How to distinguish fiber materials

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We have been researching methods to identify fibers. We discovered a physical and chemical method of distinction.We did experiments of water absorption as a physical method and fluorescent paint as a chemical method.Physical method based on water absorption can be used for immediate identification, but it is considered to be greatly affected by temperature and humidity. Chemical method using fluorescein, which reacts with proteins, showed a clear difference even with a small amount of specimen.

1 Background

It is difficult to determine the material of a fiber, and it is necessary to have a good eye of a craftsman in a kimono store. It is possible to determine the material by burning the fiber, but this method is also based on the senses and is not reliable. In addition, it is difficult to identify in second-hand shops by burning because of the loss of fibers. In particular, many second-hand shops, unlike traditional kimono stores, do not have advanced identification technology, and fiber identification has become one of the issues. If it becomes possible to identify fibers easily and at low cost, the recycling of fibers can be promoted. Therefore, we aimed to find a low-cost method of fiber identification that has a scientific basis. Silk and polyester fibers are mostly used for kimonos. In addition, it is difficult to distinguish between silk and polyester only by feel. For this reason, this study explores a method to reliably distinguish between silk and polyester using two types of experiments. In this study, we assume that the fibers are not blended and that no surface treatment such as water repellent treatment was applied.The general properties of silk and polyester are summarized here. Silk is a natural fiber made from silkworm cocoons, and is light and strong, but relatively expensive. Polyester fiber, on the other hand, is classified as a chemical fiber, and is a polycondensation product synthesized by dehydrating and condensing polyvalent carboxylic acids (dicarboxylic acids) and polyalcohol (diols) to form ester bonds. In general, it is less expensive than silk. In this study, silk and polyester fibers were used for dyeing experiments. In this study, we used silk fibers and polyester fibers for dyeing experiments so that we could compare them without any surface treatment such as water repellent treatment.

2.1 Experiment 1: Distinction by Dropping Method

Two experiments were conducted. The drop method is a kind of fiber identification method using the difference in water absorbency.

The drop method is a type of fiber distinction method that uses the difference in water absorbency. Measure the time it takes for a drop of water to be absorbed by a fiber specimen. Here, we defined "absorbed" as the time when the specular reflection of the water drop disappears. Specular reflection is a state in which light reflects off the water droplet, giving it a glossy appearance (Fig. 1). When the specular reflection disappears, the gloss of the water droplet disappears and only wetness remains on the specimen. In this experiment, water droplets were dropped using a pipette.

Fig. 1 State of specular reflection

Water droplets were dropped from a certain height, and the time until the specular reflection of the water droplets disappeared was measured with a stopwatch. The test was performed three times for silk and polyester fibers, respectively. The average time is shown in Fig. 2.

Fig. 2 Results of the drop method

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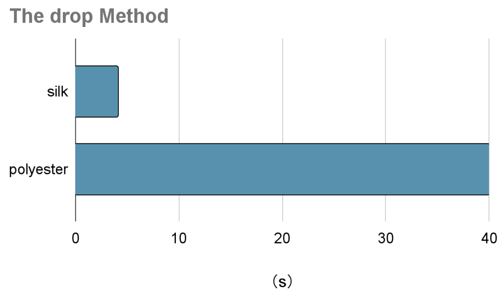

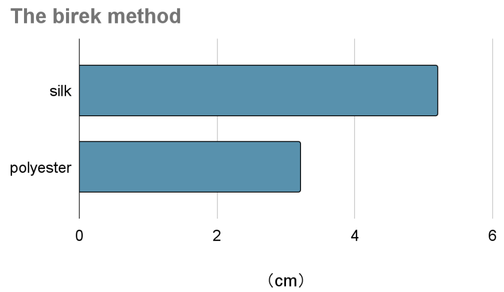

The absorption time for polyester was 30.4 seconds, while the time for silk was 4.1 seconds. This result indicates that there is a significant difference in water absorbency between polyester and silk fibers, and it was possible to distinguish between them. However, since only one drop was applied, it is considered to be greatly affected by temperature and humidity. In addition, it is difficult to discriminate fibers with water-repellent finishes. Therefore, the drop method is very effective for the identification of fiber specimens, but it is not suitable for the identification of fibers whose surface treatment is unknown. On the other hand, the drop method provides immediate results and can be used for experimental verification.

2.2 Experiment 2: Determination by the Birek method

The Birek method was also used to determine the water absorbency. In this method, a fiber specimen is hung and its lower end (3 mm) is immersed in water, and the height of water absorbed by the fiber after a certain period of time is measured (Fig. 3). In this experiment, we measured the height of the water that rose after being left for 10 minutes. This was done three times each for silk and polyester fibers, and the average is shown in Fig.4.

