

Textile Research Journal

<http://trj.sagepub.com/>

A novel bioactive fabric dyed with unripe *Citrus grandis* Osbeck extract part 2: effects of the Citrus extract and dyed fabric on skin irritancy and atopic dermatitis

Eunjou Yi, Jung Yun Hong and Eun Sook Yoo

Textile Research Journal published online 9 August 2010

DOI: 10.1177/0040517510373634

The online version of this article can be found at:

<http://trj.sagepub.com/content/early/2010/08/02/0040517510373634>

Published by:



<http://www.sagepublications.com>

Additional services and information for *Textile Research Journal* can be found at:

Email Alerts: <http://trj.sagepub.com/cgi/alerts>

Subscriptions: <http://trj.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.com/journalsPermissions.nav>

A novel bioactive fabric dyed with unripe *Citrus grandis* Osbeck extract part 2: effects of the Citrus extract and dyed fabric on skin irritancy and atopic dermatitis

Eunjou Yi¹, Jung Yun Hong² and Eun Sook Yoo³

Abstract

This study aimed to investigate the skin irritancy with unripe *Citrus grandis* Osbeck extract and to determine the effect of cotton underclothes dyed with the citrus extract on the severity of atopic dermatitis by in-vivo methodology. The skin irritancy from the extract was assessed by Kawai's method and the severity of atopic dermatitis was evaluated by measuring the quantitative index of SCORAD for human subjects wearing the citrus-dyed underclothes. Skin reactions were not found by Kawai's method, which suggests that the citrus extract does not cause irritancy on human skin. In a wear test, a marked clinical improvement of atopic dermatitis indicated by a decrease of SCORAD index value was observed in human subjects wearing the dyed underclothes compared to the values for subjects with undyed clothes. These results imply that *Citrus grandis* Osbeck could be utilized as a bioactive natural material for dermal healthcare-related textiles.

Keywords

Atopy dermatitis, bioactive fabric, *Citrus grandis* Osbeck, functional dyeing, Kawai method, SCORAD, skin irritation

Nowadays consumers are pursuing more active involvements of textiles in providing and maintaining an optimal environment for healing dermal disorders such as wounds and dermatitis. This stimulates both researchers and manufacturers to develop new healthcare textile products with more active functions. Natural materials which could be incorporated into fibers and be efficient in medicinal functions seem to be preferred more because they are also non-toxic and eco-friendly.¹ The use of natural resources for dyeing is, especially, of growing interest as a functional dyeing which can provide hygienic and medicinal efficacy as well as coloring to textiles. For these reasons, considerable efforts have been carried out to explore antimicrobial activities of fabrics treated with natural products by dyeing in textile fields.^{2–8} However, so far research has been rare on medicinal functions of naturally dyed fabrics as a clinical practice used to improve skin disease such as atopy dermatitis.

Atopy is a long-term skin ailment and the most common type of eczema which is an allergic condition that makes human skin dry and itchy. It frequently

appears in babies and children and is usually characterized as redness, swelling, crusting, and so on.⁹ The cause of atopy is not clearly proven but is likely to be caused by genetic and environmental factors.⁹ As for the influence of fabrics, synthetic fibers and some rough fibers like wool tend to make the skin irritate and itch. Cotton is traditionally recommended but its structure contains short fibers which expand and contract, causing rubbing movement that can irritate delicate skin.¹⁰ However cotton fabric softened by liquid fabric

¹Department of Clothing & Textiles, Jeju National University, Republic of Korea.

²Department of Pediatrics, Jeju National University, Republic of Korea.

³Department of Pharmacology, Jeju National University, Republic of Korea.

Corresponding author:

Eunjou Yi, Department of Clothing & Textiles, Jeju National University, Ara-Dong, Jeju-City, Jeju-Do, 690-756, Republic of Korea
Email: ejyi@jejunu.ac.kr

softener was less aggressive to atopy patient's skin than the unsoftened material when each of them was rubbed on the pre-irritated skin of a forearm.¹¹ Silk is preferred by medical doctors owing to its smoothness and flexibility when in contact with the skin. A special silk fabric with antimicrobial finish exhibited an improvement on atopy dermatitis after seven days from when it was worn in child patients.¹² On the other hand, some functional treatments for antimicrobial or antifungal efficacy may cause problems when applied under stress conditions.¹³ Therefore, in the process of developing skin health-related textiles, the skin innocuousness of a natural resource needs to be ascertained first. Then medicinal efficacy of the natural product-treated textiles on dermal illness should be also assessed by using in clinical practice. In addition, researches on dermal health-related functions of clothing materials will also advance in collaboration with medical fields because the examination on hygienic functions of fabric is inherently multidisciplinary.

