Synergic Effects of Surfactant and Chelating Agent on Stubborn Keratin Grime for Easy Cleaning

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Abstract: We report on the synergic effect of surfactants and chelating agents on the mechanism to remove stubborn keratin grime (keratin-Ca), which is bound with calcium ions and one of the most difficult grimes to remove, in order to make it easier to clean bathtubs in less time and with less scrubbing. Our approach was to focus on keratin swelling, which we achieved by applying aqueous solutions with chelating agents and anionic surfactants, the combination of which greatly improved the swelling ratio, resulting in quick, easy removal of keratin-Ca with water rinsing and little scrubbing. For the swelling process, we added chelating agents and anionic surfactants to swell the keratin-Ca by both capturing calcium ions and improving solution permeation. Furthermore, we measured the structural change of the keratin-Ca during swelling by TD-NMR and confirmed that a certain combination of chelating agent and anionic surfactant improved swelling by affecting not only the amorphous part such as the keratin matrix, but also the crystalline part such as the intermediate filaments (IFs).

Key words: bathtub grime, keratin, easy cleaning, swelling, wettability, penetration, anionic surfactant, chelating agent

1 Introduction

Detergents play an important role in keeping our living environments clean and hygienic, and are appropriately designed according to the type of soil and soiled material: clothes, dishes, bathrooms, etc. Soils are generally classified into three types: water-soluble soils, oily soils, and particulate soils, and they are washed efficiently by emulsification and dispersion with surfactants. Furthermore, it is well known that chelating agents improve detergency when cleaning with hard water. Calcium ions in water not only combine with surfactants to reduce cleaning performance but also form stubborn soil called scum, making it necessary to chelate Ca ions to prevent this.

Most modern unit baths are made of fiberglass reinforced plastics (FRP), whose surface is hydrophobic. Hydrophobic soils such as sebum and stratum corneum from the body are easily and firmly adsorbed onto the bathtub surface, resulting in the surface appearing rough. It has been reported that the main component of such soils is insoluble keratin, so we presumed that this keratin would be keratin calcium (keratin-Ca) combined with calcium ions in tap water, making it more hydrophobic and promoting adhesion to the bathtub. In order to remove this keratin-Ca, it is essential to use a detergent combining surfactants and chelating agents and apply strong mechanical force. Although excellent formulae with higher detergency against keratin-Ca have been developed, at present, they have not reached the stage where keratin-Ca can be removed quickly with little mechanical force, such as during a shower. Therefore, we focused on the swelling of insoluble keratin to achieve efficient, residue-less cleaning without lengthy washing and strong mechanical force such as scrubbing. In this paper, we report on the contribution of swelling to the keratin-Ca removal process and the effect of surfactants and chelating agents on that swelling. We also identified the basics of the optimal keratin-Ca cleaning composition and evaluated the effect of surfactants and chelating agents on the keratin-Ca structure during the swelling process.

2 Experiment

2.1 Materials

Keratin from wool was obtained from Tokyo Chemical Industry Co., Ltd. Calcium chloride dehydrate was purchased from FUJIFILM Wako Chemicals Co., Ltd. All pH adjusters such as hydrochloric acid (HCl) solution and...
sodium hydroxide (NaOH) solution and all chelating agents such as ethylenediaminetetraacetic acid (EDTA), diethylaminoethylenediamine pentaacetic acid (DTPA), triethylenetetramine-N,N,N',N'',N'''-hexaacetic acid (THA), nitrilotriacetic acid (NTA), and N-(2-hydroxyethyl) ethylenediamine-N,N',N'''-triacetic acid trisodium salt hydrate (HEDTA) were obtained from Kanto Chemical Co., Inc. Anionic surfactants such as α-olefin sulfonate (AOS, LIPOLAN PJ-441), linear alkylbenzene sulfonate (LAS, LIPON PS-230), and sodium dodecyl sulfate (SDS, SANNOR LM-1130) were supplied by Lion Specialty Chemicals Co., Ltd. Methyl ester sulfonate (MES) was synthesized in-house. Diethylene glycol monobutyl ether (DEMB) was purchased from Nippon Nyukazai Co., Ltd. as a solvent.

