Fermentation of Hectorite Using Lactobacillus plantarum for Enhancing Dispersion Stability and Removal of Pollutant

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Abstract

Hectorite is a trioctahedral clay mineral with surface reactivity and adsorption, cation exchange capacity. It can interact between organic molecules with the active sites of the interlayer, surface, edge and inter-particle via ion exchange, intercalation and grafting. In recent years, the clay minerals-microbes interaction has been investigated, which represents microbial bioremediation and biodegradation of pollutants. We obtained fermented hectorite of the reaction with *Lactobacillus plantarum* as a chemical modifier to provide morphological properties. We demonstrated that the interaction of hectorite with Lactobacillus ferment enhanced the dispersion stability by preventing aggregation and promoting its diffusion without any pressure, and improved removal efficiency for particular pollutant by wedge film formation. Thus, the study suggested that the fermented hectorite may have a promising potential for use as a novel cosmetic ingredient.

Keywords: Hectorite; Fermentation; *Lactobacillus plantarum*; Dispersion; Pollutant Removal

Introduction

Hectorite is a trioctahedral clay mineral with surface reactivity and adsorption, cation exchange capacity. It can interact between organic molecules with the active sites of the interlayer, surface, edge and inter-particle via ion exchange, intercalation and grafting. The layered structure of hectorite has great affinity for water and confined water molecules in interlayers are important elements of their structure. However, due to their chemical characteristics, such as aggregation and coalescence, it is necessary to improve dispersion stability in order to apply the clay minerals in cosmetic formulations as cream, foam cleansing.

The interaction of clay minerals with microorganisms has great interest over recent decades. The clay minerals-microbes interaction has been investigated, which represents microbial bioremediation and biodegradation of pollutants. We aimed at covering the interactions with hectorite and microorganisms affecting the morphology and characteristic properties through the fermentation process, which is a process of decomposing organic matter using the enzyme possessed by microorganisms.

Materials and Methods

Hectorite was supplied by Elementis Specialties Inc Ltd. 1,2-Hexanediol was obtained from Gene Bio Chem. Co., Ltd and Ethylhexylglycerin was bought from FTC KOREA Co., Ltd. Lactobacillus Ferment was purchased from CoSeedBioPharm Co., Ltd. Deionized doubled distilled water (D.I Water) was used through the experiment.

Fermented hectorite (F-Hectorite) was prepared by the fermentation method for 55˚C at mixing rate (500 rpm). After the sterilization and freeze-drying process, the F-Hectorite can be obtained.

The morphology of the Hectorite and F-Hectorite was characterized by using a Tescan VEGA 3 LM Scanning Electron Microscope (SEM) and a JEOL microscope model JEM-2100PLUS for the Transmission Electron Microscope (TEM) images.

To measure rheological properties in a non-contact and non-destructive manner, such as viscoelasticity changes in comparison with time, Rheolaser MASTER was used. Hectorite and F-Hectorite cream were poured into 20 mL disposable glass cell and equilibrated at 40°C. Measurements were taken every 1 min. Collection and analysis of original data were performed by the software attached to the instrument and directly provided the rheological parameters MSD.

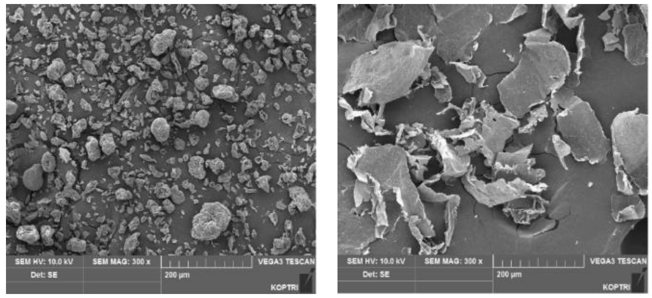
The measurements of viscosity were done using the Fluidicam RHEO technology (FORMULACTION, Toulouse France), a fully automated rheometer combining microfluidic and imaging technologies. Measurements were done at a shear rate range between $7 \cdot 10^1\ s^{-1}$ to $2 \cdot 10^3\ s^{-1}$.

The accelerated stability of an oil-in-water emulsion dispersions with F-Hectorite was measured using LUMiSizer® (LUM GmbH, Germany) by adding to the bottom of the cell (2 mm disposable polycarbonate sample cell with a rectangular cross-section) which was placed horizontally into the instrument after capping and exposed to centrifugal force under 2300 g (4000 rpm rotor speed) at 50 ˚C. A total of 900 profiles were recorded in intervals of 100 seconds. Instability indexes were calculated using the SEPView® software.

