied by Jong Stit Co., Ltd. and β-cyclodextrin was from Wacker Chemicals (South Asia) Pte., Ltd. three local detergents consisting of two powder detergents (diluted and concentrated) and one liquid detergent (concentrated), supplied by Lion (Thailand) Co., Ltd., were used. In addition, all of detergents consisted of anionic surfactants, for two powder detergents (linear alkyl benzene sulfonate) and one liquid detergent (linear alkyl benzene sulfonate and alcohol ethoxylate sulfate). Isovaleric acid from Sigma-Aldrich (Thailand) Co., Ltd. was used as a source of body-odor in this research.

2.2 Methods

2.2.1 Preparation of detergents and detergents containing cyclodextrin

Detergents and detergents containing β-cyclodextrin were prepared for fabric laundry. In terms of detergents, 0.3 g; 0.8 g; and 10 g (manufacturer's recommendations) of concentrated powder detergent; diluted powder detergent; and concentrated liquid detergent, respectively, were used for laundering 2.4 g of fabric. For preparation of detergents containing cyclodextrin, 0.3 g; 0.8 g; and 1-6 g of cyclodextrin were added into those detergents, respectively.

2.2.2 Preparation of fabric containing body-odor

According to our previous research (Nimsuk, 2011), it showed that the average body-odor level on sports shirts after one-hour exercise (plus one-hour rest with shirts on) was found to be level 3 or a moderate body-odor level. Based on a research work by Hooper, 1982, isovaleric acid at a concentration of 0.22 mL/L was used to represent a source of the body-odor level 3. Therefore, in this work 0.22 mL/L isovaleric acid was prepared and 1 mL of it was dropped on microfiber polyester fabric to make fabric containing body-odor level 3.

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2.2.3 Washing condition

Approximately 10×10 cm or 2.4 g of microfiber polyester fabric was used as an experimental sample. Each sample was washed, in 460 mL of water containing each detergent, at room temperature for 1 h in a stainless-steel cylindrical container of a laboratory laundering machine. After each washing cycle, fabric was water rinsed for 30 min and then air dried. In this research, fabric with body-odor level 3 was washed one to several cycles or until it was odorless.

2.2.4 Determination of body-odor level on fabric using Electronic nose analysis (E-nose)

The electronic nose (E-nose) used in this research following the method of (Nimsuk, 2011) was supplied by the National Nanotechnology Center (NANOTEC). It equips with 5 different sensors (sensor array metal oxide group). Once a fabric sample is placed in a glass container attaching to E-nose, sensors immediately detect for the existence of volatile isovaleric acid (body-odor source) on fabric and transform it will be into electrical potential signals (Fig. 1) in a metric form (Fig. 2). Then electrical signals were modified into displacements plotted among group data of standard body-odor level 0 (no smell) to level 5 (very strong smell) in a PCA (Principal Component Analysis) three-dimensional plot (Fig. 3). The shortest displacement or the closest distance between group data of fabric to group data of any level of standard body-odor (levels 0-5) indicates the body-odor level of that sample to that level. Table 1 indicates a correlation between isovaleric acid concentrations and body-odor levels, being used to explain the body-odor removal efficiency of detergents in this research.

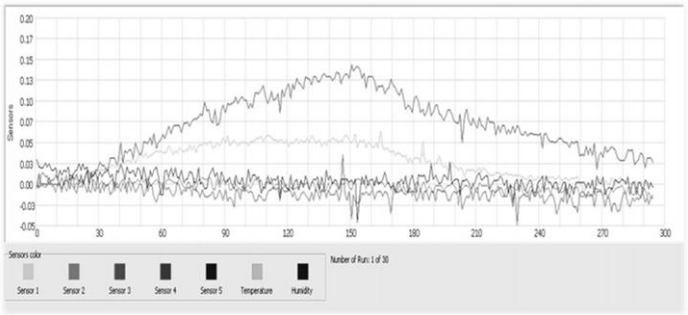

Figure 1. Electrical signals of isovaleric acid picked up by 5 sensors of E-nose.

