HIGH-MOLECULAR CONNECTIONS

DOI: 10.32743/UniChem.2021.86.8.12068

SWELLING OF HYDROLYZED FIBROIN IN WATER, ACIDIC AND ALKALINE SOLUTIONS

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НАБУХАНИЕ ГИДРОЛИЗОВАННОГО ФИБРОИНА В ВОДЕ, КИСЛОТНЫХ И ЩЕЛОЧНЫХ РАСТВОРАХ

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Библиографическое описание: Swelling of hydrolyzed fibroin in water, acidic and alkaline solutions // Universum: химия и биология : электрон. научн. журн. Eshchanov K.O. [и др.]. 2021. 8(86). URL: *https://7universum.com/ru/nature/archive/item/12068*

ABSTRACT

This article provides information on the swelling of hydrolyzed fibroin derived from natural silk fibroin in water, acids and alkalis. The swelling properties of hydrolyzed fibroin derived from natural silk fibroin in different media were studied. Swelling levels of hydrolyzed fibroin were studied by observation on a swell meter and an optical microscope. As a result of the research, we found that the results obtained in both methods differed sharply from each other and studied its causes.

АННОТАЦИЯ

В этой статье представлена информация о набухании гидролизованного фиброина, полученного из натурального фиброина шелка, в воде, кислотах и щелочах. Изучены набухающие свойства гидролизованного фиброина, полученного из натурального фиброина шелка, в различных средах. Уровни набухания гидролизованного фиброина изучали путем наблюдения с помощью набухометра и оптического микроскопа. В результате исследования мы обнаружили, что результаты, полученные обоими методами, резко отличаются друг от друга, и изучили его причины.

Keywords: silk fibroin, swelling, hydrolyzed fibroin (“HF”), optical microscope, amorphous part.

Ключевые слова: фиброин шелка, набухание, гидролизованный фиброин («ГФ»), оптический микроскоп, аморфная часть.

Introduction. 70–75% of natural silk fiber consists of fibroin protein. Silk fibroin consists of amorphous (α-structure) and crystalline (β-structure) parts. The study of the swelling levels of silk fibroin helps to draw definite conclusions about its interactions with solvents in determining its sorption properties [1][2][3].

Silk fibroin is insoluble in water. Silk fibroin is extracted by washing the silk fiber with water. Fibroin is insoluble in alcohol, ether, benzene, acetone, carbon (IV) sulfide, and other organic solvents. Salts of calcium, strontium, barium, which form a solution in a neutral medium, and hydrogen halide acids, Schweitzer reagent, form colloidal systems in alkaline solutions [4]. It is also soluble in concentrated $ZnCl_2$ solution and ammonia solutions of nickel(II) hydroxide [5].

Fibroin can absorb moisture in water-resulting in a limited swelling of 30–40%. The moisture retention of pure fibroin is 1,2 % lower than that of silk. It was found that the swelling of silk fibroin in the water at a temperature of 18°C increased the cross-section of the fiber by 18,7 % and the length by 1,3 % [6][7]. In his research, S.Sommer found that the swelling of silk fiber in the water at a temperature of 20°C increases the length of the fiber by 1,3–1,7%, the cross-sectional area by 19–46 %, and the mass by 35–54%.

Amorphous parts of natural silk fibroin absorb 70% moisture, while crystalline parts absorb 30% moisture. In acids and especially alkaline solutions, fibroin swelling increases. The swelling of fibroins in alkalis can be irreversible. Swelling of silk fibroin in dilute solutions of NaCl and $NaNO_3$ salts is observed as in water [8].

We formed powdered hydrolyzed fibroin (“HF”) by hydrolyzing natural silk fibroin in a 3% hydrochloric acid solution [9][10]. We conducted studies to determine the degree of swelling of powdered “HF” under acidic conditions (3% hydrochloric acid), alkaline (3% KOH) conditions, and water.

Experimental section

Materials. Fibrous of silk (Cleaned of additives. Khorezmipagi LLC, Urgench, Uzbekistan), HCl (chemically pure) and potassium hydroxide was purchased from Chimreaktivinvest (Uzbekistan).

Instrumentation. Bidistilled water is obtained from the “GFL 2104 Double distillation water still” device (Germany), swell meter (Russia), optical microscope ("Optika_B-150 DBR").

Procedure

Detection of “HF” powder swelling with a swell meter. The swelling of the “HF” powder was detected on a swell meter. On the swell meter, we found that the swelling levels of “HF” powder change over time under acidic, alkaline conditions and in water. The experiments were performed at a temperature of 20°C for 192 h.

Swelling was determined using the following formula.

$$\alpha_V = \frac{V - V_0}{V_0} \cdot 100\% \quad (1)$$

V_0-the initial volume of the polymer, V-the volume of the polymer at time-*t*.

Detection of “HF” swelling by optical microscopy. The swelling of “HF” particles was determined by optical microscopy using the Optika_B-150 DBR optical microscope in acidic, alkaline conditions and bidistilled water at a temperature of 20°C.

