ORIGINAL ARTICLE

The Study of the Foaming Ability of Magnesium Laureth Sulfate at Different pH Values

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Abstract

Aim: The aim of our work was to study the physicochemical properties of the surfactant to compare the foaming ability (foam number and foam stability) at different pH values as well as to conduct them icroscopic analysis of the massive foam of the samples with magnesium laureth sulfate. **Materials and Methods**: 70% magnesium laureth sulfate ("EOC", Belgium) was chosen as an anionic surfactant providing the safe cleansing of the skin and its appendages. The samples were given by the Pharmaceutical Science and Research Centre "Aliyance Krasoty" (Beauty Alliance, Kyiv, Ukraine). Lactic acid (lactic acid, "Galactic", Belgium) was used as a pH adjuster of the foaming base value. The foaming ability of the test samples was determined by the method specified in DSTU ISO 696:2005 "Determination of the foaming ability by the modified method of Ross-Miles" and GOST 22567.1-77 "Synthetic detergents". For this, we used the method for determining the foaming ability. The level of the pH value of the test samples was determined by potentiometry (SPhU 1.2, 2.2.3) using a "pH Meter Metrohm 744." The quality of the bases prepared was assessed according to the following criteria: Appearance, organoleptic indicators (color, odor), determination of the pH value, the foaming ability (foam number, foam stability). These indicators were considered for the qualitative assessment of the current foaming detergents according to DSTU 4315:2004 "Cosmetic products for cleansing the skin and hair" and TU U 24.5-31640335-002:2007 "Skin care cleaning products." According to DSTU 4315:2004, the foam number should not be <145.0 mm, and the foam stability should be 0.8-1.0 c.u. In addition, the microscopic analysis of the foam was conducted using a "Konus-Akademy" laboratory microscope with the ScopeTek DCM510 eyepiece camera. **Results and Discussion:** When analyzing the data obtained for the foaming ability of the test sample of the anionic surfactant, it was found that it had a relatively high value of both the foam number and the foam stability, and it corresponded to the requirements of the current normative documents of Ukraine. The next step of our experiment was to determine the foaming ability of magnesium laureth sulfate at the acid pH value (3.5-4.0). This research stage was necessary for comparison of the physicochemical properties of the surfactant selected. This is due to the peculiarities of foaming detergent development. The pH was adjusted using lactic acid. According to the experimental data, it was found that at the acid pH range, the foaming base with magnesium laureth sulfate insignificantly improved its indicators of the foaming lability (both the foam number and the foam stability). **Conclusions:** It has been found that by the main physicochemical indicators (foaming ability) of quality, the foaming bases with magnesium laureth sulfate in two pH ranges fully comply with the standard values of the existing state standards of Ukraine. When studying the structure of the massive foam in the samples with magnesium laureth sulfate at the pH ranges of 5.5-6.0 and 3.5-4.0 using microscopy, it has been determined that in both cases, the foam has a stable structured system, i.e., it has a spherical shape and is characterized by the minimal surface energy, thus indicating its stability.

Key words: Foaming ability, foam structure, magnesium laureth sulfate, pH value

INTRODUCTION

When analyzing formulations of products for personal hygiene, in particular shampoos for children aged from 0 to 3 years and products for intimate hygiene presented at the Ukrainian market on the basis of surfactants, it has been found that exactly anionic surfactants such as sodium lauryl

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sulfate (SLS) or sodium laureth sulfate (SLES), ammonium lauryl sulfate (ALS), or ammonium laureth sulfate (ALES) are the most common in the list of major components among the various market segments (mass market, luxury market, premium market, and professional products).[1-3] As it is known, addition of sulfates in combination with viscosity regulators (solutions of electrolytes, for example, sodium chloride) to the composition of foaming bases is the easiest way to make dense foam, and this is the cheapest method of production. It should be noted that SLS and SLES are used in most foaming detergents of the segments of the luxury and premium market as well as professional products while ALS and ALES are applied in foaming detergents of the mass market segment.[4-7] However, it is known that high concentration of sulfates in foaming detergents can cause irritation of the skin and mucous membranes.

