Changing properties of mechanically activated water suspensions

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Abstract. The authors carried out a series of experimental studies to research the changes of properties in mechanically activated water and suspensions. This article presents a part of the combined temperature and hydrogen exponent studies carried out at two different universities, using two separate approaches to mechanical dispersion. Study I used a planetary whisk mixer, whereas study II used a vibrating mechanical activator, which is a modern alternative to dispersion devices used at food production facilities. The research of the properties of mechanically activated water and liquid suspensions using these methods was conducted due to both the importance of these substances for all areas of the food production industry, and the modern development of technologies and techniques used at production facilities, as well as the lack of unity among the numerous research studies conducted by leading scientists specializing in the study of the properties of water, liquid suspensions and emulsions in resting and activated states. The results of the experimental studies conducted directed authors to conduct further research of mechanically activated suspensions during the filtration process.

1. Introduction

Water is the most common binary inorganic component on the planet, as it plays a key role in various processes of flora and fauna, inanimate nature and in human production activities (it is the main part of the hydrosphere, is found in the compositions of earth rocks and minerals, can be found in soil and in the atmosphere, occupies 50÷99% of the animal and plant mass, and it is a fundamental link in the maintenance of most of technological operations etc.) [1-3].

Currently, water is the most well-studied substance in the world (by composition, structure, properties, purpose, abnormal properties, changes upon activation by various methods, etc.). Leading scientists have proposed a myriad of theories that can explain most of water’s properties, however, the area of mechanical activation of water and liquid suspensions has not been fully researched. Understanding of the structure and properties of water, as well as the possibility of its correction using mechanical activation, carries a practical importance when used in technological processes, especially in food production industries, which explains the goal and purpose of jointly conducted experiments [1-6].
2. Literary overview
It is known that under the activation by external thermal, mechanical, and other influences, solid matters and liquid states are able to change its properties. Mechanical activation plays a paramount role in preparation of raw food materials for various production processes [7-19].

The process of mechanical activation of solid matters (shock, shock-abrasive or abrasive effects leading to structural, chemical or state changes [12]) is fragmentarily researched and generally recognized. However, despite the extensive number of scientific studies conducted in regard to this topic, the area of mechanical activation of liquids requires further research.

At this time, leading scientists researching the mechanical activation of liquids [1, 2, 5, 6, 8-19] have already established that the given process is capable of inflicting complex effects on the matter, triggering chemical reactions. Direct mechanical effects on the molecular formation led to a disordered state, as well as the weakening and rupture of intermolecular bonds and their self-organization until an energy equilibrium can be reached (giant heteropatic water clusters break into many smaller clusters), thus reducing viscosity ($\mu$) and surface tension ($\sigma$). One of the modern methods of mechanical activation in the food industry is vibration activation, and the leading devices of our time are the devices of vibration activation [2, 5, 9, 11, 13, 14, 16, 19].

Vibration activation of water and liquid solutions is a complex, multi-stage process of altering the energy state of the matter under the influence of vibrations. Vibration effects are able to speed up many production processes and obtain numerous additional effects. The effects that arise from the action of vibration of nonlinear mechanical systems are discussed in detail in source [19]. The reversible change of some properties of water and dispersed systems containing liquid state matters are discussed in sources [6, 15].

The interest in the study of changes in temperature ($t$) and hydrogen exponent, the activity of hydrogen ions ($pH$) properties during the process of mechanical activation (vibration activation) of water and liquid suspensions is driven by the fact that the said indicators are the most significant factors in the processes of food production. Additionally, $pH$ is linearly connected to the hardness of water. This indicator leads to premature corrosion and equipment failure and is not applicable in a number of technological processes [3, 6-8].

3. Research methods and materials
The research of changes of properties of mechanically activated water and liquid suspensions was carried out in several stages on the premises of two different universities: stage I was conducted at Kemerovo State University and stage II was conducted at the Far Eastern State Technical Fisheries University.

3.1. Stage I of the experimental study
At this stage, distilled water (hereinafter, water) was exposed to mechanical activation. A planetary rim mixer with volume ($V$)=$4\times10^{-3}$ m$^3$ and number of revolutions of the activation device ($n$)=$10^2\div320$ min$^{-1}$ was used as the activation device. All measurements of $t$ of the air in the research room and in the water (during the process of mechanical activation), as well as the $pH$ level, were done electrometrically, in accordance with the current standards, using a universal pH-meter (graduation: 0.1 and 0.01). The process was recorded using photo and video footage [1].

3.2. Stage II of the experimental study
During stage II, water and liquid suspension (hereinafter, suspension) where subjected to mechanical activation (vibration and vibration mechanical activation). A vibrating mechanical activator was used as the activating device ($n$=$10^4$ min$^{-1}$, amplitude of vibration ($A$)=$2.5\div5.3$ mm, time ($\tau$)=$180$ s). All measurements of $t$ in air in the laboratory, water and in the suspension (before and after mechanical activation) were carried out in accordance with the current standards, using measurement tools with graduation: 1, 0.1 and 0.01°C). The $pH$ levels of the water and suspension were established using
indicators, which were determined through the comparison of samples under study to the standard scale. The process was recorded using photo and video footage.

4. Results and discussion
This section presents a summary of the general results of two independent experiments, depicted through the use of graphics (figures 1, 2).

![Figure 1](image-url)

**Figure 1.** Temperature change of the mechanically activated water and suspension over time

The results obtained through the tracking of $t$ during $\tau$ during the process of mechanical activation of water (I) using a mixer (at $n=10^2$ min$^{-1}$ and $n=180$ min$^{-1}$) are shown on figures 1(a), 1(b); after mixing – shown in figure 1 (denoted I.1); before and after vibration activation of water (I) and suspension (II) using the vibrating mechanical activator in the «vibration» mode (at $n=10^3$) in figure 1(c) (I.2 and II.2); before and after vibrating activation of water – in figure 1(d) (I.3 and II.3); and with no activation (I.0 and II.0). Figure 2 demonstrates the results of changing the pH level of mechanically activated water (I) and suspension (II). All designations are duplicated in figure 1.

The analysis of figures 1(a), 1(b) demonstrates that when water is stirred, a decrease in the $t$ typical to this process can be observed (by $11.54\div17.96\%$). According to Newton’s law of viscosity, the $\mu$ of water must increase as the temperature decreases, however, the literary overview and previous studies [1, 9] indicate its decrease upon mechanical activation. The unusual behaviour of $\mu$ can be explained using the cluster theory [6].
Changes in pH level of mechanically activated water and suspension

This also explains the growth of \( t \) when using a mechanically activated water mixer over time (figure 1(c)). During the vibration and vibration activation of water and suspension (figures 1(d), 1(e)), a steady growth and maintenance of \( t \) level can be observed (by 12.08\( \pm \)13.46\%). Going forward, a study is planned to find the levels of \( n \) at which the temperature of water and suspension would not decrease under when put through the action of mechanical activation, but rather increase instead.

The analysis of hyetographs (figure 2) demonstrates that during the process of mechanical activation (vibration and vibration mechanical activation) with various \( n \), the pH level may decrease both below its neutral state (pH\(<\)7), assuming an acidic state, or increase above the neutral state (pH\(>\)7), assuming an alkaline state [1]. However, the following indicators remain within the acceptable limits for drinking water and technological needs (pH=6-9).

5. Conclusion
The literarily review on the methods of mechanical activation of liquids, in combination with the results derived from previous and current studies, conclude that the vibration mechanical activation of water, suspensions, and emulsions presents a great interest for further research of various technological processes. Particularly the filtration process, as it retains the activate state for the longest duration of time with a minimum time required for activation.

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