Analysis and results

Swelling results of “HF” powder detected on the swell meter. The swell meter found that the swelling levels of “HF” powder did not change after 192 hours. Measurements on the swell meter revealed that the “HF” powder had a swelling rate of 15% in water and 23 and 70% swelling levels in acidic and alkaline conditions, respectively (Figure 1). A high degree of swelling in an alkaline environment means that the number of crystalline particles decreases due to structural changes in the “HF” and the number of amorphous particles increases.

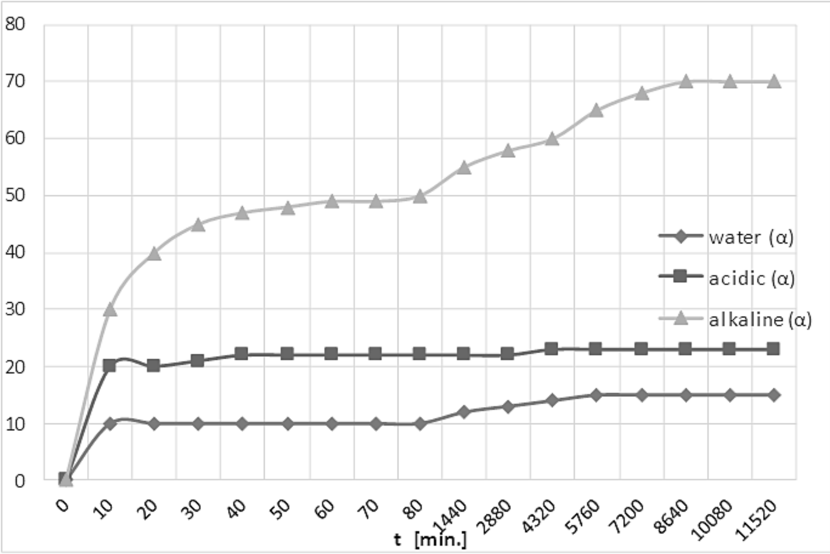

Figure 1. Swelling (%) of “HF” powder in water, alkaline and acidic solutions 20°C

Swelling results of “HF” detected under an optical microscope. The cylindrical shape of the “HF” particle allows precise calculations to be performed (Figure 2). Expressions (2) and (3) were used to calculate the volume of cylindrical particles.

$$S = \pi \cdot r^2 \qquad (2)$$

$$V = S \cdot l \qquad (3)$$

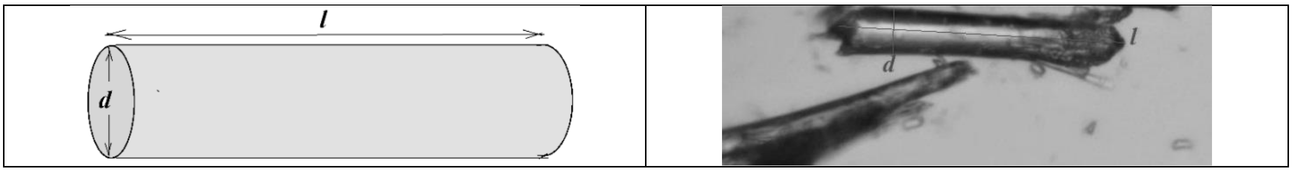

Figure 2. Determining the diameter and length of an “HF” particle

The time-dependent graph of the values of the swell levels determined by the optical microscopy method is shown below (Figure 3).

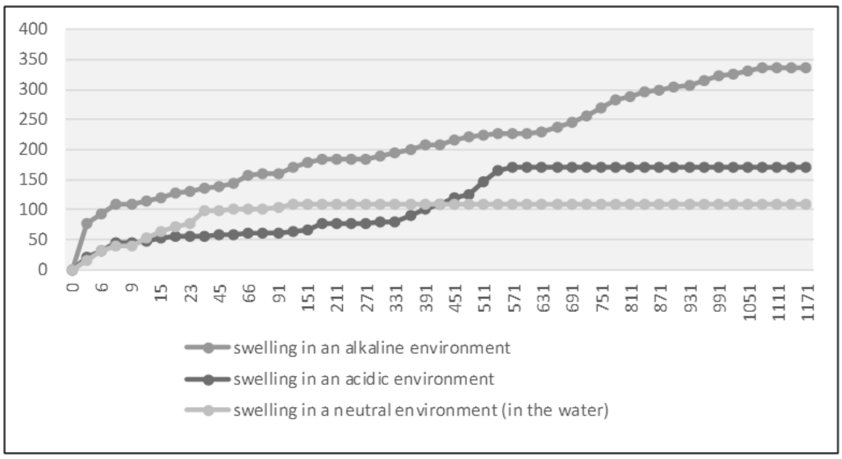

Figure 3. Time dependence of “HF” particle swelling (%) in acidic, alkaline media and water as determined by optical microscope (20°C)

It can be seen that the differences between the degree of swelling of the individual "HF" particle detected by optical microscopy and the degree of swelling of the "HF" powder detected on the swell meter are very large (Figure 4).