Analyzing the current trend in the production of domestic and foreign foaming detergents of the given market segment, it can be argued that one more representative of anionic surfactants, namely, magnesium laureth sulfate, is also used. In contrast to SLS and SLES, it does not irritate the skin and mucous membranes. By its properties, magnesium laureth sulfate is referred to very mild, however, more expensive surfactants.[6-8] It is used as the main surfactant mainly in baby shampoos, shampoos for sensitive skin as well as in products for daily use (in products for intimate hygiene).[9,10]

The main aim of our work was to study the physicochemical properties of the surfactant to compare the foaming ability (foam number and foam stability) at different pH values as well as to conduct the microscopic analysis of the massive foam of the samples with magnesium laureth sulfate.

MATERIALS AND METHODS

About 70 % Magnesium Laureth Sulfate ("EOC", Belgium) was chosen as an anionic surfactant providing the safe cleansing of the skin and its appendages.[11] The samples were given by the Pharmaceutical Science and Research Centre "Aliyance Krasoty" (Beauty Alliance, Kyiv, Ukraine). Lactic acid (Lactic Acid, "Galactic," Belgium) was used as a pH adjuster of the foaming base value. In our opinion, it is the optimal component because it is part of the acid mantle of the skin, moisturizes and improves its condition and the thickness of the epidermis; moreover, it is allowed for use in foaming detergents for children (Regulation [EU] No.1907/2006).

A specific feature of this experiment is the use of water. Since water is the main solvent of the system, which constitutes the greatest part; therefore, the quality of this component is of great importance. In this regard, in "Aliyance Krasoty" company, much attention is paid exactly to preparation and purification of water used in manufacturing the products. Water from artesian wells with the depth of over a 100 m is used at production site. However, the chemical composition of water is very unstable, and the amount of impurities varies depending on season and rainfall. The system of water treatment is designed in such a way that its chemical composition is always the same; it should not contain hydrogen sulfide, which changes the odor of both water itself, and the finished product; it should be free of a great amount of iron ions that can change the color of the final product; it should have a small amount of ions of chlorine, calcium, magnesium since they affect the process of the system thickening. These indicators are very important to control in the process of manufacture. The system of water treatment includes the following stages: Water purification from particulate contamination, iron ions, microbiological contamination, finely dispersed ion cleaning, and the process of the temporary storage of the treated water.

All samples were prepared according to the conventional technology: The required amount of the surfactant was calculated and dissolved in water at the desired temperature (40-45°C). For further studies, 5% aqueous solutions of the surfactant obtained were adjusted to the required temperature (37°C). The time for preparing the samples was from 30 to 60 min. All samples were prepared and calculated with reference to 100% substance.[12,13] These studies were carried out at the premises of the Research Laboratory of the Commodity Science Department of the National University of Pharmacy.

The Ross-Miles foam analyzer is the most widely used device for obtaining a foam and the assessment of its stability and volume. It was approved by the American society for testing and materials as a standard device for measuring the foaming ability of soaps and synthetic detergents. The Ross-Miles foam analyzer is suitable both for studies of foam in dilute solutions with low viscosity of the completely soluble surfactants and for measuring stability of the poorly soluble foam. However, it should be noted that the Ross-Miles foam analyzer as well as many other devices allow studying only some of the properties of the foam; at the same time, until today, there is no single method that would be universal and suitable for complete characterization of the properties of the foam. Thus, the foaming ability of the test samples was determined by the method specified in DSTU ISO 696:2005 "Determination of the foaming ability by the modified method of Ross-Miles" and GOST 22567.1-77 "Synthetic detergents."[14] The method to determine the foaming ability. To perform this test, the Ross-Miles foam analyzer, the ultrathermostat UT-15, a stopwatch timer, a rubber squeeze bulb, the analytical balance of the accuracy Class 3 for general purposes, pipettes: 1-2-50, pipettes: 1-2-1-2,[10] flasks: 1-1000-2, measuring glasses: B-1-100 (500) (1000) TC were used. The water jacket was connected to a thermostat, switched on, and the temperature of the liquid in the water jacket was adjusted to 37 ± 2°C. Simultaneously, 300 cm^3 of the solution of the surfactant studied was adjusted to the same temperature. Of this amount, 50 cm^3 of the solution was taken and poured down the sides of the graduated cylinder not to form the foam. In 10 min, using a rubber squeeze bulb or a pump, the test solution of the surfactant in the volume of 200 cm^3 was introduced into the pipette in such a way that no foam could form. The pipette with the solution was fixed to the stand so that its outlet was at a distance of 900 mm from the level of the liquid in the cylinder, and the flow could get to the center of the liquid. Then, the tap of the pipette was opened. When there was no solution in the pipette, a stopwatch timer was switched on, and the height of the foam column formed (mm) was measured. The measurement was carried out in 30 s. In 5 min, the height of the foam column formed (mm) was measured again.