2.2 Preparation of keratin calcium (keratin-Ca) salt

In preparation for keratin-Ca, we used keratin from wool, which is classified as α-type, similar to human skin-derived keratin contained in bathtub grime. Keratin powder (5 g) and calcium chloride dehydrate (1.25 g) were added to deionized water (100 mL) and the mixed solution was adjusted to pH 7.0 using HCl and NaOH solutions. After stirring for 10 min at room temperature, keratin calcium salt was filtered and mixed with tap water with a hardness of about 60 ppm (600 mL) to wash it. After repeating this washing several times, keratin-Ca powder was obtained by freeze-drying.

2.3 Evaluation of detergency

2.3.1 Evaluation of detergency against actual bathtub grime

The FRP test pieces (10 cm × 10 cm) were attached to the bathtub surface and actual grime, which developed when three adult men took baths for 10 minutes each day for a total of 3 days, adhered to the test pieces. It has been reported that the main component of actual bathtub grime is protein such as keratin containing free fatty acids, triacylglycerols and fatty acid salts [16]. To evaluate detergency, the detergent solution (0.5 mL) was applied to the test pieces with bathtub grime for 1 min at room temperature and rinsed with deionized water for 10 seconds twice. The peak intensities of sulfur derived from keratin were quantified by fluorescent X-ray analysis (Rigaku, ZSX 100e), and the keratin removal efficiency was calculated from the difference in peak intensities before and after washing, using the following formula (Eq. 1):

\[
\text{Removal ratio of keratin (\%) } = \left( I_o - I \right) / I_o \times 100 \quad \text{(Eq. 1)}
\]

where \( I_o \) and \( I \) respectively indicate the peak intensities of sulfur on the test pieces before and after washing.

2.3.2 Evaluation of detergency against model bathtub grime

Model bathtub grime was prepared by mixing keratin-Ca (150 mg) and artificial sebum (7.5 mg) composed of oleic acid, triolein, cholesterol oleate, squalene, liquid paraffin, and cholesterol. This model was molded into pellets with 70 kgf/cm² compression. After the pellets were put into quartz glass cells, the detergent solution (5 mL) was gently poured, and the pellets’ morphology change was observed with a video microscope (KEYENCE, VHX-2000). After 90 seconds, the supernatant was rinsed with water and then residues were checked.

2.4 Determination of swelling ratio of keratin and keratin-Ca

All sample solutions were adjusted to the specified pH using HCl or NaOH solutions. Keratin or keratin-Ca powder (0.1 g) was mixed with each sample solution (2 mL), and the mixtures were left in a glass tube (Φ5 mm) until the powder precipitated. The initial volume of keratin or keratin-Ca (\( V_o \)) and the volume (\( V_e \)) after 6 hours at swelling equilibrium were estimated by measuring the height of the powder in the glass tube and the swelling ratio was calculated using the following equation (Eq. 2):

\[
\text{Swelling ratio (\%) } = \left( V_e - V_o \right) / V_o \times 100 \quad \text{(Eq. 2)}
\]

2.5 Measurement of the carboxylate groups in keratin-Ca applying chelating agents

In order to confirm the effect of the chelating agents to capture Ca ions from the keratin-Ca, the swollen keratin-Ca was freeze-dried and the IR spectrum derived from the carboxylate groups in the keratin-Ca powder was measured by FT-IR (PerkinElmer, Spectrum 100). Gaussian fitting was used for the curve fitting of the obtained spectrum.

2.6 Measurement of contact angle of keratin-Ca powder

To clarify the effect of the surfactant on the keratin-Ca swelling process, the contact angles of the keratin-Ca powder were determined using the Washburn method [17] in which the amount of liquid permeation into the powder bed over time is measured by tensiometer (KRUSS, K100). The permeation rate of the anionic surfactant (AOS, LAS, SDS and MES) solution with EDTA was obtained and the contact angle, \( \theta \), could be calculated from the Washburn equation (Eq. 3):

\[
\cos \theta = \eta (C \rho g \gamma l) / m^2 \eta \quad \text{(Eq. 3)}
\]

where \( C \) is the material constant, \( \rho \), \( \eta \) and \( \gamma \) are the density, viscosity, and surface tension of the liquid respectively, and \( m^2 \eta \) is the slope of the absorption curve with increasing liquid permeation. The material constant could be defined with a completely wetting liquid, like hexane, which gives a contact angle of zero.

