

A study on the application of alkaline cellulases in the cleaning and care of fabrics

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pick Alkaline cellulase is a cellulase enzyme developed especially for the characteristics of detergent formulations. Adding alkaline cellulase alone or in combination with alkaline protease in the formulations can effectively improve the stain removal performance of national or international stained cloths. Alkaline Cellulase removes stains from EMPA-253 fabrics and used fabrics. The fluff on the surface of striped shirts enhances the color contrast and gives the detergent excellent fabric care performance. As an efficient and environmentally friendly daily chemical raw material, alkaline cellulase is an important choice for the development of detergent products towards concentration, greening and functionalization.

Key Words: Alkaline Cellulase; Alkaline Protease; Fabric Cleaning; Fabric Care; Synergistic Effect

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With the continuous development of the domestic economy, the type of outdoor activities of the residents is gradually diversified, and the diet structure is also becoming more and more complex. This has led to the fact that in daily life, clothes are easily stained with various types of stains, such as grass stains, soil stains, oil stains, coffee stains, red wine stains, lipstick stains, glue stains, etc. Most of the stains do not exist alone, but are usually mixed together and adhered to the fabric. Most of these stains do not exist alone, but are usually mixed together and adhere to the fabric. In addition, these stains are denatured by the oxidizing effect of external conditions, forming stubborn stains that are even more difficult to remove^[1]. Currently, commercially available protease-only detergents have difficulty in removing these stains.

In recent years, under the guidance of national policies and industry calls, detergents have developed towards concentration and greening, with the emergence of concentrated laundry detergents including concentrated laundry powder, concentrated laundry detergent, concentrated laundry gel and other concentrated detergent products. Taking the "Concentrated Detergent Certification Mark" launched by China National Detergents Industry Association as an example, in order to meet the basic condition of qualified detergency, concentrated detergents are not only required to reach a certain standard in terms of the total active substance (the total active substance content of the laundry detergent labeled "Concentrated" should not be less than 30%, and the total active substance content of the laundry detergent labeled "Concentrated +" should be more than 45%^[2]), but also need to reduce the amount of detergent according to the corresponding requirements, for example, "Concentrated +" laundry detergent is only one-third of the amount of ordinary laundry detergent. For example, "Concentrate +" laundry detergent requires only one-third of the amount of regular laundry detergent. In addition, from the perspective of product selling point, the claim of stain removal power of laundry gel^[3] has evolved from 4 times stain removal power to 8 times stain removal power and 10 times stain removal power. With the support of protease enzyme in the gel formula, it is not difficult for the gel products to achieve 8 times or more stain removing power on JB-02 protein soiled cloth, but if they want to achieve 8 times stain removing power on JB-01 and JB-03, the formula of the gel puts forward higher requirements.

Alkaline cellulase is a member of the cellulase family^[4-5], which is specially designed for the structural characteristics of detergent formulations and the washing process, and is able to withstand the effects of surfactants, auxiliaries and alkaline environment on the stability of the enzyme molecules in detergents, and fully release its vitality during the washing process to achieve good fabric cleaning and caring effects. The principle of alkaline cellulase in achieving fabric cleaning and care is different from that of other washing enzymes such as protease, amylase and lipase. Instead of catalyzing and disintegrating specific stains, alkaline cellulase efficiently anchors the amorphous zone^[6] of damaged fibers in cotton fabrics for degradation. By degrading the molecules of damaged cotton fibers in the amorphous region, the gel structure formed by the combination of fibers, water and stains was softened, and the stains enclosed in the gel structure were separated from the fibers more easily, thus removing the stains that adhered to the surface of the fabrics and intruded into the interior of the fabrics^[7]. In addition, targeted degradation of damaged cotton fibers removes lint and hairballs attached to the fabric surface, significantly improves the color contrast of the fabric, and improves the yellowing and hardening of the fabric to the touch and feel, and achieves the effect of renovating the fabric care^[8]. Due to the high efficiency and specificity of bio-enzymes, alkaline cellulase

does not act on the normal, undamaged crystalline areas of cotton fibers, so repeated washing will not damage the fabric^[9].

