ISSN 1311-3321 (print)
ISSN 2535-1028 (CD-ROM)
ISSN 2603-4123 (on-line)

UNIVERSITY OF RUSE "Angel Kanchev"
РУСЕНСКИ УНИВЕРСИТЕТ "Ангел Кънчев"

PROCEEDINGS

Volume 57, book 10.2.
Biotechnologies and food technologies

НАУЧНИ ТРУДОВЕ

Том 57, серия 10.2.
Биотехнологии и хранителни технологии

Ruse
Русе
2018

Volume 57 of PROCEEDINGS includes the papers presented at the scientific conference RU & SU'18, organized and conducted by University of Ruse "Angel Kanchev" and the Union of Scientists - Razgrad. Series 10.2. contains papers reported in the Biotechnologies and Food Technologies section.

Book	Code	Faculty and Section
Razgrad Branch of the University of Ruse		
10.1	FRI–LCR-1-CT(R) SAT–LB-2-CT(R)	Chemical Technologies
10.2	FRI–LCR-1-BFT(R) SAT–LB-P-2-BFT(R)	Biotechnologies and Food Technologies
10.3	TUE-SSS-CT(R)	Chemical Technologies
	TUE-SSS-BFT(R)	Biotechnologies and Food Technologies

The papers have been reviewed.
ISSN 1311-3321 (print)
ISSN 2535-1028 (CD-ROM)
ISSN 2603-4123 (on-line)

The issue was included in the international ISSN database, available at https://portal.issn.org/.
The online edition is registered in the portal ROAD scientific resources online open access

SAT–LB-P-2-BFT(R)-14

INFLUENCE OF ELECTROPHYSICAL WATER TREATMENT ON THE PROCESS OF BEVERAGES SATURATION

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Abstract: *The content of carbon dioxide, which is actively used by producers of carbonated beverages as a preservative, acidity regulator and antioxidant, significantly affects the quality of finished products.*

The possibility of changing the ph value, which affects the balance between carbon dioxide, bicarbonate and carbonate during saturation, by electrophysical treatment of water was considered. Industry produces various variants of electrolysers, but they are not suitable for saturation of drinks. Therefore, the development of an appropriate design is an urgent task.

It is expedient to carry out the process of saturation simultaneously with the electrophysical treatment of pre-prepared (cooled and deaerated) water. The parameters that influence the efficiency of electrophysical treatment and the quality of finished products are the voltage, the voltage-ampere characteristic, the mutual placement of the electrodes, the duration of activation, the degree of mineralization of the solution. The influence of material of equipment, including electrodes, on the content of metals in the carbonated beverages is also taken into account. Electrodes in the process of operation should not experience electrochemical destruction. It is expedient to make an anode from a titanium, a cathode - from a corrosion resistant steel AISI 321.

Keywords: *Saturation, Beverage, Electrophysical treatment, ph value.*

INTRODUCTION

The non-alcoholic beverages market is one of the few that is showing positive dynamics in Ukraine. At the same time, sales of aerated diet and soft drinks are increasing, despite the warnings of doctors and scientists about the harm of such products for health (Shenkin, J. D., 2003; Malik, V.S., 2006).

An important stage in the production of carbonated beverages is their saturation - the saturation of the drink with liquid carbon dioxide at a certain temperature and pressure. The basis of this process is the ability of carbon dioxide to interact with water to form an aqueous solution.

By the level of saturation of carbon dioxide, the largest share on the market is concentrated in medium- and stronglycarbonated beverages. Such a structure of consumption is justified by the fact that carbon dioxide is actively used by non-alcoholic beverage producers as a preservative, acidity regulator and antioxidant (Solov'yeva, M. P., Karkh, D. A., CHugunova, O.V., 2017).

EXPOSITION

The content of carbon dioxide in beverages has a significant effect on the quality indicators of finished products, so looking for ways to intensify the saturation process is an urgent task.

For revealing of factors influencing saturation of water by CO_2, and intensification of this process, the scientific and scientific-technical literature for the last twenty years has been analyzed. Attention was paid to both the technical side of the process and the impact of products on consumer health.

The amount of gas G absorbed by the liquid phase

$$G = k \cdot F \cdot \Delta p \cdot \tau, \quad (1)$$

k – the absorption coefficient of carbon dioxide by water (may be 12,8, which corresponds to the solubility of 87 ml of gas in 100 mg of water); F – the phase contact surface, Δp – the difference of partial pressures in the gaseous and liquid phases; τ – the process duration.