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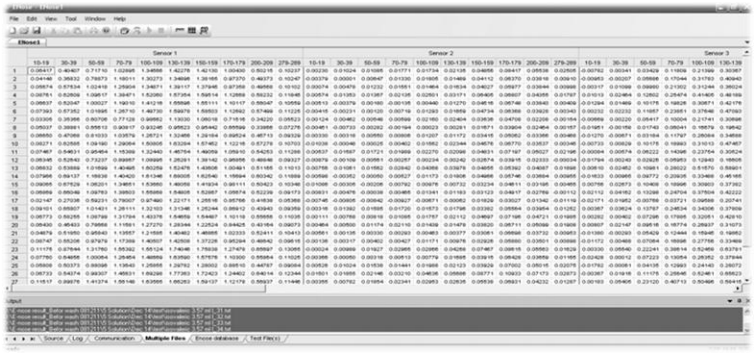

Figure 2. Metric of electrical signals of isovaleric acid picked up by 5 sensors of E-nose.

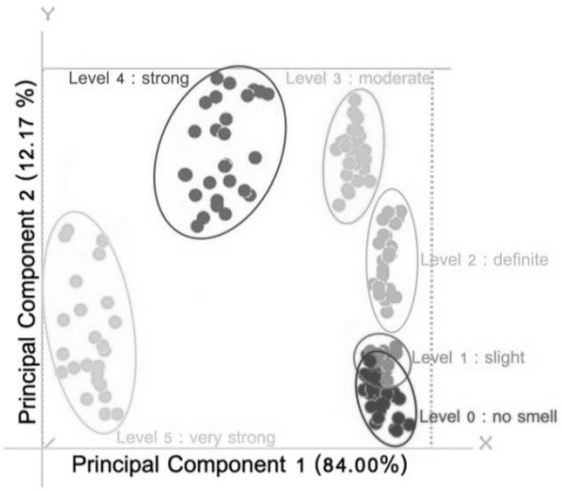

Figure 3. PCA score plot of group data of standard body odor levels (levels 0-5).

Table 1. Relation between isovaleric acid concentrations and body odor levels.

Level	Isovaleric acid Concentrations (mL/L)	Body-odor strength
0	0	no smell
1	0.013	slight
2	0.053	definite
3	0.220	moderate
4	0.870	strong
5	3.570	very strong

Source: Hooper et al. (1982).

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2.2.5 Determination for the existence of cyclodextrin (odor absorber) on fabric using FT-IR and SEM analyses

Fabric washed with detergents containing cyclodextrin was analyzed for a presence of cyclodextrin on its surface using a Nicolet 6700 ATR-FTIR spectroscopy in the range of 4000-400 cm^{-1}, at 4 cm^{-1} resolution. The fabric was also surface analyzed using SEM Technique (JEOL, JSM-5410LV), under a working voltage of 30 kV at 10 μm.

3. Results and Discussion

3.1 Washing with concentrated liquid detergent

3.1.1 E-nose analysis

Before washing microfiber polyester fabric with concentrated liquid detergent, fabric containing body-odor level 3 was prepared according to Method 2.2.2 and its body-odor level 3 was confirmed with e-nose analysis shown in Table 2 as the shortest displacement of 4.64, which was the distance between the group data of body-odor on fabric and group data of body-odor level 3 or the moderate level. When fabric containing body-odor level 3 was washed one time using either detergent or detergent with cyclodextrin, the shortest displacement was at body-odor level 1 (slight smell), which meant that washing fabric one time using either detergent system can reduce the body-odor level 3 to level 1 or reduce from a moderate smell to a slight smell of body-odor. Results in Table 2 also showed that the body-odor of fabric can be completely removed (body-odor level 0 or no smell) from 2.4 g fabric only when it was washed twice using 10 g concentrated liquid detergent with 1 g cyclodextrin and washed at least 3 times using 10 g concentrated liquid detergent alone. It can be said that cyclodextrin in detergent helps absorbing body-odor and removing it from the fabric or cyclodextrin can improve the body-odor removability of this detergent. Fig. 4 exhibits displacements of fabric after washing 3 times with concentrated liquid detergent containing cyclodextrin (see data at the last row of Table 2), showing the shortest displacement of 3.02 at body-odor level 0 (no smell).

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Table 2. Displacements at various body-odor levels of 2.4 g fabric before and after washing with 10 g concentrated liquid detergent vs 10 g concentrated liquid detergent + 1 g cyclodextrin.

