Enzyme Finishing of Natural Polyamide Fabric Using Transglutaminase

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INTRODUCTIONS

Utilizations of enzymes have been popular in the development of the textile processing technologies in these decades. Various kinds of technologies in the textile industry utilizing enzymes have been developed and some of them have been already practically applied. Most of the technologies developed and applied, however, are related to the enzymatic degradation of textiles aiming to obtain softer handle of the textiles or to perform effective degradation treatment of the textile dyeing effluents. Very few studies concerning the utilization of the enzymes that catalyze chemical bond formation reaction such as transferases have been found in the field of textile engineering [1].

Recently, Cortez et al. [2], reported that transglutaminase (TGase) treatment of shrink proofed (chemically oxidized) wool fabric brought about an increase of the tensile strength by forming cross-linkages, and the treated wool fabric showed the less damages from the proteases attacks during domestic laundry. Transglutaminase (TGase) are a family of enzymes that catalyze acyl transfer between the γ-carboxyamide groups of glutamine residues within peptides and the ε-amino group of lysine residues, resulting in the formation of (ε-γ-glutamyl) lysine cross-linkages.

In this paper, enzymatic cross-linking finishing of natural polyamide fabric, regular (unprocessed) silk and wool, using a transglutaminase (TGase: protein-glutamine γ-glutamyl-transferase, EC 2.3.2.13) with or without certain assistant substance (secondary substrate) that helps the cross-linking reaction of the TGase in such a case as silk that contains insufficient amount of lysine and glutamine residue has been investigated.

EXPERIMENTALS

Materials

Silk and wool fabric used was a woven fabric that was provided for an adjacent fabric for color fastness testing (JIS L 0803, silk: warp 21D 276/5cm, weft 21D/2 192/5cm; wool: warp 19tex 142/5cm, weft 15tex 136/5cm).

Transglutaminase preparation (Ajinomoto Co., Inc., 1150U/g) used in this study was a mixture of transglutaminase isolated from *Streptomyces mobaraensis* and maltodextrin as stabilizer.

Various kinds of partially hydrolyzed protein were added on silk as a secondary

substrate (spacer). The hydrolyzed proteins added are as follows;

(A) Glutamine peptide A; enzymatic digest of wheat gluten, WGE 80GPU (9.65kDa), DMV International
(B) Glutamine peptide B; enzymatic digest of wheat gluten, WGE 80GPA (0.66kDa), DMV International
(C) Gelatin; alkaline hydrolyzed bovine protein (100kDa), Kishida Chemical Co., Ltd.
(D) Casein; from milk, Kishida Chemical Co., Ltd.

All other chemicals used in this study were reagent grade.

Methods

Silk and wool fabric was treated with a partially hydrolyzed protein before the TGase treatment in order to provide a sufficient amount of lysine and glutamine residue by immersing 1g of the fabric specimen in 200mL of the aqueous protein solution (conc. 0-10g/L) at 40°C for 1 hour. TGase treatments were then carried out by incubating the fabric in 100mL of Tris-HCl buffer pH7 containing 100mg/L of TGase at 40°C for 1 hour.

The tear strengths (warp) of the treated fabrics were measured following JIS L 1096 D-method (falling pendulum method). The measurement was carried out in each case with at least three or more samples and the average value of them was taken.

RESULTS AND DISCUSSIONS

Tear strength of TGase treated silk

The tear strengths of TGase treated silk fabrics that are pretreated with or without partially hydrolyzed protein are shown in Figure 1. The partially hydrolyzed protein pretreated on silk prior to the TGase treatment is glutamine peptide A (9.65kDa), enzymatic hydrolyzate of wheat protein, which contains remarkable amount of glutamine and lysine residues. As can be seen from the figure 1, the tear strength of the TGase treated silk in the presence of glutamine peptide increases remarkably with increasing the amount of pretreated glutamine peptide on the silk fabric, whereas silk fabric treated with TGase without adding the glutamine peptide shows only slight increase in the tear strength. In addition, a washing experiment revealed that the increase of the tear strength of silk by the TGase treatment is stable after the three times of warm water washings.