The level of the pH value of the test samples was determined by potentiometry (SPhU 1.2, 2.2.3) using a "pH Meter Metrohm 744" device (Germany).[8,15]

The quality of the bases prepared was assessed according to the following criteria: Appearance, organoleptic indicators (color, odor), determination of the pH value, the foaming ability (foam number, foam stability). These indicators were considered for the qualitative assessment of the current foaming detergents according to DSTU 4315:2004 "Cosmetic products for cleansing the skin and hair" and TU U 24.5-31640335-002:2007 "Skin care cleaning products."[16,17]

According to DSTU 4315:2004, the foam number should not be <145.0 mm, and the foam stability should be 0.8-1.0 c.u.

In addition, the microscopic analysis of the foam was conducted using a "Konus-Akademy" laboratory microscope with the ScopeTek DCM510 eyepiece camera. For visualization of the images obtained, the ScopePhoto™ software (version 3.0.12.498) was used, it allowed measuring linear dimensions in real time and static image.[18]

RESULTS AND DISCUSSION

The first stage of our research was to study the foaming ability of magnesium laureth sulfate at the neutral pH (5.5-6.0). According to the data from table, it was determined that the foaming base prepared had the following indicators: It was a homogeneous liquid of a transparent color without impurities and with a characteristic odor of detergents, it corresponded to the requirements of the current normative documents. The results of the study of the test sample are given in Table 1.

When analyzing the data obtained for the foaming ability of the test sample of the anionic surfactant, it was found that it had a relatively high value of both the foam number and the foam stability, and it corresponded to the requirements of the current normative documents of Ukraine.

The next step of our experiment was to determine the foaming ability of magnesium laureth sulfate at the acid pH value (3.5-4.0). This research stage was necessary for comparison of the physicochemical properties of the surfactant selected. This is due to the peculiarities of foaming detergent development. As it is known, most foaming detergents have the neutral pH value (5.5-6.0); however, there are detergents with the acid pH value (e.g. gels for intimate hygiene). The test sample was prepared according to the technology mentioned above. The pH was adjusted using lactic acid. The results of the study of the test sample are given in Table 1.

According to the experimental data, it was found that at the acid pH range, the foaming base with magnesium laureth sulfate insignificantly improved its indicators of the foaming lability (both the foam number and the foam stability). Based on the research data obtained, it can be concluded that it is possible to use magnesium laureth sulfate when developing various foaming detergents at different pH ranges, i.e. the value of the foaming ability at different pH ranges is within the requirements regulated by the current normative documents of Ukraine.

It is commonly known that dense and stable foam is one of the criteria of any foaming detergent.[19,20] Therefore, the next stage of our study of the physicochemical properties of magnesium laureth sulfate was to examine the foam structure using the

Table 1: The physicochemical indicators of magnesium laureth sulfate

Sample	Appearance, organoleptic indicators	Temperature of dissolution, °C	pH value (10 % solution)	Foaming ability	
				Foam number, mm	Foam stability, c.u.
Magnesium laureth sulfate	A homogeneous solution of a transparent color with a characteristic odor of detergents	44±1	6.0±0.1	205	0.87
After pH adjusting					
Magnesium laureth sulfate	A homogeneous solution of a transparent color with a characteristic odor of detergents	43±1	3.8±0.2	231	0.9

n=5, *P*=95%

method of microphotography. The test samples were prepared according to the technology mentioned above. However, the main requirement of this research stage was to study the foam freshly prepared. Hence, directly before the study, the massive foam was formed using a "Deluxe Cordless Mini Mixer" manual mixer (China), which was then put on a glass slide; then, the foam was examined under the microscope.

The main structural element of the foam is gas bubbles that coalesce and form a single pseudocrystalline system where small bubbles are systematically arranged around large bubbles and create the equilibrium structure in the foam volume [Figure 1a]. When examining the film between the bubbles (partition), it has been found that they have rather thick walls (containing a lot of liquid); therefore, the bubbles retain a spherical shape [Figure 1b], which has a high water content and thereby low resistance. Hence, they are referred to metastable (conditionally stable) foams. As the liquid is saturated with air bubbles, the thickness and number of partitions reduce because of the liquid flowing through Plateau–Gibbs canals formed in the area of contact of three films (Plateau triangle) [Figure 1c] having a gap between three adjoining cylinders in the plane of the pattern, i.e., a constant cross section in the form of a triangle with concave sides. When the liquid flows through these canals, coalescence occurs. After that, the bubble shape begins slowly changing from spherical to polyhedral [Figure 1d].