In our previous study,¹⁴ unripe *Citrus grandis* Osbeck was introduced as a new functional natural dye in terms of its dyeing optimization and in-vitro antimicrobial activity on cotton knit fabric. The citrus-dyed fabric showed an excellent inhibitory activity against *Staphylococcus aureus* (*S. aureus*). The bacterium has been regarded as significantly related with atopic dermatitis because the bacterial colonization is frequently found at increased levels on atopy patients' skin.^{15,16} Therefore, the dyed cotton fabric was considered previously to have a potential to also be effective in alleviating and or improving dermal disease such as atopy dermatitis. Now it is required to evaluate its bioactivity on skin by employing an in-vivo method in alliance with clinical practice. In this context, this study was carried out to discuss dermal responses to cotton knit fabric dyed with unripe *Citrus grandis* Osbeck extract by observations using human subjects. Precisely, it aimed to investigate skin irritancy against the citrus extract by the Kawai method^{17,18} in which weak and subtle damages on human skin by patching are assessed and to evaluate the effects of the citrus-dyed cotton knit clothing on the severity of atopic dermatitis using the SCORAD (SCORing Atopic Dermatitis) index^{19,20} for quantification of atopy severity.

Experimental

Materials

As explained in the preliminary study,¹⁴ extract of unripe *Citrus grandis* Osbeck grown in Jeju Island, Korea was obtained from 80% aqueous ethanol solution by filtration, concentration, and evaporation to a final solid of dye powder. The test samples for skin irritancy were prepared by soaking some pieces of

standard cotton fabric (KS K 0905–2003) in aqueous solution of the extract (800% owf by the optimum dye condition) followed by drying them. In order to evaluate the effects of the citrus-dyed clothing on atopy dermatitis, some pairs of underclothes were made with long-sleeved shirts and long-legged trousers using identical cotton knit fabrics (Jersey, 0.73 mm, 157 g/m²) to those used previously.¹⁴ Among them, some were dyed under the conditions (60 °C, 60 min, 800% owf, and 1:50 of liquor ratio) optimized for the fabric¹⁴ and the others were used as control garment without being dyed.

Skin irritancy test

Kawai's method/nitrocellulose replica method^{17,18} was employed in order to investigate if any weak skin irritancy might occur from the unripe *Citrus grandis* Osbeck extract in spite of no visible inflammatory changes. The test samples were prepared as mentioned above and the control substance was made by soaking the same cotton fabric in 2.5% aqueous solution of Di(Stearo Amino Ethylene) Amide Epichlor Hydrine and sequentially by drying to 1% add-on in order to be patched on human skin. Twenty healthy adults were invited as human subjects to the experiments after informed consents were obtained from all of them. A test sample and a control sample of 1.5 cm² were patched on the inner sides of the lower arm of each subject using a semi-open test.¹⁷ After 24 hrs, the patches were removed and the skin replicas for both were taken by using a nitrocellulose disk coated with *n*-butyl acetate. Figure 1(a) and (b) show the attachment of test samples and control substance on the lower arm and the application of skin replica respectively.

The skin replicas were viewed under a microscope with a 50 × magnification and observed for deepened skin furrows which occur the most frequently even on subtly irritated skin. The degree of skin irritancy was judged by the help of a dermatologist on the basis of criteria to calculate the B-score. In Kawai's method, B-score is defined as the number of subjects who show deepened skin furrows for more than 50% of the area of the replica from the control substance, subtracted from the number of subjects who exhibit the same reaction from the test sample. Criteria for its grading are presented in Table 1. If the B-score is estimated at approximately zero, the test sample can be graded as negative, which means it is not expected to cause any weak skin irritancy.¹⁷

Evaluation of atopic dermatitis severity

In order to investigate the effects of the citrus-dyed underclothes on atopic dermatitis, the SCORAD index,^{19,20} the most commonly used scoring system