From equation (1) it can be seen that the speed of the mass transfer process is directly proportional to the absorption coefficient, the contact surface of the phases and the difference of the partial pressures. The absorption coefficient depends on the temperature. The dissolution of gases in liquids is almost always accompanied by the heat release. Therefore, the solubility of gases with increasing temperature, in accordance with the principle of Le Chatelier, is reduced. The absorption coefficient decreases with increasing temperature. There is a concentration of gas at which the equilibrium between its gaseous and dissolved forms is established. When dissolving gas in water there is a significant decrease in the system volume. Therefore, increasing the pressure, in accordance with the principle of Le Chatelier, should lead to a shift of equilibrium to the right, that is, to increase the solubility of gas. If the gas is slightly soluble in the liquid and the pressure is small, then the solubility of the gas is proportional to its pressure. This dependence is expressed by Henry's law (1803): the amount of gas dissolved at a given temperature in a certain volume of a liquid, at equilibrium is directly proportional to gas pressure. Henry's law can only be used for relatively dilute solutions, with low pressures and the absence of chemical interaction between soluble gas molecules and solvent.

Saturation is carried out to the carbon dioxide content in a solution of 0.5 - 0.6% by mass. The saturation limit depends on the temperature and pressure at which the gas is dissolved. Such, at 2 ° C and an excess pressure of 490 kPa, the gas solubility is 19.234 g/l. However, obtaining an extremely saturated solution is not expedient, since the bulk of carbon dioxide is absorbed in the initial period of saturation at a significant difference in partial pressure. In the next period, as the system approaches the conditions of the phase equilibrium, mass exchange becomes ineffective and a long time is required to achieve the boundary saturation. When choosing the optimal saturation regime, it should be kept in mind that too high a difference of partial pressures in the solution and gas environment causes the formation of a supersaturated solution. In such a solution, carbon dioxide is not tightly bound to water, quickly desorbed and does not provide high quality beverages.

Therefore, an intensive mass transfer can be achieved at high gas pressure, a large contact surface of the phases and low temperature of the aqueous solution. The rational conditions of carbonation are: pressure of CO_2 0,49 – 1,18 MPa, water temperature 1 – 2 °C. Salt content in water also changes the solubility. The contact surface can be increased by vigorous mixing of water in the atmosphere of CO_2, fine water sputtering, water drainage on a nozzle with a large surface in the form of a film in CO_2 atmosphere. To change the absorption coefficient, water activation methods are used which involve the use of shock waves, ultrasound, magnetic field, microwave radiation.

Taking into account this information, in the industry, water is pretreated before saturation - cooled to 2 – 6 ° C and deerated (dissolved air and other gases remove from the water). These processes are a requirement of technology aimed at both improving the quality of beverages and increasing the efficiency of carbonation.

In addition to external factors - pressure and temperature - the carbon dioxide solubility also depends on the nature of the gas and its properties to enter into chemical reactions with water.

In terms of chemical kinetics, the process of carbon dioxide dissolving in water is quite complex. When CO_2 dissolved in water, then the equilibrium between the carbonic acid H_2CO_3, bicarbonate HCO_3^- and carbonate CO_3^{2-} is established:

$$H_2O + CO_2 \leftrightarrow^* H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow H^+ + CO_3^{2-}.$$

The equilibrium of this system is strongly shifted to the left, because carbon dioxide - the compound is unstable and easily decomposes into carbon dioxide and water. The ionization constant of the pKa process at the same time is 2,46 × 10^{-17}.

However, only 1% of CO_2, which is in an aqueous solution, is present in it in the form H_2CO_3. Many researchers have drawn attention to this discrepancy, therefore, for the convenience of calculations of chemical equations, pKa and pH it is assumed that everything CO_2 reacts with water.

The balance between carbon dioxide, bicarbonate and carbonate depends on pH. Here the principle of Le Chatelier's affects: a presence in the solution of hydrogen ions displaces the alkaline reaction of the medium to the acid side (pH up to 5.5). Conversely, removing protons from the system displaces the reaction equilibrium to the left when carbon dioxide is rehabilitated oneself from carbonate and bicarbonate (Homen, 1992). Thus, at a low pH value, carbon dioxide prevails in the system, and in fact no bicarbonate or carbonate is formed, whereas at a neutral pH value, bicarbonate dominates. And only at high pH carbonate predominates (Fig. 1).