Wash Cycle	Detergent	Displacements at various body-odor levels					
		Level 0 No smell	Level 1 Slight	Level 2 Definite	Level 3 Moderate	Level 4 Strong	Level 5 Very strong
0	-	13.62	5.98	5.05	4.64	10.61	16.77
1	det	6.06	3.30	4.38	6.02	10.41	15.16
	det+CD	7.83	2.90	3.43	4.80	9.74	15.00
2	det	6.08	3.01	4.51	6.39	10.49	14.59
	det+CD	4.22	4.91	7.32	6.08	10.49	14.59
3	det	4.87	5.15	6.48	8.12	11.89	16.03
	det+CD	3.02*	5.56*	6.79*	7.86*	10.33*	14.00*

det = detergent

CD = cyclodextrin

*displacement shown in Fig. 4

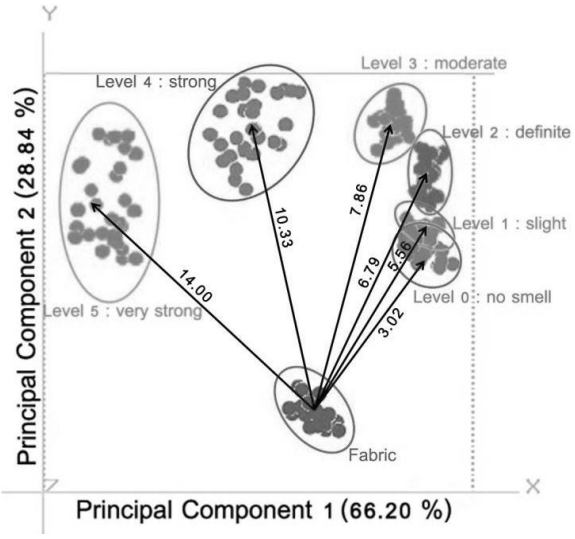

Figure 4. PCA score plot exhibiting displacements at body-odor levels 0-5 of 2.4 g fabric after washing for 3 cycles with 10 g concentrated liquid detergent + 1 g cyclodextrin.

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In order to remove the moderate smell of body-odor (level 3) from 2.4 g fabric through one cycle washing with 10 g concentrated liquid detergent containing cyclodextrin, various amounts of cyclodextrin (1-6 g) were mixed well with 10 g detergent and the mixed detergents were used to wash fabric for one cycle before analyzing for its body-odor using E-nose. Table 3 shows that when 2.4 g fabric containing body-odor level 3 (moderate smell) was washed one time using 10 g concentrated liquid detergent plus 6 g cyclodextrin, the fabric was free of body-odor (body-odor level 0, no smell) after washing. It means that it is possible to completely wash out the body-odor level 3 with only one wash using this concentrated liquid detergent containing higher content of cyclodextrin.

Table 3. Displacements at various body-odor levels of 2.4 g fabric before and after one cycle washing with 10 g concentrated liquid detergent vs 10 g concentrated liquid detergent + 1-6 g cyclodextrin.

CD content (g) in 10 g det	Displacements at various body-odor levels					
	Level 0 No smell	**Level 1 Slight**	**Level 2 Definite**	**Level 3 Moderate**	**Level 4 Strong**	**Level 5 Very strong**
Before wash	13.62	5.98	5.05	4.64	10.61	16.77
0	6.06	3.30	4.38	6.02	10.41	15.16
1	7.83	2.90	3.43	4.80	9.74	15.00
2	8.12	3.25	3.40	4.67	6.98	15.01
3	9.04	2.51	2.69	4.21	9.84	15.42
4	4.57	3.65	4.92	9.40	9.95	14.90
5	4.03	3.38	5.32	6.60	10.84	15.71
6	2.15	8.81	10.15	11.27	13.00	15.57

det = detergent.

CD = cyclodextrin.

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3.1.2 SEM analysis

Fabrics before and after washing with concentrated liquid detergent vs washing with this detergent containing cyclodextrin, were analyzed with SEM showing results as micrographs in Fig 5. This Figure shows that before washing, fiber surface of fabric (A) is clean and contains only residual impurities. After washing with detergent, fiber surface contains some more impurities (B). Especially when washing with detergent containing cyclodextrin 1 g and 6 g, the fiber surface shows higher amount of impurities ((C) and (D) respectively). The additional impurities shown on fabric ((C) and (D)) are speculated to be cyclodextrin which can help absorbing body-odor on fabric.