2.7 Measurement of change in internal structure of keratin-Ca

Regarding the swelling process of the keratin-Ca powder
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(0.2 g) after applying sample solutions (4 mL, pH 10), the change in keratin-Ca’s internal structure was evaluated using the solid spin-echo method by means of time domain NMR spectrometer (Bruker, minispec Mq20). This method provides the relaxation time for the crystalline state on the order of 0.01 msecs and the amorphous state on the order of 0.1 msecs, and thus the changes in the crystalline and amorphous states of the swollen keratin-Ca were measured.

3 Results and Discussion

3.1 Relationship between keratin-Ca swelling and bathtub grime removal ratio

The relationship between the keratin-Ca swelling and bathtub grime removal ratio was evaluated in terms of swelling ratio and rate. Keratin-Ca’s swelling ratio and the bathtub grime removal ratio were determined with various detergents containing typical anionic surfactants, chelating agent, and solvent (Table 1). The sulfur removal ratio in actual grime increased with the swelling ratio of keratin-Ca as shown in Fig. 1, suggesting that the keratin-Ca swelling contributes to efficient cleaning of bathtub grime.

In order to clarify the relationship between the keratin-Ca’s swelling ratio and rate, changes in the swelling ratio over time when applying various detergents were investigated (Fig. 2). With a detergent showing effective swelling, the swelling ratio became high in a short time range. On the other hand, a detergent with little swelling effect had a low swelling ratio even in a short time range, clarifying that when the equilibrium swelling ratio is high, the swelling rate is also high.

In order to investigate keratin-Ca swelling in the washing process, the morphological changes in keratin-Ca pellets and the model bathtub grime, were observed. Typical detergent-caused morphological changes with a large or small

Table 1 Keratin-Ca powder swelling ratio and bathtub grime removal ratio with various detergents. Component of Formula A is water (pH 7) and Formulae B-G exhibit different compositions that combine anionic surfactant with chelating agent and solvent (surfactant 1 wt%, EDTA 2 wt%, DEMB 1.5 wt%, pH 10.0).

| Samples     | Main components | Swelling ratio / % | Removal ratio of sulfur / % |
|-------------|-----------------|--------------------|-----------------------------|
| Formula A   | water           | 54                 | 9                           |
| Formula B   | AOS, DEMB, water| 92                 | 12                          |
| Formula C   | EDTA, DEMB, water| 145               | 42                          |
| Formula D   | MES, EDTA, DEMB, water| 155             | 43                          |
| Formula E   | SDS, EDTA, DEMB, water| 185             | 51                          |
| Formula F   | LAS, EDTA, DEMB, water| 205             | 26                          |
| Formula G   | AOS, EDTA, DEMB, water| 218             | 56                          |
effect on keratin-Ca’s swelling ratio are shown in Fig. 3. With the high swelling ratio detergent, pellet volume increased immediately after adding the detergent. While partially collapsing from the surface, it swelled to a brittle and sparse state after 90 seconds (Fig. 3a). On the other hand, with the lower swelling ratio detergent, pellet volume increased very slightly and no significant change in its morphology was observed (Fig. 3b), suggesting that applying a detergent with a large effect on the swelling ratio has a higher swelling rate than applying a detergent with a small effect on the swelling ratio. When rinsed with water, the pellet with much swelling was easily removed from the cell, whereas that with little swelling remained attached to the bottom of cell. This revealed that a detergent with a large effect on the equilibrium swelling ratio causes rapid keratin-Ca swelling, resulting in a high removal ratio, while that with a small effect on the equilibrium swelling ratio causes hardly any swelling regardless of length of time, resulting in a low removal ratio.