In this paper, the role of alkaline cellulase in fabric care is investigated in the stain removal enhancement of national standard stained fabrics and international stained fabrics, and the role of alkaline cellulase in fabric care is explored in the EMPA 253 and T-shirt de-pilling experiments.

1. The experimental part

1.1 materials and instruments

1.1.1 Material

National Standard Laundry Detergent, JB-01 Carbon Black Stained Fabric, JB-02 Protein Stained Fabric, China Research Institute of Daily-use Chemical Industry; E-163 Congee Stained Fabric, E-164 Grass Stained Fabric, EMPA-253 Hairball Fabric, Swisstatest Testmaterialien; C-05 Blood, Milk and Ink Stained Fabric, C-10 Dye, Oil and Milk Stained Fabric, C-S-01 Aged Blood Stained Fabric C-S-43 Carbon Black Guar Gum Stained Fabric, C-S-53B Carbon Black Pectin Stained Fabric, C-S-73 Acacia Bean Gum Stained Fabric, C-H-018 Clay Stained Fabric, C-H-131 Butter Stained Fabric, CFT; Laundry Detergent A, Concentrate B (Concentrate +), C-S-53B Carbon Black Fruit Gum Stained Fabric; Laundry Detergent A, Concentrate B (Concentrate +) Laundry Detergent A, Concentrated Laundry Detergent B (Concentrated +), Laundry Gel C (4x stain remover), Laundry Gel D (8x stain remover), Laundry Gel E (10x stain remover), inactivation of mainstream brands plus protease products. Adult cotton short-sleeved striped shirt, Uniqlo; adult polyester short-sleeved accompanying laundry, Zenith.

1.1.2 Instruments

RHLQ III Vertical Decontaminator, China Research Institute of Daily-use Chemical Industry; CR-400 Colorimeter, Konica Minolta, Japan; Automatic Whiteness Meter WSD-3C, Beijing Kangguang Optical Instrument Co. Guangzhou Xinhong Laundry Machinery Co.

1.2 Experimental Methods

1.2.1 Stain removal test

Referring to the standard method of GB/T 13174-2021, the washing concentration of the national standard laundry detergent and ordinary laundry detergent was 2 g/L, the washing concentration of the concentrated + laundry detergent was 0.67 g/L, and the washing concentration of the laundry gel claimed to be 4-fold stain removing, 8-fold stain removing and 10-fold stain removing were 0.5 g/L, 0.25 g/L and 0.2 g/L respectively. The whiteness value of the national standard soiled cloths was tested by the automatic whiteness meter before and after washing, and the color difference value of the overseas standard soiled cloths was tested by the colorimeter before and after washing. The whiteness value of the national standard soiled cloth before and after washing was tested by automatic whiteness meter, and the color difference value of the overseas standard soiled cloth before and after washing was tested by color difference meter.

1.2.2 fabric care testing

Six cotton short-sleeved striped shirts were washed continuously for 8 hours at room temperature in an industrial washing machine to produce a uniform appearance of lint and hairballs on the surface of the shirts, which was used to simulate the aging condition of the clothes after daily wear.

EMPA 253 lint free fabrics or washed and aged short sleeved striped shirts were placed in a tumble dryer with 1.2 kg of laundry and 20 g of liquid detergent A. Two sets of experiments were started with the addition of alkaline cellulase equivalent to 0.5% of the mass of liquid detergent A, and the other set of experiments was started without the addition of alkaline cellulase. The washing temperature was set at 40°C and the washing time was 46 minutes. 5 cycles of washing were performed continuously, and the washing items were taken out of the washing machine and hung up to dry naturally.