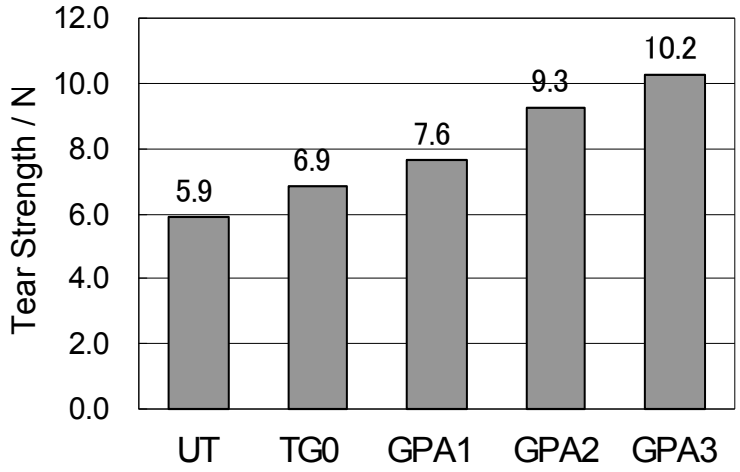

Figure 1. Tear strengths of TGase treated silk fabrics that are pretreated with or without partially hydrolyzed protein. UT:untreated silk (control); TG0:TGase treated silk without partially hydrolyzed protein; GPA1:TGase treated silk that is pretreated with 1g/L of glutamine peptide A; GPA2: TGase treated silk that is pretreated with 10g/L of glutamine peptide A; GPA3: TGase treated silk that is pretreated with 20g/L of glutamine peptide A.

These results indicate that TGase acts effectively to silk fabric that is pretreated with partially hydrolyzed protein and remarkable cross-linkages may form within the silk fabric and also with the added protein. The partially hydrolyzed protein (glutamine peptide A in this case) added on silk may act as an effective spacer for the enzymatic cross-linkage formation. Thus, it is obvious that TGase can be used to enhance the tear strength of silk, if the silk is properly pretreated with partially hydrolyzed protein to provide enough amount of glutamine or lysine residue as a cross-linking spacer. This enzymatic action can also be expected to solve the problems of silk such as scuff and fibrillation by friction.

Figure 2 shows the searching results of the actions of several peptides as a spacer for the TGase cross-linking on silk. The figure 2 indicates that peptide obtained from wheat protein by the enzymatic hydrolysis, glutamine peptide A (GPA) that has relatively large molecular size (9.65kDa), shows an excellent action as a spacer to increasing the tear strength of silk. The larger molecular size of spacer may provide the more possibilities to be a cross-linking site on the silk fabric. On the other hand, gelatin and casein obtained from the other protein sources shows fair or poor action as a spacer, indicating that these proteins, although the molecular size of which are large, provide less cross-linking site as a spacer than glutamine peptide.