3.2 Effects of chelating agents on keratin-Ca swelling

In order to investigate the difference in properties between keratin and keratin-Ca swelling, their respective swelling ratios were measured, which confirmed that when exposed to water, keratin swelled by about 80% and keratin-Ca swelled by only about 50% (Fig. S1). Therefore, binding calcium ions may contribute to preventing keratin swelling, suggesting that removing calcium is essential for keratin-Ca swelling. We evaluated the swelling ratio of keratin-Ca when applying aqueous solutions of various chelating agents at equilibrium swelling, and the keratin-Ca swelling ratio increased with the calcium ion stability constant, showing a strong correlation between the swelling ratio and the Ca stability constant of the chelating agent. EDTA was the most effective for keratin-Ca swelling (Fig. 4). When keratin-Ca powders were measured by FT-IR before and after applying an EDTA aqueous solution, the peak area derived from calcium salts decreased from 78% to 6% and that derived from carboxylate increased from 22% to 94%, confirming that EDTA captures keratin-Ca calcium ions and converts keratin-Ca to keratin (Fig. S2) and suggesting that keratin-Ca swelling is caused by the stronger electrostatic repulsion and looser networks due to increased dissociated carboxylate and hydrated keratin fiber.

Calcium ion capture and carboxyl group dissociation depends on chelating agent concentration and pH respectively. We evaluated the effect of EDTA concentration and pH on the swelling ratio. At pH 7, when the concentration

Fig. 2 Changes in keratin-Ca swelling ratio over time when applying various detergents such as Formulae A, B, C, and G shown in Fig. 1 and Table 1.

Fig. 3 Video microscope images of morphology changes of keratin-Ca pellets immersed in detergents: a) highly effective for swelling and b) less effective for swelling.
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of EDTA was increased, the swelling ratio of keratin-Ca was increased, suggesting that EDTA efficiently captures calcium ions of keratin-Ca (Fig. 5). Furthermore, the swelling ratio improved as the concentration of EDTA increased at pH 10 rather than pH 7. These results suggest that promoting carboxylate dissociation under high EDTA concentrations and high pH conditions is essential.

3.3 Effects of anionic surfactants and solvents on keratin-Ca swelling

In order to encourage rapid keratin-Ca swelling, it is significant to effectively permeate the chelating agent solution into the keratin-Ca powder. Therefore, we investigated the effect of surfactants and solvents on keratin-Ca swelling.

At equilibrium swelling after adding only the anionic surfactant solutions, the keratin-Ca swelling ratios were higher than that of EDTA only and similar among AOS, LAS, and SDS but not MES (Fig. 6). On the other hand, when aqueous solutions mixing various anionic surfactants and EDTA were applied to keratin-Ca, the swelling ratios were better than with only anionic surfactant or EDTA solutions. The anionic surfactant effect on the swelling ratio diminished in the order of AOS > LAS > SDS > MES. Furthermore, addition of a typical solvent such as DEMB further increased the swelling ratio, but changes in the swelling ratios between keratin-Ca with surfactant/EDTA solutions and surfactant/EDTA/DEMB solutions were exactly the same regardless of the type of surfactant, whereas those between keratin-Ca with surfactant/EDTA solutions and
surfactant only solutions decreased in the order of AOS > LAS > SDS > MES. These results suggest that surfactants and chelating agents contribute significantly to the swelling ratio and that the solvent plays an auxiliary role in increasing swelling. Moreover, they clarified that the synergic effect on keratin-Ca swelling is optimal in the combination of AOS and EDTA.

### 3.4 Evaluation of wettability on keratin-Ca powder

In the keratin-Ca swelling process, the role of anionic surfactants is assumed to be permeability. To confirm the contribution of various anionic surfactants to permeation, the contact angles of surfactant solutions on keratin-Ca powder were determined by the Washburn method. The contact angle was $86.8^\circ$ with the EDTA only solution, and lower with anionic surfactant only solutions (Fig. 7a), suggesting that surfactant wettability prompts solution permeation. In addition, the solutions combining anionic surfactants and EDTA further lowered the keratin-Ca contact angles, meaning that the surfactant improved chelating agent penetration into the keratin-Ca. The difference in contact angles between the mixed solution and the surfactant only solution grew in the order of AOS > LAS > SDS > MES, similar to the order of keratin-Ca swelling ratios, revealing that the optimal combination of AOS and EDTA contributed to the permeation and swelling of keratin-Ca. We believe they are the optimal combination because AOS not only has an excellent ability to reduce dynamic surface tension but also can exist in a monomer state that does not interact with calcium ions due to resistance to hard water. Furthermore, we confirmed that keratin-Ca’s swelling ratio tended to increase as the contact angles decreased as shown in Fig. 7b.