2. Results and Discussion

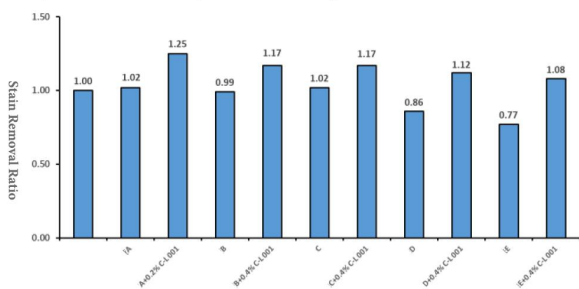
2.1 Enhancement effect of alkaline cellulase on the decontamination of JB-01 carbon black stained cloth

Alkaline cellulase Spectrum C-L 001 was added to the enzyme-inactivated laundry detergent A, concentrated laundry detergent B, laundry gel beads C, laundry gel beads D and laundry gel beads E according to the dosage levels shown in Table 1, and the washing tests were carried out according to the national standard method after mixing.

Table 1 Alkaline cellulase additions to formulations, the

Formulation	alkaline cellulase
Laundry detergent A	0.2%
Concentrated laundry detergent B	0.4%
Laundry Gel Beads C	0.4%
Laundry Gel Beads D	0.4%
Laundry Gel Beads E	0.4%

From the results in Fig. 1, it can be seen that the addition of alkaline cellulase can significantly improve the ability of the formulation to remove carbon black stains. In Laundry Detergent A, for example, the addition of 0.2% cellulase increased the removal of carbon black stains by 23%. The addition of alkaline cellulase at 0.4% to Laundry Detergent B with triple stain removal claims and Laundry Gel C with quadruple stain removal claims improved the removal of carbon black stains by approximately 17% and 15%, respectively. Laundry Gel D and Laundry Gel E, which claimed 8x and 10x stain removal, respectively, were tested on samples of non-enzyme inactivated laundry gel and were found to meet the claims for protein stain removal. However, when combined with the results in Figure 1, neither product was able to achieve 8x or 10x removal of carbon black stains. The addition of 0.4% of EVERGREEN C-L 001 Alkaline Cellulase to the two laundry gel formulations increased the charcoal stain removal by 30% and 40%, respectively, and helped to achieve a more comprehensive stain removal performance for both products.



> Fig. 1 Enhanced stain removal performance of formulated carbon black stains by alkaline cellulase

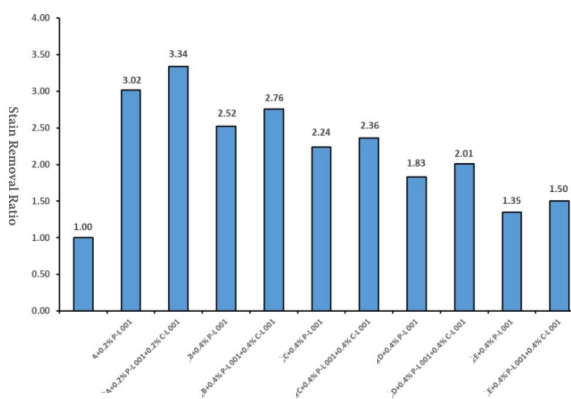
2.2 The synergistic effect of alkaline cellulase and alkaline protease on the decontamination of JB-02 protein stained cloth

Enzymes are specialized and highly effective, and only a small amount of protease added to the detergent formulation can increase the protein stain removal ability several times. Alkaline cellulase can degrade damaged cotton fibers in a targeted manner to remove stains on the surface of damaged cotton fibers and achieve fabric cleaning effect. The alkaline protease Spectrum P-L 001 and alkaline cellulase Spectrum C-L 001 were added into the formulations to be tested according to the ratios shown in Table 2, and their synergistic effects on the removal of JB-02 protein stains on fabrics were investigated.

