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Study of Foam Stability Kinetics of Protein Blowing Agents Based on Solid Keratin Hydrolysates Synthesized with a Mixture of Sodium and Calcium Hydroxide and Individually†

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Abstract: This study is dedicated to the investigation and comparison of the kinetics of foam stability of protein foaming agents based on hydrolysates of solid keratin. The work utilized ready-made hydrolysates based on sodium hydroxide and a mixture of sodium hydroxide with calcium hydroxide for the synthesis of foaming agents. The synthesis was carried out according to the author's methodology. Among the indicators studied were foam multiplication, foam specific weight, foam stability over time, and average foam stability reduction rate. Experiments were conducted with various concentrations and ratios of components at constant temperature, pressure, and pH values, as well as mixing speed, mixing time, and observation time. It is hypothesized that protein foaming agents based on hydrolysates of solid keratin using a mixture of hydroxides will not be able to achieve optimal values in the kinetics of foam stability. In contrast, protein foaming agents based on hydrolysates of solid keratin using sodium hydroxide individually have high potential foaming properties and, consequently, good foam stability kinetics indicators. The results of this study may be useful in the development of new synthesis methods for protein foaming agents with optimal foaming properties or for improving those that already exist. The research itself and the products obtained during it—protein foaming agents, are mainly aimed at expanding the industrial sphere of human activity. This may also have practical applications in other areas such as the food industry, cosmetology, medicine, and others.

Keywords: foaming agents; foam stability kinetics; foam multiplication; foam specific weight; synthesis of foaming agents; hydrolysates based on solid keratin; keratin-containing raw materials

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1. Introduction

Nowadays, human activity is accompanied by the formation of a huge amount of secondary biological waste, which, polluting the environment, in turn remain very important sources for the production of other valuable products. The problem of complex processing of raw materials, with the involvement in industrial and economic turnover of production wastes as by-products, becomes very relevant and significant in the scale of modern industry [1–3].

In recent years, the volume of work and research aimed at studying such a multicomponent system as raw materials of animal origin has increased dramatically, a large number of ways to extract valuable chemical products from it have appeared. Mainly keratin, a protein with increased strength, is obtained. Protein blowing agents based on hydrolysates of keratin-containing raw materials obtained using alkaline hydrolysis have properties indispensable for the construction industry. For example, protein blowing agents produce foamed concrete with the highest quality characteristics [4].

Synthesis of blowing agents based on keratin-containing raw materials is an effective way to recycle secondary raw materials to obtain products useful to society, such as building materials. We have carried out a unique synthesis of these compounds with subsequent evaluation of their properties. The development of the production of blowing agents is an urgent task and has great prospects for the expansion of production [5].

2. Materials and Methods

The main component of protein blowing agent is hydrolysate obtained by alkaline hydrolysis of keratin-containing raw materials. Foaming properties of protein blowing agent depend on many factors, including the parameters of the process of hydrolysis of keratin-containing raw materials, namely, the origin of keratin-containing raw materials, the nature of alkaline hydrolyzing reagent and its concentration in the hydrolyzing solution, the conditions of hydrolysis of keratin-containing raw materials. The component composition of the protein blowing agent is also important [6]**.**

2.1. Raw Materials and Reagents for Preparation.

For preparation of protein blowing agents we used hydrolysates of keratin-containing raw materials obtained in laboratory conditions by alkaline hydrolysis of keratin-containing raw materials—horny hoof raw material (HHRM) using sodium hydroxide as a hydrolyzing agent, as well as a mixture of sodium hydroxide and calcium hydroxide. The component composition included protein hydrolysate, hydrochloric acid, hydrogen peroxide, magnesium chloride, water, iron (II) sulfate crystallohydrate, isobutyl alcohol and other.

2.2. Products Obtained.

The methodology of protein blowing agents preparation in laboratory conditions is based on the sequence of operations used in production conditions, it was adapted to the conditions of the laboratory experiment.

In our work we used already ready hydrolysates on the basis of keratin-containing raw materials (HHRM), from which we obtained 11 protein blowing agents, in 6 of them sodium hydroxide (NaOH) was the alkaline agent during hydrolysis, and in the remaining 5—a mixture of sodium hydroxide and calcium hydroxide ($Ca(OH)_2$). Characterization of these hydrolysates is presented in Table 1.

Table 1. Characterization of the obtained blowing agents.

No. n/a of Blowing Agent Composition	Distinctive Feature of the Blowing Agent: Nature and Mass Ratio of Alkaline Reagent, HHRM and Water in Obtaining HHRM Hydrolysate, $m_{alk.reag}$:$m_{HHRM.}$:m_{water}, g:g:g
1	NaOH, 5,5:43:130
2	NaOH, 7:43:130
3	NaOH, 8,5:43:130
4	NaOH, 10:43:130
5	NaOH, 11:43:130
6	NaOH, 12:43:130
7	NaOH+ $Ca(OH)_2$, (8 + 0,5):43:130
8	NaOH+ $Ca(OH)_2$, (8,1 + 0,4):43:130
9	NaOH+ $Ca(OH)_2$, (8,2 + 0,3):43:130
10	NaOH+ $Ca(OH)_2$, (8,3 + 0,2):43:130
11	NaOH+ $Ca(OH)_2$, (8,4 + 0,1):43:130

After following the production methodology for BA assembly, it is recommended to infuse each blowing agent for 24 hours. And after that to obtain the foam and to determine the foam multiplicity, specific gravity and foam stability.