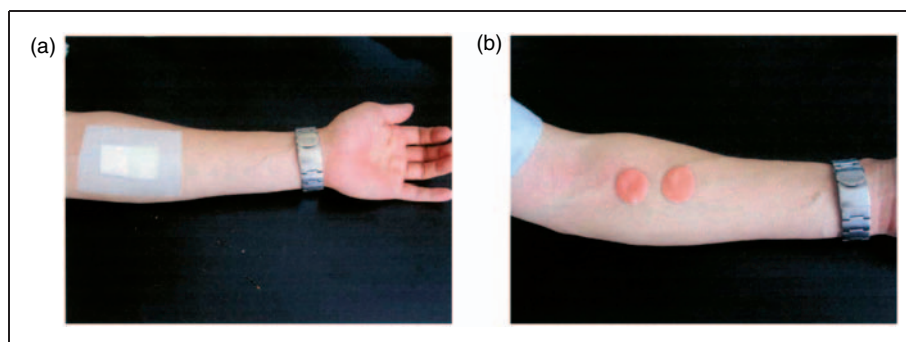


Figure 1. Irritant application and obtaining skin replica: (a) test sample and control substance; (b) skin replica disks.

Table 1. Criteria of skin irritancy grading

Range of B-score	Dermal reaction	Grading
B-score ≤ 0	No change	Negative
$1 \leq \text{B-score} \leq 2$		Grade 1 (almost negative)
B-score = 3	Loss of the triangle configuration of the skin furrow pattern for one or more subjects Macroscopic inflammatory changes such as redness, swelling, etc.	Grade 2 (almost positive)
B-score ≥ 4		Grade 3 (positive)
		Grade 4 (positive macroscopically)

for measuring the severity of atopic dermatitis, was employed in a wear test. Twin male brothers (age 4 years) having severe atopic dermatitis were invited as subjects because they were relatively more liable to be controlled under the same conditions of daily lives to each other. They had had severe cases of atopy dermatitis along with prurigo nodularis since they first showed a dermal disorder two years ago. The doctor had not reported any improvement of their dermal health ever since. The authors informed their parents of the experimental procedures and obtained consents from them. Each of the subjects was requested to wear the suits of the dyed underclothes as test garments next to skin. They were each supplied with three suits to be changed daily and worn for four weeks. After four repetitions of laundering, each of the test garments was dyed again with the citrus extract, as previous in-vitro tests¹⁴ showed the dyed cotton remained antimicrobial against *S. aureus* for up to five laundering repetitions. The clinical activity of skin lesions was established using the SCORAD index every week by their medical doctor in charge. Figure 2 shows body sections for calculating SCORAD. The SCORAD index is a composite score based on three subscores as follows:

A = the extent score based on body surface area calculated from 0 to 100%.

B = Intensity score based on 6 clinical findings in atopic dermatitis graded on a scale of 0 to 3.

(0 – absent, 1 – mild, 2 – moderate, 3 – severe). The maximum subjective score is 18.

C = the score for pruritus and sleep loss graded on a visual analog scale of 0 to 10. The maximum subjective score is 20.

$$\text{SCORAD} = A/5 + 7(B/2) + C \quad (1)$$

SCORAD values in test garments were compared with those in another four-week term before the subjects wore the test garments. The subjects were instructed to be under the same conditions of daily life such as clinical treatment, dietary, laundry, and bathing except their inner clothes in that the test underclothes dyed with unripe *Citrus grandis* Osbeck extract were worn during four week-test term whereas undyed cotton underclothes were worn during the former four week-control term.

Reduction rate of SCORAD of each week in the test period was calculated for each subject as follows;

$$R(\%) = (C - T)/C \times 100 \quad (2)$$

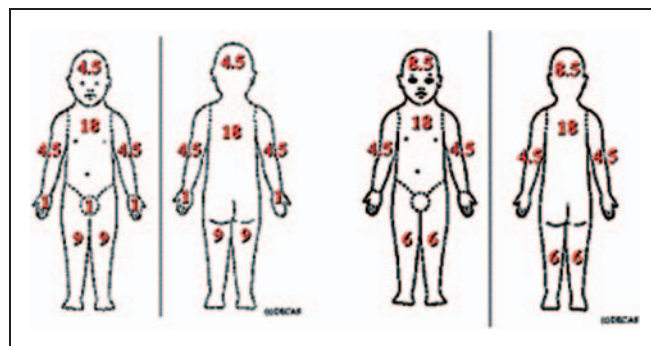


Figure 2. Body sections and area ratio for SCORAD.

Where R is the percentage reduction of SCORAD value; C is mean of SCORAD in the control period, and T is the SCORAD value for each week in the test period.