Table 2 Alkaline cellulase and alkaline protease additions to formulations, the

Formulation	Alkaline protease	alkaline cellulase
Laundry detergent A	0.2%	0.2%
Concentrated laundry detergent B	0.4%	0.4%
Laundry Gel Beads C	0.4%	0.4%
Laundry Gel Beads D	0.4%	0.4%
Laundry Gel Beads E	0.4%	0.4%

The five formulations tested covered three common types of liquid fabric detergents, i.e., regular laundry detergents, concentrated laundry detergents and laundry gels. Combined with the results in Figure 2, it can be seen that the addition of alkaline cellulase to any of the formulations, in addition to protease, can further enhance the removal of protein stains. The alkaline cellulase and protease showed good synergistic stain removal ability.



> Fig. 2 Enhanced stain removal performance of formulated protein stains by synergizing alkaline cellulase and alkaline protease

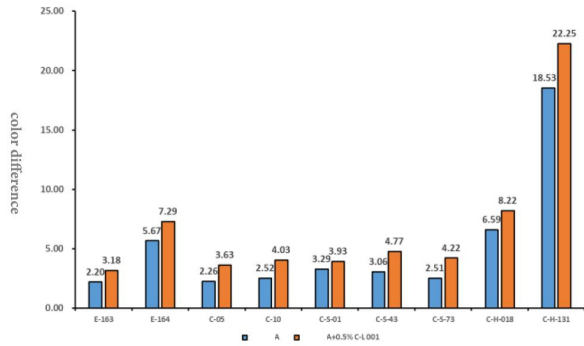
2.3 Enhancement of stain removal performance of international soiled cloth by alkaline cellulase

At present, the evaluation method of detergent decontamination performance in China mainly refers to GB/T 13174-2021 standard, which stipulates only three types of stained cloths JB-01, JB-02 and JB-03. With the continuous development of the society, there are more and more kinds of stains and more and more complicated compositions on the clothes of the residents. Consumers and detergent manufacturers have an urgent demand for detergent products with stronger detergent removing ability, and it is difficult to reflect the comprehensive performance of detergents if only the stained cloths under the existing standards are used in the experimental evaluation. Referring to the method in 2.1, we added 0.5% alkaline cellulase Spectrum C-L 001 into the formulation of laundry detergent A to investigate the effect of alkaline cellulase on the detergency performance based on the condition of international stained cloth.

From the results of Fig. 3, it is clear that the addition of alkaline cellulase to laundry detergent A had a significant effect on E-163

Gruel-stained cloths, E-164 Grass-stained cloths, C-05 Blood, milk and ink-stained cloths, C-10 Dyes, oils and

Milk Stain Cloth, C-S-01 Aged Blood Stain Cloth, C-S-43 Carbon Black Guar Stain Cloth, C-S-53B Carbon Black Pectin Stain Cloth, C-S-73 Stained Acacia Bean Stain Cloth, C-H-018 Clay Stain Cloth, C-H-131 Stained Butter Stain Cloth, and so on, all of these cloths have different degrees of stain removing performance.



> Fig. 3 Enhancement of stain removal performance of international soiled cloth by alkaline cellulase

2.4 the role of alkaline cellulases in fabric care

In each of the two drum washing machines, a piece of EMPA-253 lint cloth and 1.2 kg of laundry were washed with 20 g of liquid detergent A. In one of the machines, an additional 0.1 g of alkaline cellulase was added, which was equivalent to 0.5% of liquid detergent A, and the other group was labeled as the cellulase-added group. As a control, no alkaline cellulase was added to the other washing machine. The fabric care test method in Section 1.2.2 was repeated for 5 wash cycles and the results are shown in Figure 4.



> Fig. 4 Dehairing effect of alkaline cellulase on EMPA-253, the

From Fig. 4, it can be clearly observed that, compared with the control group, the fine fuzz and hairballs on the surface of the EMPA-253 toweling cloth in the alkaline cellulase-added group have been almost completely removed, and the color contrast has been greatly improved.