3. Results and Discussion

3.1. Analysis of Foam Stability Kinetics

Foam stability of blowing agent solutions (BA) foam is of great importance in the process of making foam concrete, which is evaluated by the change in foam volume over time, it is determined by the ratio of foam volume at the current time to the initial time. Foam should be stable for 0.5–1h. We recorded the foam volume every 10 minutes for 1.5 h in most cases, the initial foam volume was taken as 100% and for each measurement the foam volume was calculated as a percentage of the initial volume. Figure 2 shows the time dependences of foam volume change (kinetics) for the investigated blowing agent solutions depending on the content of hydrolyzing agent or mixture of hydrolyzing agents.

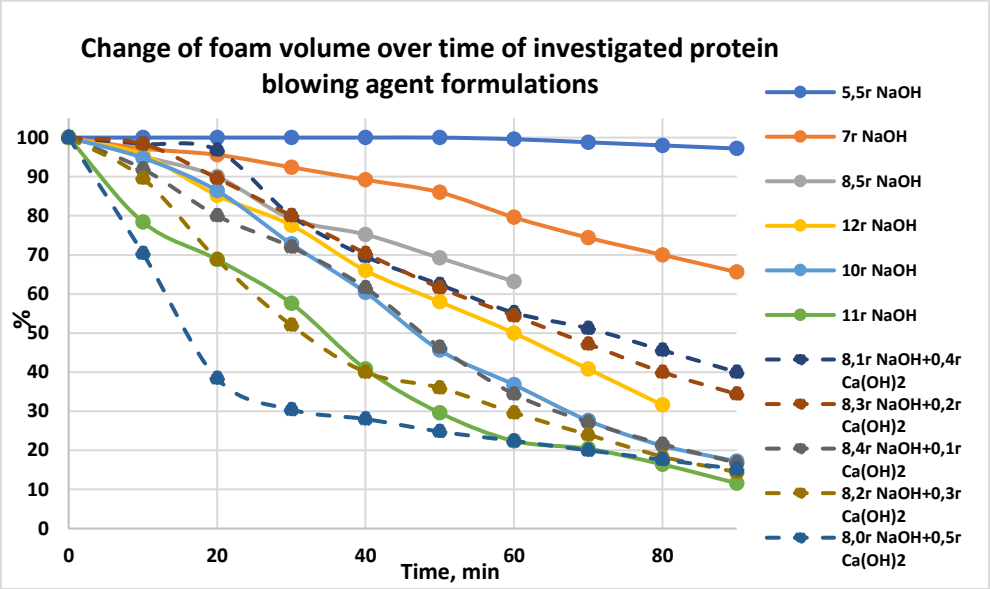

Figure 2. Change of foam volume over time of investigated protein blowing agent formulations.

3.2. Determination of the Average Rate of Foam Stability Decrease

It was decided to determine the average rates of decrease in foam stability, which are given in Table 2, as arithmetic mean values for the whole time of the experiment.

Table 2. Average rates of foam stability reduction for the investigated blowing agent solutions.

No. n/a of Blowing Agent Composition	Distinctive Feature of the Blowing Agent: Nature and Mass Ratio of Alkaline Reagent, HHRM and Water in Obtaining HHRM Hydrolysate, $m_{alk.reag}$:m_{HHRM}.:m_{water}, g:g:g (Ratio $m_{alk.reag}/m_{water}$, g/g)	Average Rate of Foam Stability Reduction, υ_{av}, %/minute
1	5,5:43:130 (0,042)	0,031
2	7:43:130 (0,054)	0,382
3	8,5:43:130 (0,065)	0,613
4	10:43:130 (0,077)	0,920
5	11:43:130 (0,085)	0,982
6	12:43:130 (0,092)	0,848
7	(8 + 0,5):43:130(0,0615 + 0,0038)	0,942
8	(8,1 + 0,4):43:130(0,0623 + 0,0031)	0,667
9	(8,2 + 0,3):43:130 (0,0631 + 0,0023)	0,951

10	(8,3 + 0,2):43:130 (0,0638 + 0,0015)	0,729
11	(8,4 + 0,1):43:130 (0,0646 + 0,0008)	0,924

The average rate of foam stability decrease is defined as the ratio of the difference of initial and final foam volumes, in %, to the duration of foam stability determination. Based on the results of Table 2, we can conclude that the slowest to lose its volume of foam solutions BA № 1 and 2. The others, in turn, lose approximately 1% of their foam volume per minute.

4. Conclusions

Thus, under the experimental conditions, it was found that reducing the ratio of the mass of hydrolyzing agent(s) to the mass of HHRM used in the hydrolysis of HHRM to a certain value leads to an increase in the stability of foam and its achievement of optimal values. Under the conditions of the experiment it was found that the optimal of the 11 compositions studied can be called the composition of protein foaming agent prepared on the basis of hydrolyzed HHRM using sodium hydroxide in the ratio m_{NaOH}:$m_{HHRM.}$:m_w, equal to 5.5:43:130.

Other alkaline reagents can also be used in the alkaline hydrolysis of keratin-containing raw materials. The data obtained in the present work suggest that when using other alkaline reagents, it is also necessary to reduce the content of alkaline reagent in the hydrolysis of keratin-containing raw materials to a certain value to achieve the required indicators of foaming ability of protein blowing agents prepared on the basis of hydrolysates.

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