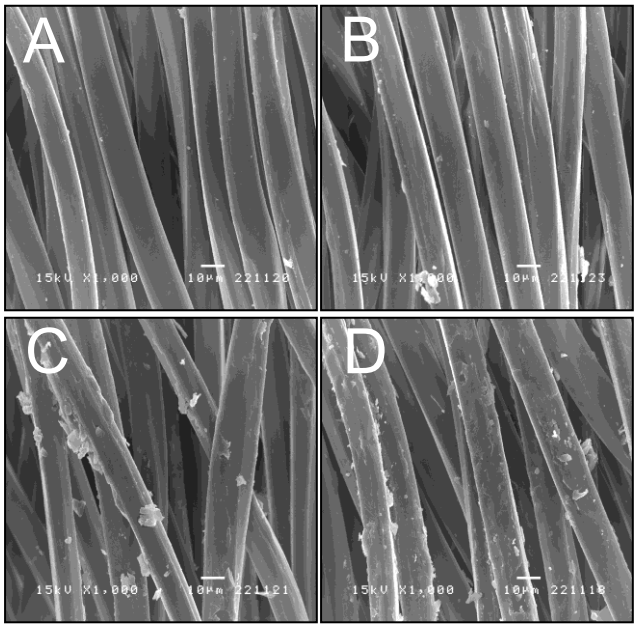

Figure 5. Scanning Electron Micrographs of fabric before washing (A), after washing with 10 g concentrated liquid detergent (B), after washing with 10 g concentrated liquid detergent + 1 g cyclodextrin (C), and after washing with 10 g concentrated liquid detergent + 6 g cyclodextrin (D).

3.1.3 FTIR analysis

After one-cycle washing fabric containing body-odor level 3 with 10 g concentrated liquid detergent + 6 g CD, the fabric was free of body-odor. Then, it was analyzed for impurities left on fabric surface using FTIR technique showing results as IR spectra in Fig. 6, as cyclodextrin

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(spectrum a), fabric (spectrum b), fabric after washing with detergent + CD (spectrum c), and fabric coated with CD solution (spectrum d). In this Figure, cyclodextrin (spectrum a) shows its frequencies at 3385.6 cm^{-1}, 2921.1 cm^{-1}, 1157.5 cm^{-1}, and 1028.6 cm^{-1} corresponding to the symmetric and asymmetric stretching of frequencies of O-H groups, $-CH_2$ groups, C-C bonding, and bending vibration of O-H respectively. Polyester (spectra b, c, d) showed its frequencies at 2922.9 cm^{-1}, 1713.1 cm^{-1}, and 1238.4 cm^{-1} representing $-CH_2$ stretching, -C=O vibrating, and -C-O of ester group, respectively. Results in Fig 6 indicated that once the fabric is washed with detergent + CD (spectrum c) or is coated with CD solution (spectrum d), the characteristic of polyester shown in IR spectrum decreases as observing the decrease of intensity of each frequency representing polyester. The decrease of polyester characteristic in this case may be due to a presence of impurities such as cyclodextrincovering on the fabric after washing or coating, as also found this evidence in SEM analysis.

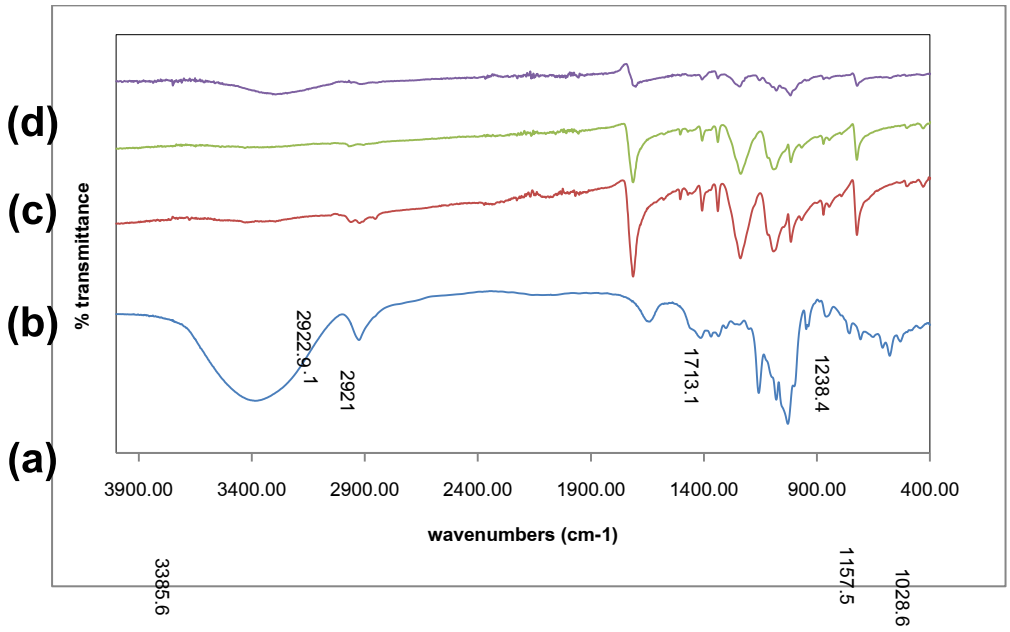

Figure 6. FTIR spectra of (a) Cyclodextrin, (b) Fabric, (c) Fabric after washing with 10 g concentrated liquid detergent + 6 g CD, (d) Fabric coated with CD solution (10 g water + 6 g CD).