In order to verify the effect of alkaline cellulase on real clothing care, an industrial washing machine was used to make old cotton striped shirts so that the surface of the shirts would have a more uniform appearance of lint and hairballs, which was used to simulate the old state of clothing after daily wear. Take an old cotton striped shirt, as shown in the upper part of Fig. 5, and cut the striped shirt into two halves from the center. Add the left half of the shirt, 1.2 kg of washing water and 20 g of washing liquid A to the washing machine. Add the right half of the striped shirt, 1.2 kg of laundry detergent, 20 g of liquid detergent A and 0.1 g of alkaline cellulase to the other washing machine. Repeat the 5 wash cycles according to the fabric care test method in section 1.2.2.

As can be seen from the enlarged picture in Fig. 5, since no alkaline cellulase was added to the left half of the striped shirt during the washing process, it was not possible to obtain any fabric refurbishment effect in terms of lint removal and color restoration, and there was no significant change in the surface condition of the striped shirt from that before the washing process. On the right half of the striped shirt, 0.5% alkaline cellulase was added during the washing process, and with the help of alkaline cellulase, lint and hairballs were almost completely removed from the surface, and the grayish and hazy appearance was greatly improved.



> Fig. 5 Effect of alkaline cellulase on the renovation of cotton striped shirts, the

From the comparative washing experiments of EMPA-253 woolen fabrics and cotton striped shirts, it can be clearly perceived that alkaline cellulase has a significant effect in improving the appearance of fabrics. The alkaline cellulase can be combined with detergent formulations to provide excellent fabric care functions for the detergents.

2.5 Stability testing of alkaline cellulase in formulations that

The alkaline cellulase enzyme was added into the formulations according to the additive amounts and ratios in Table 3, either alone or in combination, mixed well, and placed in a closed box at 37°C for 1 month of accelerated aging experiment, and the simulated enzyme-added formulations were stored at room temperature for 1 year. The stain removal ability of the samples on JB-01 carbon black stained cloth was tested before and after aging, and the stain removal ratio of the formulations before and after thermal storage was calculated to obtain the retention rate of the stain removal ability of carbon black stains, which was used to characterize the stability of the alkaline cellulase enzyme in the formulations of several common products.

Table 3 Experimental conditions and results of accelerated aging experiments with alkaline cellulase in different formulations, the

Formulation	Alkaline protease	alkaline cellulase	retention of detergency
Laundry detergent A	--	0.2%	92%
Concentrated laundry detergent B	--	0.4%	88%
Laundry Gel Beads C	--	0.4%	94%
Laundry Gel Beads D	--	0.4%	92%
Laundry Gel Beads E	--	0.4%	100%
Laundry Gel Beads C	0.4%	0.4%	84%
Laundry Gel Beads D	0.4%	0.4%	79%
Laundry Gel Beads E	0.4%	0.4%	89%

From the column of stain retention rate in Table 3, it can be seen that under the condition of using alkaline cellulase alone, the highest stain retention rate after aging in any of the formulations A-E was up to 100%; under the condition of using alkaline protease in combination, the stain retention rate in the formulations of laundry gels C-E was in the range of 79%-89%, which was similar to that of using alkaline cellulase alone, and the alkaline protease compatibility was very good, protease alone, showing good compatibility with alkaline cellulase.

3. Conclusion

Alkaline cellulase is a cellulase product developed especially for the characteristics of detergent formulation and washing environment. In this paper, we tested the detergency performance of alkaline cellulase added to detergent alone under the national standard and international soiled cloth through detergency experiments, and also carried out alkaline cellulase

The synergistic performance of cellulase and alkaline protease was investigated. The results showed that the addition of alkaline cellulase to the detergents could significantly enhance the detergency of the detergents, both individually and in combination. In addition, from the comparative washing experiments of EMPA-253 hairball fabric and short-sleeved striped shirt, it was found that alkaline cellulase had unique effects in removing lint and hairballs and restoring the color of the fabrics. From the above conclusions, it can be seen that alkaline cellulase has the dual effects of cleaning and caring for fabrics.

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