Statistical Analysis

In order to figure out the significant differences in SCORAD values of human subjects between test garments and control garments, paired t-test was used.

Results and Discussion

Effect of *Citrus grandis* Osbeck Extract on Skin Irritancy

After the irritancy patch testing, each subject was observed both microscopically and macroscopically in terms of several skin surface changes including round ridges, the appearance of deepened skin furrows, membranous desquamation, and loss of normal triangular configuration of the skin furrow pattern. Table 2 presents the observation results from both visual and microscopical examination of each subject after patching. First, no visual inflammatory changes, such as erythema and edema, were found on the skin of any subject. This means that the extract of unripe *Citrus grandis* Osbeck does not appear to cause visual skin irritancy. For the purpose of medicinal application of the citrus dyed textiles, we also investigated if it may cause any weak and invisible dermal reaction for skin safety. With a microscope, the skin replica from each of the subjects was observed in terms of the appearance of deepened skin furrows because they are the most sensitive change which occurs on the skin after irritant application.¹⁷ The results showed there were no skin furrow changes on the skin replicas for both tested samples and control substances from any of the subjects except for one, Subject 17, as given in Table 2. He was evaluated as '− + ' because he showed deepened skin furrows for less than 25% of the area of his skin replica from the test sample whereas there were no changes in the replica

Table 2. Skin irritancy evaluation by Kawai method for unripe *Citrus grandis* Osbeck extract

Subject No.	Microscopic Evaluation		Visual Evaluation
	Control Substance	Test Sample (Unripe <i>Citrus grandis</i> Osbeck extract)	
1	—	—	No change
2	—	—	
3	—	—	
4	—	—	
5	—	—	
6	—	—	
7	—	—	
8	—	—	
9	—	—	
10	—	—	
11	—	—	
12	—	—	
13	—	—	
14	—	—	
15	—	—	
16	—	—	
17	—	− +	
18	—	—	
19	—	—	
20	—	—	

— means no skin furrow change

− + means skin furrow deepened and widened up to 25% of the area

+ − means skin furrow deepened and widened 25% – 50% of the area

++ means skin furrow deepened and widened more than 50% of the area

from the control substance. Figure 3 shows skin replicas of a subject who presented no loss of the triangular configuration of the skin furrow patterns for both control and test sample. Therefore the number of subjects who showed deepened skin furrows for more than 50% of the area of the replica from the control substance was zero and the number of subjects who exhibit the

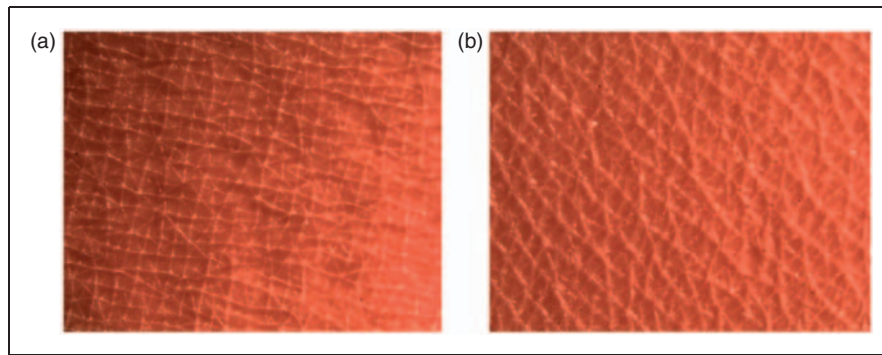


Figure 3. Photographs of skin replicas from a subject who showed no change in the furrow pattern: (a) control substance; (b) test sample.

same reaction from the test sample was also zero because the only subject who showed a little skin furrow as deepened for less than 25% of the area was not counted for test sample. Finally the B-score for the unripe citrus extract was calculated to be zero and the judgment rank of skin irritancy was concluded to be negative for unripe *Citrus grandis* Osbeck extract. This indicates that extract of *Citrus grandis* Osbeck would rarely cause even weak skin irritancy on humans and furthermore it may be safe even to dermal patients with high susceptibility to irritants which come into contact with their skin.