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3.2 Washing with diluted powder detergent

3.2.1 E-nose analysis

Before washing, fabric contained a moderate level of body-odor (level 3) as previously mentioned and shown the shortest displacement (4.64) at body odor level 3 in Table 4. When this 2.4 g fabric was washed one time using either 0.8 g diluted powder detergent or 0.8 g diluted powder detergent plus 0.8 g cyclodextrin, the body-odor level of fabric was reduced from level 3 (before washing) to level 2 (after one washing). Then after two washing cycles with both detergents, the fabrics were odorless (body-odor level 0). Results in Table 4 indicate that washing fabric with either diluted powder detergent or with diluted powder detergent containing cyclodextrin shows similar body-odor removability. Therefore, an addition of cyclodextrin into this detergent does not help improving the body-odor removability of the detergent.

Table 4. Displacements at various body-odor levels of 2.4 g fabric before and after washing with 0.8 g diluted powder detergent vs 0.8 g diluted powder detergent + 0.8 g cyclodextrin.

Wash Cycle	Detergent	Displacements of at various body-odor levels					
		Level 0 No smell	Level 1 Slight	Level 2 Definite	Level 3 Moderate	Level 4 Strong	Level 5 Very strong
0	-	13.62	5.98	5.05	4.64	10.61	16.77
1	det	9.21	8.45	5.15	5.43	11.95	19.75
	det+CD	5.52	4.91	3.36	5.43	11.95	18.77
2	det	12.79	13.51	16.76	19.43	20.54	20.84
	det+CD	10.99	11.70	14.70	17.51	19.30	20.47

det = detergent.

CD = cyclodextrin.

3.2.2 SEM analysis

After fabrics containing body-odor level 3 were washed twice with diluted powder detergent and with diluted powder detergent + cyclodextrin, they were free of body-odor and were surface analyzed using SEM technique showing results as micrographs in Fig. 7. From this Figure, it shows that fiber surface of fabric contains small amounts of impurities after washing with detergent + cyclodextrin (C) compared with clean surface of fabric before washing (A) and after

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washing with detergent only (B). These impurities are speculated to be the residual cyclodextrin (C) left on fabric surface after washing with detergent containing cyclodextrin

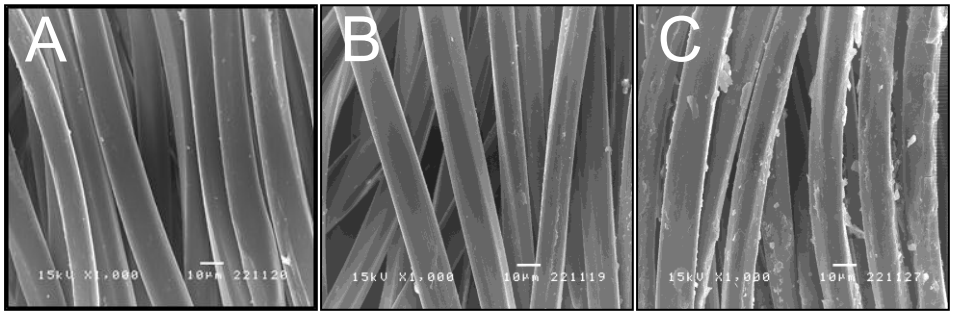

Figure 7. Scanning Electron Micrographs of fabric before washing (A), after washing with 0.8 g diluted powder detergent (B), and after washing with 0.8 g diluted powder detergent + 0.8 g cyclodextrin (C).

3.3 Washing with concentrated powder detergent

3.3.1 E-nose analysis

Fabric containing body-odor level 3 was washed 1-5 times using 0.3 g concentrated powder detergent vs 0.3 g concentrated powder detergent + 0.3 g cyclodextrin, and was analyzed for its body-odor level showing results in Table 5. Results in this Table indicate that both detergent and detergent plus cyclodextrin show similar body-odor removability through fabric laundry. After 1-3 washing cycles, fabric still contained body-odor level 3 (same level as fabric before washing). Once fabric was washed for 4 cycles, its body-odor level was reduced from level 3 to level 2, and finally to level 0 when fabric was washed for 5 cycles. This means that it's necessary to wash fabric for 5 cycles using concentrated powder detergent without or with cyclodextrin in order to totally remove body-odor from fabric. It may be said that an addition of cyclodextrin into this detergent does not help to improve the body-odor removability of detergent.