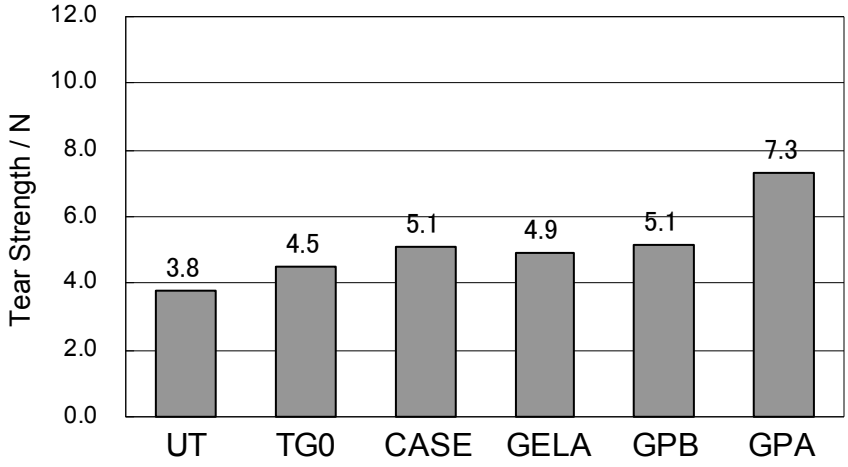

Figure 2. Tear strengths of TGase treated silk fabrics that are pretreated with or without partially hydrolyzed protein. UT:untreated silk (control); TG0:TGase treated silk without partially hydrolyzed protein; CASE:TGase treated silk that is pretreated with 10g/L of casein; GERA: TGase treated silk that is pretreated with 10g/L of gelatin; GPB: TGase treated silk that is pretreated with 10g/L of glutamine peptide B; GPA:. TGase treated silk that is pretreated with 10g/L of glutamine peptide A. The difference in the tear strength data of the two UT (control)'s between in Figure 1 and Figure2 is caused by a lot number difference of the silk fabrics.

From the results as shown above, it can be concluded that the action of TGase on tear strength of silk is remarkable if there is an appropriate protein or peptide as a spacer. The spacer may provide sufficient cross-linking site for TGase on the silk fabric. It is worth to note that the tear strength of silk can be enhanced up to two times as strong as the original if the suitable spacer is applied prior to the TGase treatment.

Tear strength of TGase treated wool

The tear strengths of TGase treated wool fabrics with or without spacers are shown in Figure 3. In the case of wool fabric, negligible effects of the TGase treatment on the tear strengths are found even if several types of spacer have been tried prior to the TGase treatment. Water repellent scale (cuticle) of wool may be a barrier for the penetration of TGase into the wool substrate.

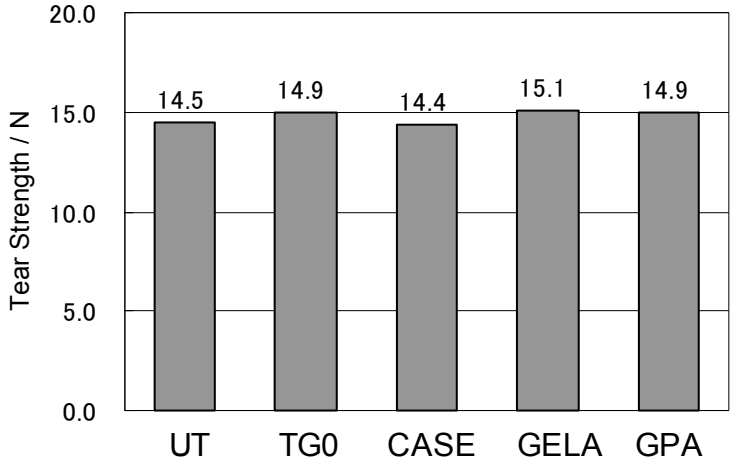

Figure 3. Tear strengths of TGase treated wool fabrics that are pretreated with or without partially hydrolyzed protein. UT:untreated wool (control); TG0:TGase treated wool without partially hydrolyzed protein; CASE:TGase treated wool that is pretreated with 10g/L of casein; GELA: TGase treated wool that is pretreated with 10g/L of gelatin; GPA: TGase treated wool that is pretreated with 10g/L of glutamine peptide A.

CONCLUSIONS

TGase treatment of silk showed remarkable increase in tear strength when the silk was pretreated with partially hydrolyzed protein that act as a spacer to provide more cross-linking site, whereas TGase treatment alone showed only slight effect. This effect was stable to multiple washings, which indicates that the TGase would catalyze the cross-linkage reaction within silk. This action of TGase can be utilized for the enhancement of the strength of silk and for the improvement of scuff and fibrillation problems of silk by friction.

TGase treatment of wool, on the contrary, did not show any remarkable effect in the tear strength. The scale of wool may be a barrier for the penetration of TGase into the wool substrate.

REFERENCES

[1] S. V. Gembeh, et al., J. Sci. Food Agric., **85**, 418 (2005)
[2] J. Cortez, et al., J. Biotech., **116**, 379 (2005)