Analyzing the above, it can be concluded that with increasing saturation of the foam with air the bubbles lose their spherical shape and become polyhedra while the films getting the uniform thickness throughout the whole volume of the foam divide them. The spatial structure, which is similar to a honeycomb in section, is obtained. When obtaining the foam, this structure appears spontaneously, in three thin films, which are arranged at an angle of 120°C, converge on each edge of the polyhedron (it is related to the peculiarity of the foam structure). This foam is characterized by the minimum surface energy, and consequently, it is the most stable.

Different groups of foaming detergents are known to have their own pH ranges (e.g. baby shampoos have pH (5.5-6.0), and products for intimate hygiene are with pH (3.5-4.0). Therefore, the next stage of our research was aimed at studying the structure of the foam at the acid pH value (3.5-4.0).

The massive foam studied had the form of a convex 14-hedron [Figure 2a]. Where the number of edges subsequently reduced because of movement of liquid through the Plateau–Gibbs canals: The liquid phase flowing down under the action of gravity was removed from the walls; as a result, there was a rapid coalescence – combination of adjoining gas bubbles. According to our observations in the process of liquid movement through these canals, the structure of the massive foam does not change basically, and the number of edges in the bubbles grew during coalescence. In other words, larger bubbles have a greater number of edges than small bubbles,

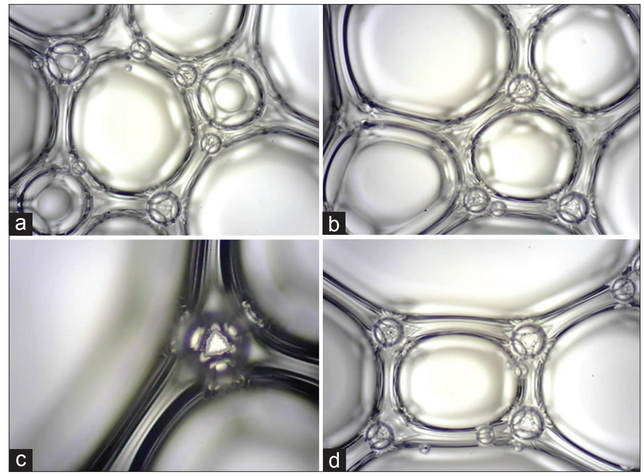

Figure 1: Microscopy of the foam with magnesium laureth sulfate at pH (5.5-6.0), (a) Microscopy of the foam with magnesium laureth sulfate, (b) the spherical structure of the foam bubbles with magnesium laureth sulfate, (c) The structure of Plateau–Gibbs, (d) the polyhedral form of bubbles

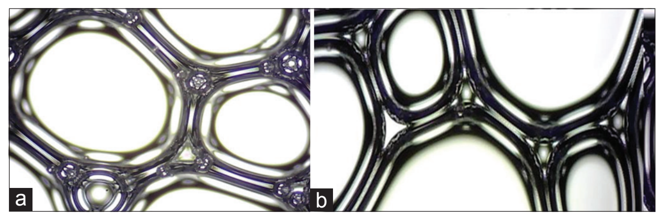

Figure 2: Microscopy of the foam with magnesium laureth sulfate at pH (3.5-4.0), (a) Microscopic analysis of the foam of magnesium laureth sulfate at the acid pH value (3.8), (b) the oval shape of the foam bubbles of magnesium laureth sulfate

and the absence of distinct angles between the edges creates the oval shape in bubbles [Figure 2b].

CONCLUSIONS

It has been found that by the main physicochemical indicators (foaming ability) of quality, the foaming bases with magnesium laureth sulfate in two pH ranges fully comply with the standard values of the existing state standards of Ukraine.

When studying the structure of the massive foam in the samples with magnesium laureth sulfate at the pH ranges of 5.5-6.0 and 3.5-4.0 using microscopy, it has been determined that in both cases, the foam has a stable structured system, i.e., it has a spherical shape and is characterized by the minimal surface energy, thus indicating its stability.

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