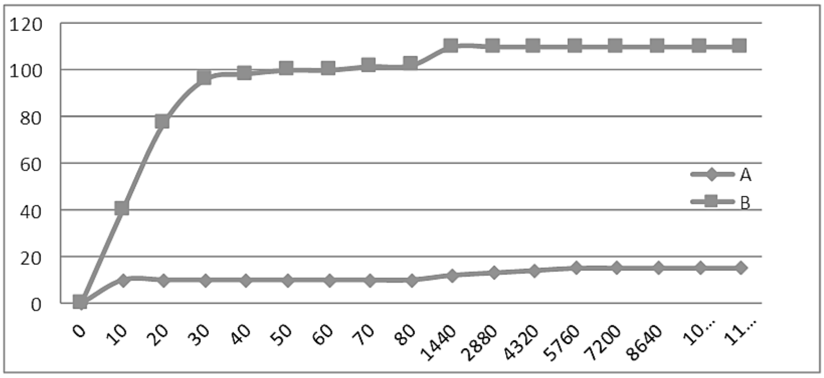

Figure 4. A) The time dependence of the swelling (%) of "HF" powder in water as determined by a swell meter at a temperature of 20ºC. B) The time dependence of the swelling of "HF" particles in water detected by an optical microscope at a temperature of 20ºC

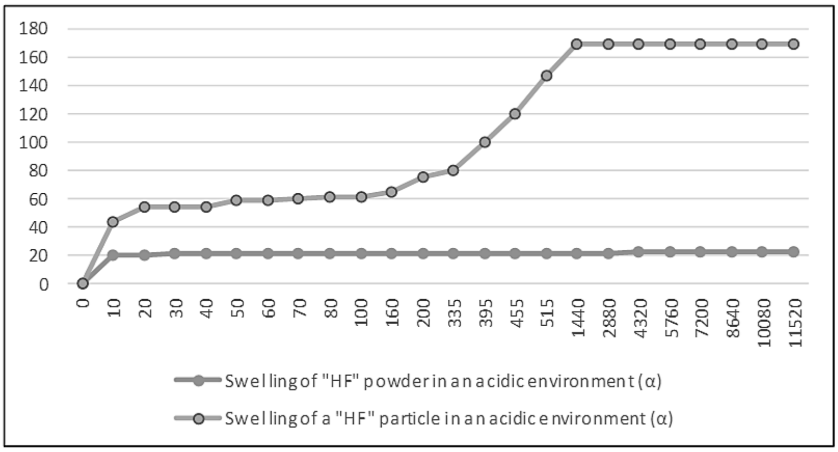

Figure 5. Time dependence of swelling (%) levels of "HF" powder and its particle in acidic environment (20ºC)

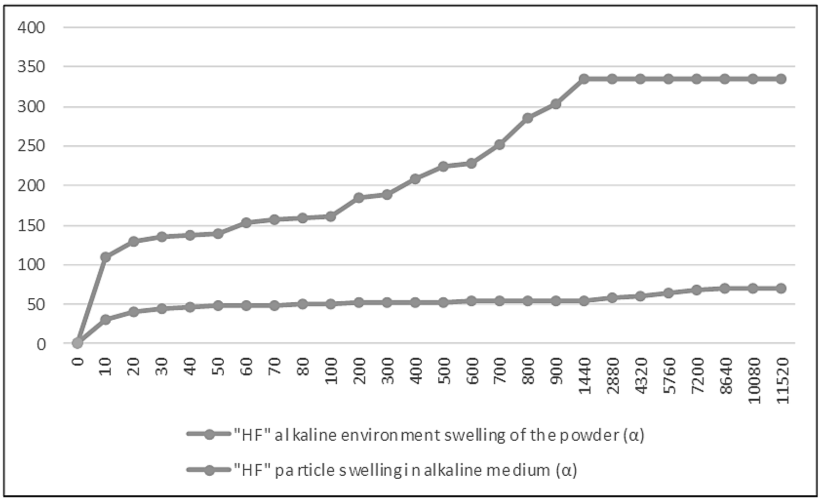

Figure 6. Time dependence of swelling (%) levels of "HF" powder and its particle in alkaline medium (20oC)

In the swell meter, an error occurs in determining the increase in total volume as a result of the increase in particle size during the swelling of the "HF", their friction against the device wall, and the filling of the gaps between the particles.

In optical microscopy, no external mechanical forces affect the swelling of “HF” particles. Therefore, it can be seen that the swelling detected by this method has a high value.

Conclusion. It can be said that the reason for the high value of “HF” swelling in an alkaline solution is due to changes in its composition and an increase in the number of amorphous parts. Hence, in an alkaline environment, the number of crystalline parts of “HF” decreases and the number of amorphous parts increases. Since there is no external influence on the swelling of the “HF” particle detected by the optical microscope, it can be considered as absolutely true about the swelling levels of the “HF” powder detected in the swell meter.

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