Fig.3 The Birek method

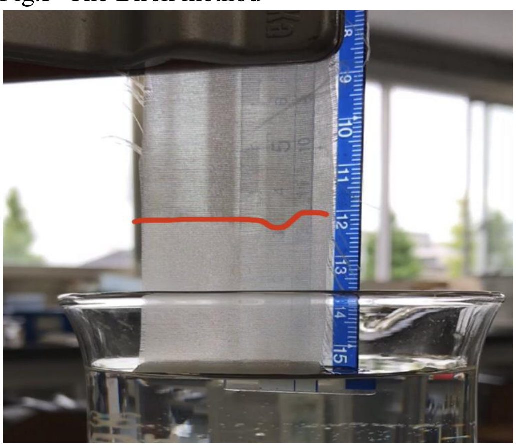

Fig. 4 Results of the Birek method

The results showed that there was a difference between silk and polyester fibers, but it was not as remarkable as that of the drop method. Therefore, it can be said that it is moredifficult to identify fibers by the Birek method.

2.3 Discussion

The drop method can be used to identify between silk and polyester fibers in terms of water absorbency. However, since these methods are greatly affected by temperature and humidity, the drop method is not always a reliable method. Therefore, it is necessary to establish a method that is not affected by temperature and humidity.

3.1 Experiment 3: distinction by dyeing

It was not possible to discriminate fibers reliably by water absorbency because of the large influence of the environment. Therefore, we thought that a fluorescent paint that reacts to silk fibers could be used as a reliable method of identification without being affected by the environment.
In this experiment, fluorescein was used as a fluorescent paint (Figs. 5 and 6). Fluorescein is a fluorescent paint that reacts to proteins, and silk contains proteins. Therefore, only the silk fibers would be stained by immersing the silk fibers in fluorescein solution. In this experiment, the fibers were soaked in saturated fluorescein solution for 20 minutes, washed with water, and then checked to see if they were stained. The results are shown in Fig.7.

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Fig. 5 Structural formula of fluorescein aqueous solution

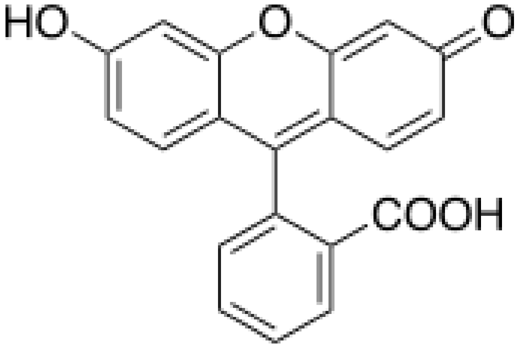
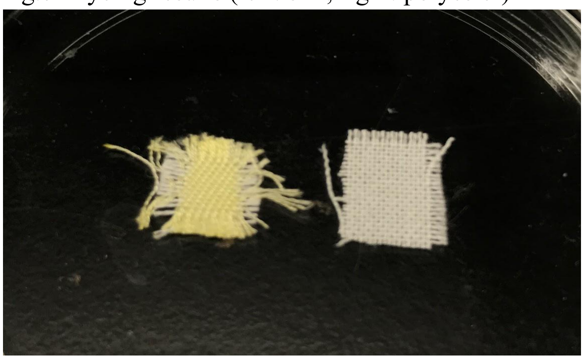


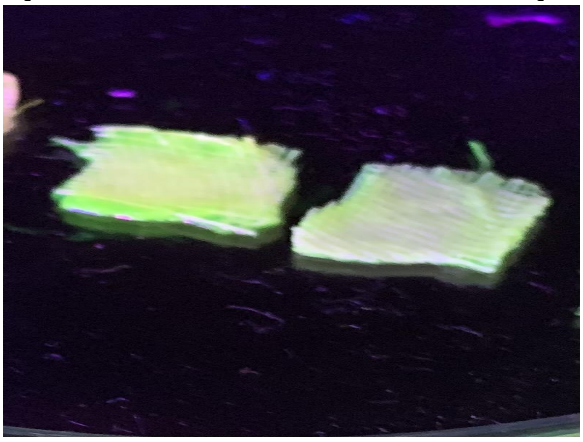
Fig. 6 Fluorescein aqueous solution

Fig.7 Dyeing results (left: silk, right: polyester)



When we immersed in fluorescein solution, the silk fibers were dyed, but the polyester fibers were not. When the dyed silk was exposed to UV light, yellow fluorescence was observed (Fig. 8).

Fig. 8 Silk fiber that fluoresces under ultraviolet light



3.2 Discussion

Fluorescein contains a carboxyl group.The carboxyl group reacts with the amino group ($-NH_2$) to form an amide bond, which fluoresces when irradiated with ultraviolet light.

Silk fiber contains lysine, an amino acid, which contains an amino group. Therefore, it is thought that the carboxyl group of fluorescein and the amino group of silk could form an amide bond, resulting in fluorescence when irradiated with UV light.Since the fluorescence is induced by ultraviolet light, it is possible to identify even colored fibers such as kimono, and it is considered to be an effective method for practical use. Furthermore, the method is not affected by environmental conditions such as temperature and humidity, so it has the advantage of providing stable results.