Effect of wearing underclothes dyed with citrus grandis osbeck extract on atopic dermatitis

Figure 4 shows body sectional photographs of both subjects in the control garment period and in the test garment period. As for subject I, severe erythema and edema were observed on his abdomen, inner arm, and anal region when he wore control garment. Since wearing the test garment dyed with the citrus extract, he has been in better state of dermal health as shown in his body sectional photographs. Subject II had much severer excoriations as well as erythema and edema on his abdomen, inner arm, and ankle area before the test garment was applied on him. However as shown in the photographs, his dermal lesions for each body section were alleviated considerably since the commencement of use of the test garment. From the photographs, it was expected that the quantitative SCORAD values would be lower for both subjects when wearing the test garment.

To evaluate the SCORAD index, three subscores A, B, and C for each subject were obtained every week for both the control and the test garment as given in Table 3. For subscore A, subject I and II showed 68.30 and 68.10, respectively, at the end of the first week with the control garment. Each of them correspond to the mean value for extent scores of body surface area showing atopic symptom such as erythema,

edema, crusting, etc. They also indicated that both subjects had such atopic symptoms over much of the extent of the body surface. During the period for the control garment, the two subjects presented a mean subscore A of 60.98 and 57.25, respectively. Subject I showed much lower subscore A for the later two weeks than for the former two weeks whereas subject II had more variation during the 4 week period. For subject II, his doctor stated that the skin lesions for him were aggravated with *pseudomonas aeruginosa* with unknown cause at that time. Therefore subscore A was likely to increase temporarily because atopy is very susceptible to virus, fungus, stress, and other unknown factors. On the other hand, in the period with the test garment, the first week scores for each subscore were measured at the end of the first week in which the subjects wore test garments. Therefore they were used to calculate the mean values in test garments. Since they wore the dyed underclothes as the test garment, subscore A tended to decrease gradually from 59.68 and 59.30 to 58.18 and 55.40, respectively, until they completed the third week. At the end of the last week with the test garments, their subscore A was 23.87 and 14.20, respectively. The decrease of subscore A for both subjects was assumed as being contributed to by the test garments dyed with extract of unripe *Citrus grandis* Osbeck because the other conditions such as medical care, dosage, dietary, and bathing were identical to the period with control garment use. Subject II whose score dropped dramatically to 14 at the end of the fourth week seemed to show more improvement than subject I. His subscore A showed an influence from the test garment. Finally the mean values of subscore A with test garments were 50.20 and 44.43, respectively, for each subject and they were much lower than their counterparts with control garments. This result indicates that the extent of area showing atopy symptoms decreased when the subjects wore the citrus-dyed underclothes.

Another subscore, B, is the intensity part of the SCORAD index consisting of six items: erythema,



Figure 4. Body sectional photographs of subjects in control and test conditions: (a) subject I in control, (b) subject I in test, (c) subject II in control, (d) subject II in test.

Table 3. Comparison of SCORAD Values Between Control and Test Garment

		Subscores						Total SCORAD		
		A		B		C				
Subject	Term	Control	Test	Control	Test	Control	Test	Control	Test	Reduction Rate of SCORAD (%)
I	1st	68.3	59.68	10	7	12	8	60.66	44	15.98
	2nd	68.52	59.08	4	6	9	6	46.3	40.12	23.39
	3rd	52.63	58.18	9	5	8	8	50.13	37.14	29.08
	4th	54.45	23.87	9	3	10	7	52.39	22.29	57.44
	mean	60.98	50.2	8	5.25	9.75	7.25	52.37	35.89	31.47
II	1st	68.1	59.3	16	6	17	10	86.22	42.46	36.27
	2nd	47.3	48.8	10	8	11	7	55.06	45.06	32.36
	3rd	48.59	55.4	10	7	10	8	54.7	43.08	35.33
	4th	64.99	14.2	13	7	12	7	70.5	34.34	48.45
	mean	57.25	44.43	12.25	7	12.5	8	66.62	41.24	38.10

A, the extent score; B, the intensity score; C, subjective sign.

edema/population, excoriations, lichenification, oozing/crusts, and dryness. Because each item can be graded on a scale 0–3, the maximum score is 18. At the end of the first week with the control garment, B scores

for both subjects were 10 and 16 respectively, which means that a subject with 16 was in a very severe state of atopic intensity. The mean values for subscore B with the control garment were 8.00 and 12.25 for two

subjects, respectively. Since subjects wore test garments, the score for subject I dropped to 7 at the end of the first week. Thereafter it decreased gradually and reached a value of 3. For subject II, the B score at the end of the first week in test garment became much lower than the period in the control garment and thereafter it was slightly higher than the first week. However, the mean of score B for subject II in the test garment was much lower than in the control garment. At the end of the period when the subjects wore the test garments, the scores resulted in 3 and 7 for both subjects, respectively. Mean scores for B were 5.25 and 7.00 which were much lower than those with the control garment. This means that the intensity of atopy dermatitis also decreased by wearing the dyed underclothes as well as the extent of area, indicated by subscore A, did.