![Fig. 7](image_url)  
**Fig. 7** a) Contact angles on keratin-Ca powders with solutions of various anionic surfactants/EDTA (surfactant 1 wt%, EDTA 2 wt%, pH 10.0) and surfactants only (surfactant 1 wt%, pH 10.0) and b) relationship between swelling ratios (shown in Fig. 5) and contact angles on keratin-Ca powders.

| Solutions     | Crystalline part | Amorphous part |
|---------------|------------------|----------------|
|               | $T_{1}/\mu s$    | ratio (%)      | $T_{2}/\mu s$ | ratio (%)      |
| Water         | 24.0             | 2.8            | 390.1         | 97.2           |
| EDTA          | 25.5             | 2.6            | 391.6         | 97.4           |
| AOS           | 30.2             | 2.6            | 394.8         | 97.4           |
| AOS + EDTA    | 35.1             | 2.6            | 394.3         | 97.4           |

### 3.5 Structural changes in keratin-Ca during swelling process

Keratin’s basic structure is composed of a crystalline part called intermediate filaments (IFs) in which protofilaments formed by dimers of $\alpha$-helix chains are organized, and an amorphous part called a matrix. It has been reported that the matrix of the amorphous part swells because it loses its rigidity with hydration when keratin is exposed to water, so we measured the structural changes in the crystalline and amorphous parts of keratin-Ca during the swelling process using TD-NMR. The solid spin-echo method of TD-NMR gives a $T_{2}$ relaxation time of 1 msec or less for a solid state. For example, in the case of polyethylene, it has been reported that the relaxation time of the crystalline part was 19.8 $\mu s$ and that of the amorphous part was 276.7 $\mu s^{21}$. In keratin and keratin-Ca powders, the relaxation times for the crystalline parts were 12.8 $\mu s$ and 12.6 $\mu s$, and for the amorphous parts, 205.1 $\mu s$ and 170.5 $\mu s$ respectively. The relaxation times for the amorphous parts of keratin-Ca were shorter than those of keratin, suggesting that most of the calcium ions might be cross-linked between the keratin fibers in the amorphous part.
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Fig. 8 Changes in relaxation time of crystalline part of keratin-Ca over time when applying water and solutions including AOS and/or EDTA.

water and various solutions containing AOS or EDTA were added to keratin-Ca; the relaxation time of the amorphous part quickly increased in the 3 min compared with that of keratin-Ca powder (Table 2), suggesting that the amorphous part is easy to hydrate and its structure is loosened in the keratin-Ca swelling process. In the crystalline part, the solutions including AOS increased the relaxation time compared with the water and EDTA solution. After that, the relaxation time of the crystalline part increased with time for the AOS solution and AOS/EDTA mixed solution. On the other hand, the water and EDTA solution did not much increase the relaxation time (Fig. 8). These results suggest that AOS contributes to the permeability of the crystalline part and allows EDTA to capture Ca ions in the keratin’s internal structure. Therefore, the mixture of AOS and EDTA effectively loosens the crystalline part and improves the swelling of keratin-Ca.

4 Conclusion

We have demonstrated that the swelling of keratin-Ca remaining and accumulated on bathtub surfaces is a key factor in ease of cleaning. The optimal combination of chelating agent and anionic surfactant, such as EDTA and AOS, synergically promotes keratin-Ca swelling due to the chelating agent’s calcium capture capability and the surfactant’s permeability. A detailed analysis of structural changes in keratin-Ca during the swelling process indicated that increasing the motility of the amorphous matrix and loosening its structure contributes to the keratin-Ca’s swelling. Moreover, it also suggested that the molecular motility of the crystalline part composed of IFs increased, the structure was loosened due to the optimal combination of AOS and EDTA, and the crystalline part changed to a state in which it could be removed quickly with little mechanical force. We expect this mechanism to be useful for developing products that enable easy, effective cleaning.