4.1 Experiment 4: pH change of fluorescein

In Experiment 3, we used fibers for dyeing experiments. When we conducted experiments using commercially available silk and polyester fibers, we found that the dyeing was light and difficult to distinguish. Therefore, we thought that changing the pH of the fluorescein solution would change the ease of dyeing, and conducted experiments. By diluting hydrochloric acid and sodium hydroxide solution with fluorescein solution, we prepared fluorescein solutions with pH adjusted to 2, 4, 7, 10, and 12. Using these solutions, we performed the same procedure as in Experiment 3. The results are shown in Fig. 9.

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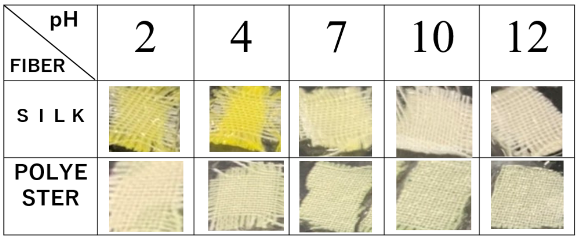
Fig. 9 Difference in fiber dyeing due to pH change

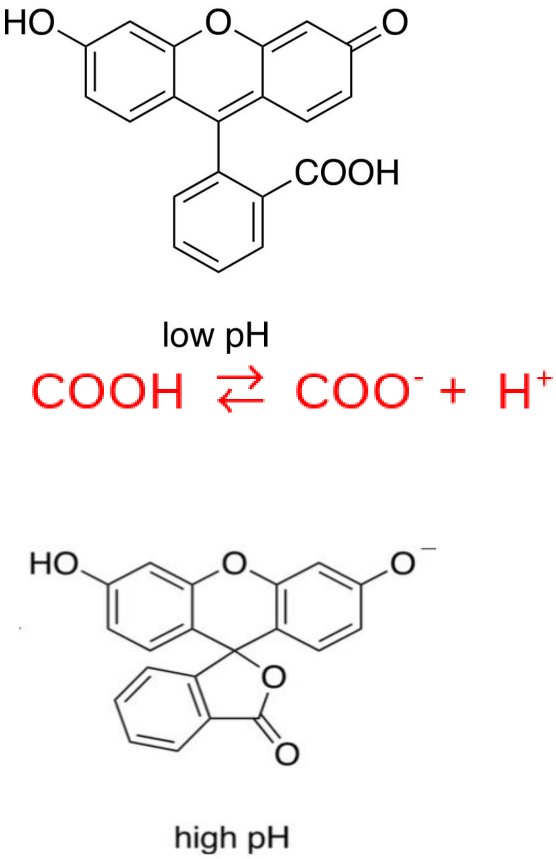


When the pH of fluorescein solution was 2,4, silk fiber reacted remarkably. Polyester fibers did not react with the fluorescein solution at any pH.

4.2 Discussion

The fact that the reaction was more pronounced when the pH of the fluorescein solution was low suggests that hydrogen ions are involved in the staining reaction. Fluorescein has a carboxyl group, which is ionized in aqueous solution (Fig. 10), and when it is ionized, it does not bind to ricin and does not stain. The following ionization equilibrium is established for the carboxyl group in aqueous solution.

Fig. 10 Ionization of fluorescein



Therefore, according to Le Chatelier's principle, the carboxyl group is maintained when the concentration of hydrogen ions is high.In conclusion, it is thought that the lower the pH, the easier it is to stain.

5 Conclusion

This study has shown that the drop method can distinguish fibers immediately except for water-repellent fibers. We also succeeded in distinguishing between silk and polyester by using fluorescein. Furthermore, by lowering the pH of fluorescein, it was possible to distinguish fibers, even commercially available silk fibers. These methods are expected to be commercially valuable in second-hand shops.

6 Future work

We try to research the case of water-repellent,woven and blended fibers.
We used to utilize two fibers,so we will do other types of fibers.

7 Acknowledgment

I would like to express my sincere gratitude to the teachers and the staff of the Tohoku University GLC for their support in this research.

8 References

(1) "Passing on and Transmitting Traditional Culture through Upcycling of Kimono Fabrics: Improving Product Appeal by Identifying Kimono Fabric Materials" WATALIS Corporation (2019.1.18)
(2) "Evaluation Test Methods for Functional Materials" Boken Quality Evaluation Organization
3) "Under What Conditions Does Fluorescein Glow Well?" Ryoya Hiraoka, Takuro Oshima
4) "distinction of Fibers Using Dyes - Dyeing of Protein Fibers with Bromocresol Purple" Noriyuki Matsuura (2017)
5) "Chemistry and Material Development of Silk" Yasushi Tamagawa, Faculty of Textile Science and Technology, Shinshu University (2016)
6) "Composite Particles for Capture or Separation of Biological Materials" ekouhou.net (2011.12.1)