Results and Discussion

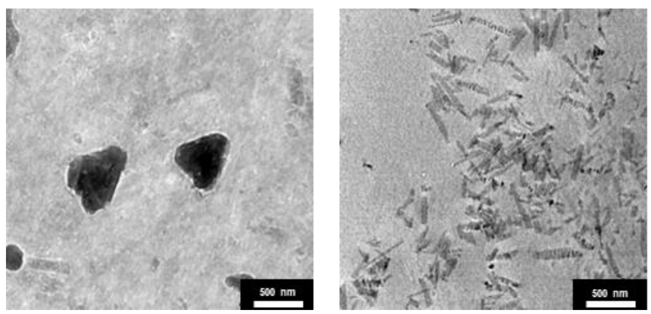
Morphology

The morphology of the Hectorite characterized using transmission electron microscopy (TEM) and field emission scanning electron microscopy (FE-SEM). Hectorite aggregates were exfoliated to fabricate a fine dispersion of nanoplatelets in the aqueous phase through the fermentation process, observed by both FE-SEM and TEM analysis. It showed that the F-hectorite could be dispersed in oil-in-water emulsion after the process of fermentation without any pressure, showed in Fig. 1 and Fig. 2. We demonstrated that the interaction of hectorite with *Lactobacillus ferment* enhanced the dispersion stability by preventing aggregation and promoting its diffusion without any pressure.



(a) (b)

Figure 1. Field emission scanning electron microscopy (FE-SEM) images of (a) Hectorite, and (b) F-Hectorite.

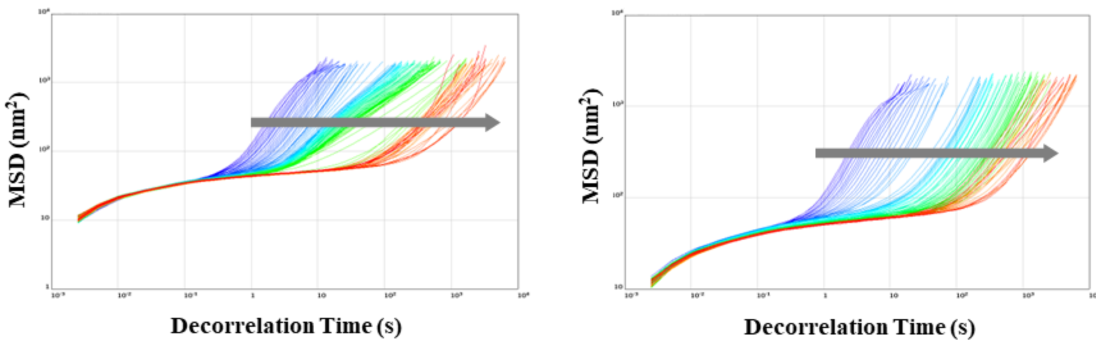


(a) (b)

Figure 2. Transmission electron microscopy (TEM) images of (a) Hectorite, and (b) F-Hectorite.

<u>Rheological properties</u>

Shear thinning behavior is observed with Non-Newtonian Fluids with a change in viscosity properties as the shear rate increases. Compared to Hectorite cream (Fig. 3(a)), the mean square displacement (MSD) curve of F-Hectorite cream (Fig. 3(b)) was shifted constantly to the right, improving uniformity and dispersion stability. Through the fermentation process, it might be contributed to enhance the dispersion stability of F-Hectorite, such as viscosity (Fig. 4), by the change of rheological properties.



(a) (b)

Figure 3. Rheology analysis of (a) Hectorite cream, and (b) F-Hectorite cream.

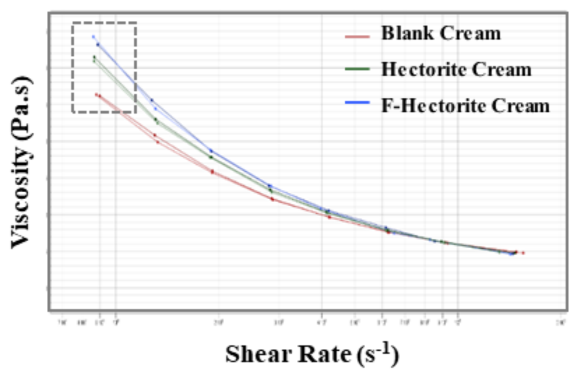


Figure 4. Analysis of the viscosity of blank cream, Hectorite cream, and F-Hectorite cream.