The third subscore, C, was measured subjectively by the parents of the twins. It included daily pruritus and sleeplessness and its maximum score is 20. The mean values of C were 9.75 and 12.50 respectively for the two subjects when they wore the control garments whereas the counterparts with the test garments were lower (7.25 and 8.00). This indicates that the subjects showed less pruritus and sleeplessness when they wore the citrus-dyed underclothes than when they wore undyed clothes. In conclusion, all of the subscores for both subjects seemed to be lower on wearing the dyed underclothes compared to the undyed ones.

The final SCORAD values for both subjects were calculated every week and are also presented in Table 3. The maximum SCORAD that can be achieved is 103. Mean values of SCORAD for subject I when he wore undyed clothes were 52.37, which indicates that he was in a severe state of atopy (SCORAD ≥ 40).¹⁹ However as the subjects kept wearing the citrus dyed underclothes thereafter, they seemed to show much lower SCORAD values. Subject I had a mean SCORAD of 35.89 when he wore the dyed clothes, which means that he came into a moderate state (SCORAD = 15–40), especially during the last week that he wore the test garment, when he reached a SCORAD of 22.29. By t-test, there were significant differences in SCORAD values of subject I between the two wear conditions for control garment and test garment ($t = 2.92$, $p < 0.05$).

On the other hand, SCORAD mean values for subject II with control garments was 66.62 of which also indicates a severe state of atopy similarly to that of subject I. As he continued to wear the test garment, the mean SCORAD reduced to 41.24. There were significant differences in SCORAD between the control and the test garment for subject II by t-test ($t = 3.23$, $p < 0.05$) as well as for subject I. These means that SCORAD index values for both subjects were significantly lower with wearing test garments than with control garments.

In addition, the reduction rate of SCORAD for each week in the test period was calculated as a percentage value of the mean SCORAD value in the control period, as given in Table 3. Both of the subjects tended to show an increase in reduction rate of SCORAD during the test period as they continued to wear underclothes dyed with the citrus extract. Finally the reduction rates of SCORAD reached 57.44% and 48.45% respectively for each subject in the last week of the test period. Meanvalues for the SCORAD reduction rate were 31.47 and 38.10 for each subject during the test period. They correspond to a marked improvement of atopic dermatitis. From these results, it can be considered that the underclothes dyed with unripe *Citrus grandis* Osbeck extract gave significant effects on lowering SCORAD. These effects were considered to be related with the excellent antimicrobial function against *S. aureus* of cotton knit dyed with unripe *Citrus grandis* Osbeck extract as previously found.¹⁴

Conclusions

This study was performed in order to assess skin irritancy from the extract of *Citrus grandis* Osbeck, previously reported as showing antimicrobial activity on fabrics,¹⁴ and to evaluate the effects of cotton underclothes dyed with the citrus extract on atopic dermatitis via in-vivo methodology. By human patch testing, no skin irritancy caused by the extract was found microscopically, which means that the citrus extract seemed to have a potential to being safe as well as to not be an irritant on human skin. In a wear test with atopy patients, SCORAD values, a quantitative index for severity of atopy, were measured for control undyed clothes and the test dyed clothes. The results showed a remarkable decrease in SCORAD values for each subject by wearing next to skin-clothes dyed with the citrus extract compared to those when subjects wore undyed ones. These results lead to the conclusions that the citrus-dyed underclothes may help mitigate the skin condition in atopic patients. Moreover, it could be thought that antimicrobial efficacy of the dyed fabric against *S. aureus*, which was identified previously,¹⁴ may contribute further to a marked clinical improvement of atopic human skin by wearing the citrus-dyed clothes. Therefore dyeing of unripe *Citrus grandis* Osbeck extract could be utilized to develop functional textiles for improving dermal health.

This study has strong implications for informing medicinal efficacy of unripe *Citrus grandis* Osbeck extract on skin by in-vivo methods to evaluate skin irritancy and atopy severity which followed the verification of antimicrobial activity by in-vitro. This approach could be a useful starting point for this kind of future study to explore such skin-related

functions of textiles which other natural materials are imparted to. In a future study, durability of antimicrobial activity against laundering should be improved by applying other additives like chitosan, silver, and some non-toxic mordants as mentioned previously.¹⁴ In addition, more human subjects should be invited to participate in an in-vivo wear test in order to establish a more general interpretation on dermal effects of the citrus-dyed clothing.