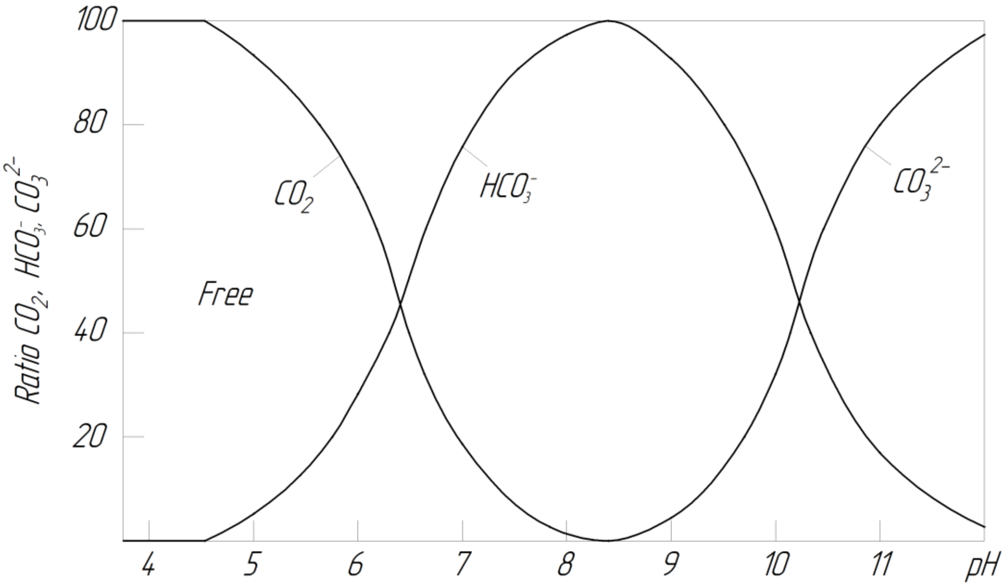

Fig.1. Relationship between Carbon species and pH

Therefore, we consider the possibility of changing the pH value of water, which determines the course of many chemical, technological and biological processes (Dolinskiy, A. A., SHurchkova, YU.A., (2013), before carbonization. pH value and oxidative-reducing potential (ORP) many scientists associate with the peculiarities of the structural water organization and its subsequent influence on living organisms. It's possible to determine pH and ORP by potentiometric method on the device pH-meter I-160 MP.

Numerous studies are devoted to the process of water activating under the influence of various factors - temperature, electric current, ultrasound, magnetic field, etc. It was decided to focus on the electrochemical treatment of water, in which water passes into a metastable state, which is characterized by abnormal values of the electrons activity and other physical and chemical parameters. When electrolysis occurs on a cathode and an anode, a series of chemical reactions takes place. As a result, the system of intermolecular interactions, the composition of water, including the water structure as a solution, changes (Tsarenko, YU.YU., 2014).

Various variants of electrolysers, which are conventionally divided into three types: static, immersed and continuous-flow (Fig.2), are produces for the electrochemical conversion of water and aqueous solutions of electrolytes (Kurchenko, N.YU., Kovko, V.A., 2012). But they are unsuitable for carbonization of beverages.

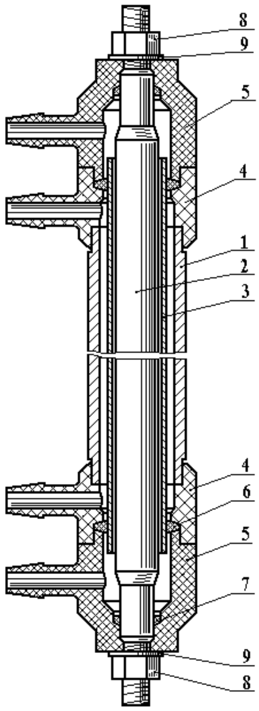

Fig.2. Continuous-flow electrolyser:
1 – cathode; 2 – anode; 3 – diaphragm; 4 – sleeve; 5 – head; 6, 7 – seals; 8 – nut; 9 – washer

The process of electrochemical activation of water and aqueous solutions is influenced by the distance between the electrodes, the voltage of the direct current supplied to the electrodes, the current strength, which is fed to the electrodes, the activation time, the degree of the solution mineralization (Amcheslavskiy, O.V., 2011).

Under the Ohm law, the current strength is a voltage function, but in experiments it also depends on the distance between electrode and a time. At a certain value of the distance L between the electrodes, the current value reaches its maximum, then begins to decrease. This is due to the counteraction of the chaotic heat motion to the electric directional charged particles movement due to rising temperature of the solution as a result of electrochemical treatment. It is also important to take into account the influence of the equipment material, including the electrodes, on the metal content of the finished product (Mareci, D., Trinca, L., Cotea, V., Souto, R., 2017). Electrodes in the operation process should not undergo electrochemical destruction. In published studies using mass-spectrometric studies of the chemical elemental composition of water before and after its electrochemical activation, it was found that the anode should be manufactured from titanium, a cathode from corrosion-resistant steel AISI 321.

As a result of electrochemical treatment the products must meet the established requirements. It is also advisable to control the size of carbon dioxide bubbles, because carbonated beverages containing smaller bubbles have the advantage in taste (Barker, G., Jefferson, B., Judd, S., 2002).

CONCLUSION

It is advisable to realize the saturation process simultaneously with the electrochemical treatment of pre-prepared (cooled and deaerated) water. Parameters that influence the efficiency of electrochemical treatment and the quality of finished products are the magnitude of the voltage, the voltage-ampere characteristic, the relative position and the electrodes material. They will be considered as controlled parameters in further research.

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