Supporting Information

This material is available free of charge via the Internet at doi: 10.5650/jos.ess21239

References

1) Cutler, W.G.; Davis, R.C. Detergency: Theory and Test Methods Part I. Dekker, New York (1972).
2) Oya, M. Basic knowledge of washing, cleaning and detergents. Shuwa System, Tokyo (2011).
3) Komatsu, J.; Tamogami, R.; Oya, M. Experimental verification of consumer information on calcium stain removal with citric acid J. Jpn. Soc. Home Eco. 70, 643-652 (2019).
4) Ferlin, N.; Grassi, D.; Ojeda, C.; Castro, M.J.L.; Fernández-Cirelli, A.; Kovenisky, J.; Grand, E. Calcium chelating sugar-based surfactants for hard-water detergency. J. Surfact. Deterg. 15, 259-264 (2012).
5) Hisanaga, K.; Yamada, K.; Tsutsui, T.; Tanizawa, Y. Dirt and grime in bathrooms: Their chemical composition and the origin of the triacylglycerols contained therein. J. Surfact. Deterg. 11, 315-322 (2008).
6) Ojima, M.; Toshima, Y.; Koya, E.; Ara, K.; Tokuda, H.; Kawai, S.; Kasuga, F. Hygiene measures considering

J. Oleo Sci. 70, (12) 1769-1776 (2021)
actual distributions of microorganisms in Japanese households. *J. Appl. Microbiol.* 93, 800-809 (2002).

7) Koga, R.; Masunaga, S. Status of dirt on the surface of bath module materials. *Indoor Environment* 21, 9-18 (2018).

8) Feughelman, M. A two-phase structure for keratin fibers. *Text. Res. J.* 29, 223-228 (1959).

9) Fudge, D.S.; Gosline, J.M. Molecular design of the alpha-keratin composite: Insights from a matrix-free model, hagfish slime threads. *Proc. Biol. Sci.* 271, 291-299 (2004).

10) Feughelman, M.; Robinson, M.S. The relationship between some mechanical properties of single wool fibers and relative humidity. *Text. Res. J.* 37, 441-446 (1967).

11) Bertram, J.E.; Gosline, J.M. Functional design of horse hoof keratin: the modulation of mechanical properties through hydration effects. *J. Exp. Biol.* 130, 121-136 (1987).

12) Winegard, T.M.; Fudge, D.S. Deployment of hagfish slime thread skeins requires the transmission of mixing forces via mucin strands. *J. Exp. Biol.* 213, 1235-1240 (2010).

13) Kitchener, A.; Vincent, J.F.V. Composite theory and the effect of water on the stiffness of horn keratin. *J. Mater. Sci.* 22, 1385-1389 (1987).

14) Abe, K.; Kawakami, Y.; Suyama, H. *Microbial countermeasures in indoor environment.* Gihodo-shuppan, Tokyo (2016).

15) Washburn, E.W. The dynamics of capillary flow. *Phys. Rev.* 17, 273-283 (1921).

16) Schwarzenbach, G.; Anderegg, G.; Sallman, R. On the coordination tendency of N-substituted iminodicarboxylic acids. *Helv. Chim. Acta.* 38, 1147-1170 (1955).

17) Gillespie, J.M. The proteins of hair and other hard alpha-keratins. in *Cellular and molecular biology of intermediate filaments* (Goldman, R.D.; Steinert, P.M. eds.). Springer, US, pp. 95-128 (1990).

18) Crick, F.H.C. Is alpha-keratin a coiled coil? *Nature* 170, 882-883 (1952).

19) Crick, F.H.C. The packing of alpha-helices: simple coiled-coils. *Acta Cryst.* 97, 689-697 (1953).

20) Pauling, L.; Corey, R.B.; Branson, H.R. The structure of proteins; Two hydrogen-bonded helical configurations of the polypeptide chain. *Proc. Natl. Acad. Sci.* 37, 205-211 (1951).

21) Teymouri, Y.; Adams, A.; Blümich, B. Impact of exposure conditions on the morphology of polyethylene by compact NMR. *Macromol. Symp.* 378, 1-8 (2018).

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