3.3.2 SEM analysis

After washing with concentrated powder detergent and concentrated powder detergent + cyclodextrin, fabric was analyzed for its surface using SEM technique showing results as micrographs in Fig. 8. This Figure indicates that after washing with detergent + cyclodextrin, fiber surface of fabric contains small amounts of impurities (C), compared with clean surface of fabric

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before washing (A) and after washing with detergent only (B). It's speculated that these impurities may be residual cyclodextrin left on fabric surface after washing with detergent containing cyclodextrin.

Table 5. Displacements at various body-odor levels of 2.4 g fabric before and after washing with 0.3 g concentrated powder detergent vs 0.3 g concentrated powder detergent + 0.3 g cyclodextrin.

Wash Cycle	Detergent	Displacements at various body-odor levels					
		Level 0 No smell	Level 1 Slight	Level 2 Definite	Level 3 Moderate	Level 4 Strong	Level 5 Very strong
0	-	13.62	5.98	5.05	4.64	10.61	16.77
1	det	19.05	9.75	8.20	7.73	13.91	19.86
	det+CD	16.41	8.68	7.16	6.91	12.18	18.32
2	det	19.35	18.53	15.40	13.52	18.24	26.28
	det+CD	21.35	20.70	17.55	15.67	18.24	28.28
3	det	15.00	14.18	11.05	9.43	15.00	23.11
	det+CD	12.76	11.95	8.90	7.59	13.35	21.32
4	det	8.15	7.57	5.29	6.02	12.24	19.49
	det+CD	7.96	5.24	4.67	7.28	12.19	19.71
5	det	5.32	6.35	9.47	12.29	14.71	17.47
	det+CD	4.99	6.19	7.97	10.90	14.20	17.88

det = detergent.

CD = cyclodextrin.

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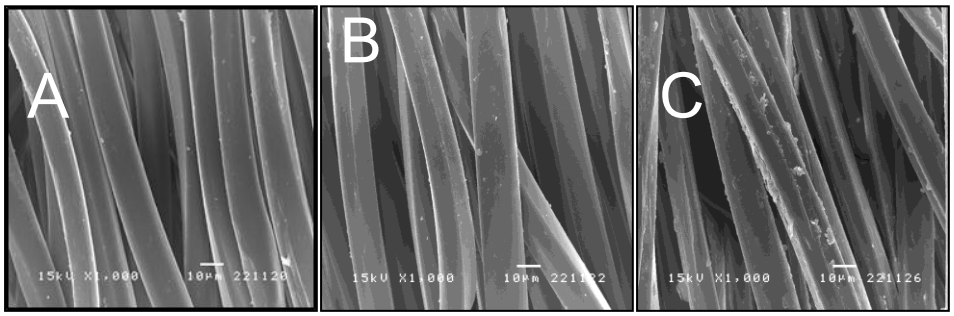

Figure 8. Scanning Electron Micrographs of fabric before washing (A), after washing with 0.3 g concentrated powder detergent (B), and after washing with 0.3 g concentrated powder detergent + 0.3 g cyclodextrin (C).

4. Conclusion

Results in this research indicated that cyclodextrin in detergents can help improving the body-odor removability of detergent, especially for the concentrated liquid detergent. Because the isovaleric acid (body-odor) can forms inclusion complex with cyclodextrin in detergents, the fabric containing body-odor can be reduces by detergents with cyclodextrin. FTIR and SEM analyses have shown that fabric often contains small amounts of cyclodextrin left on its surface after washing with detergent containing cyclodextrin.

Acknowledgements

This research was funded by Thailand Research Fund under Project: the Research and Researchers for Industries Scholarship (RRI) for Master Degree in 2013 and Lion Co., Ltd., (Thailand). Thailand Research Fund and Lion Co., Ltd., may not agree to all results and comments in this research. Authors are also grateful to the Center of Excellence on Petrochemical and Materials Technology, Chulalongkorn University for tuition supports and the Department of Materials Science, Faculty of Science, Chulalongkorn University for supporting the laboratory equipment.

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