<u>Dispersion stability</u>

The estimation of the long-term stability of the cream formulation was carried out using a centrifugal sedimentation method, LUMiSizer®. LUMiSizer® has been used in the kinetic analysis during accelerated storage time. F-Hectorite cream formulation has the lowest value of instability index (0.048), compared to the blank (0.082) and hectorite cream (0.055) (as shown in Fig. 5). Therefore, the dispersion stability might be improved because of the increase of viscosity in the aqueous phase.

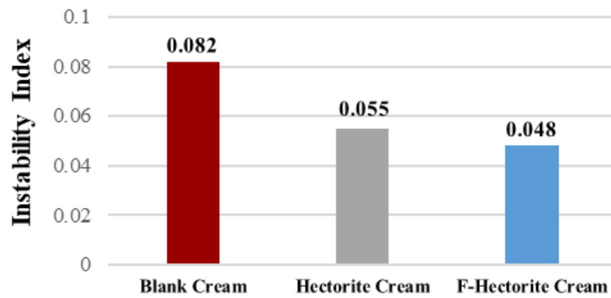


Figure 5. The instability index of blank cream, Hectorite cream, and F-Hectorite cream.

<u>The Removal of Pollutant</u>

Due to the formation of wedge film between the surface and solid particles (Fig. 6), the removal efficiency of pollutants adhering to the skin, such as heavy metals and fine dust, was effective (as shown in Fig. 7(a) and 7(b)). Therefore, it was found that the presence of shallow surface features can help to separate surfaces and obtained with smooth surfaces.

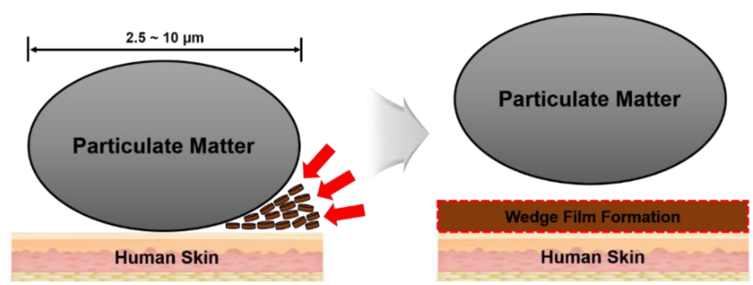


Figure 6. Scheme of wedge film formation by F-Hectorite.

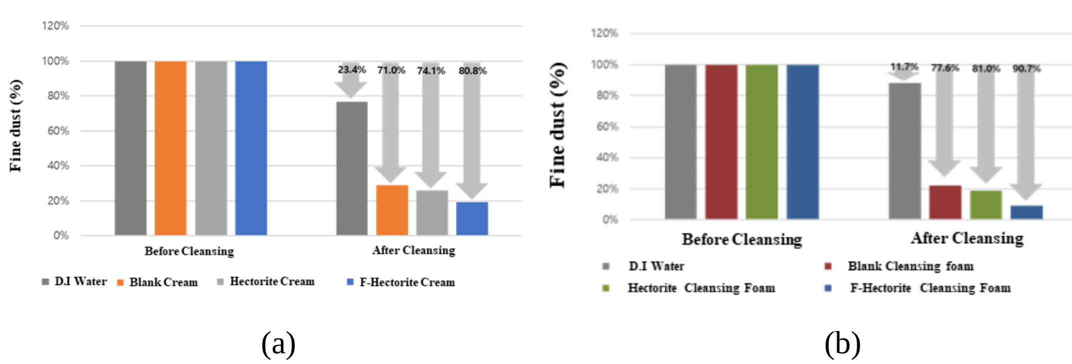


Figure 7. Evaluation of pollutant removal efficiency of (a) blank cream, Hectorite cream, and F-Hectorite cream, (b) blank cleansing foam, Hectorite cleansing foam, and F-Hectorite cleansing foam.

Conclusion

In this study, through the fermentation process using enzymes possessed by microorganisms, F-Hectorite might be contributed to change the morphology and improve the dispersion stability. In addition, when applied to a formulation of oil-in-water cream, it was found that the stability of the emulsion could be improved by increase in viscosity of particle dispersions. In the formulation of foam cleanser, it was confirmed that the amount of fine dust particles was obviously decreased by wedge film formation. These results suggest that F-Hectorite may be a novel effective for new approach in cosmetics field.

Acknowledgments

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Conflict of Interest Statement

The authors declare no conflict of interest.

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