Funding

The authors would like to thank the Korea Research Foundation which provided financial support for this work (KRF-2006-331-C00336).

References

- Kim T and Son Y. Effect of reactive anionic agent on dyeing of cellulosic fibers with a berberine colorant – part 2: Anionic agent treatment and antimicrobial activity of a berberine dyeing. *Dyes pigments* 2005; 64: 85–89.
- Gupta D, Khare S and Laha A. Antimicrobial properties of natural dyes against gram-negative bacteria. *Color Technol* 2004; 120(4): 167–171.
- Han SY and Yang Y. Antimicrobial activity of wool fabric treated with curcumin. *Dyes Pigments* 2005; 64: 157–161.
- Singh R, Jain A, Panwar S, Gupta D and Khare SK. Antimicrobial activity of some natural dyes. *Dyes Pigments* 2005; 66: 99–102.
- Park Y and Nam Y. The antimicrobial activity and deodorization of fabrics dyed with lithospermum radix extract. *J Korean Soc Clothing & Textiles* 2003; 27(1): 60–66.
- Ammayappan L and Moses JJ. Study of antimicrobial activity of aloe vera, chitosan, and curcumin on cotton, wool, and rabbit hair. *Fibers Polym* 2009; 10(2): 161–166.
- Shin Y and Cho E. Dyeing properties of cotton fabric with pomegranate colorants and antimicrobial properties. *J Korean Soc Clothing & Textiles* 2001; 25(3): 577–585.
- Kim B and Song W. The dyeability and antimicrobial properties of dryopteris crassirhizoma. *J. Korean Soc. Clothing & Textiles* 2001; 25(1): 3–12.
- Kim JH. Current understanding of atopic dermatitis. *Pediatric Allergy and Respiratory Disease* 2004; 14(2): 12–23.
- Mason R. Fabrics for atopic dermatitis. *J. Family Health Care* 2008; 18(2): 63–65.
- Hermanns J, Goffin V, Arrese J, Rodriguez C and Pierard G. Beneficial effects of softened fabrics on atopic skin. *Dermatology* 2001; 202(2): 167–170.
- Ricci G, Patrizi A, Bellini F, Mandrioli P, Specchia F, Medri M, Menna G and Masi M. Evaluation of the antimicrobial activity of a special silk textiles in the treatment of atopic dermatitis. *Dermatology* 2006; 213(3): 224–227.
- Hatch KL. Fabrics and sensitive skin, in “sensitive skin syndrome. In: Berardesca E, Fluhr JW and Maibach HI (eds) New York: Taylor & Francis, 2006, Ch.16, pp.193–213.
- Yi E and Yoo ES. A novel bioactive fabrics dyed with unripe citrus grandis osbeck extract, part 1: dyeing properties and antimicrobial activity on cotton knit fabrics. *Textile Res J* (accepted).
- Zollner TM, Wichelhaus TA, Hartung A, Mallinckrodt C, Wagner TOF and Brade V. Colonization with superantigen-producing staphylococcus aureus is associated with increased severity of atopic dermatitis. *Clin Exp Allergy* 2000; 30: 994–1000.
- Bunikowski R, Mielke MEA, Skarabis H, Worm M, Anagnostopoulos L and Kolde G. Evidence for a disease-promoting effect of staphylococcus aureus-derived exotoxins in atopic dermatitis. *J Allergy Clin Immunol* 2000; 105: 814–819.
- Kawai K. Kawai method for testing irritation. In: Marzulli F, Zhai H, Maibach HI and Wilhelm K (eds) “Marzulli and Maibach's Dermatotoxicology”. CRC Press, 2007, Ch.45, pp.391–399.
- Kawai K. Microscopic evaluation of the patch test (kawai's test). *J Japan Res Assoc Textile End Uses* 1995; 36(3): 6–10.
- Charman C, Chambers C and Williams H. Measuring atopic dermatitis severity in randomized controlled clinical trials: what exactly are we measuring? *J Investigative Dermatology* 2003; 120(6): 932–941.
- Bhor U and Pande S. Scoring systems in dermatology. *Indian J Dermatol Venereol Leprol* 2006; 72(4): 315–321.