Implementation of techniques and design of equipment for the production of the food liquids

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Abstract. This article discusses the rationale for the implementation of techniques and design of equipment, allowing to assess the quality and authenticity of sparkling wines produced in the Krasnodar region. There is an urgent question about the methods of monitoring and detecting fraud in the production and import of sparkling wines at stable positive tendency to increase volumes of these products. The main drawback of the regulatory documentation is the lack of methods for recognizing the naturalness of products presented to the consumer, which increases the risks of producing products that do not meet the requirements. In this regard, the capabilities of software and hardware systems are shown, which make it possible to assess the quality and authenticity of sparkling and carbonated wines, as well as to study the physicochemical properties of food liquids with a two-phase “liquid-CO2” system. It was established that this set of techniques allows to determine the quality indicators of sparkling and carbonated wines, as well as to analyze the applied technological methods of production and to identify the authenticity of the analyzed object. An analysis of the sparkling properties of wine confirms the influence of the biochemical factor of yeast biomass on the processes of CO2 binding to wine components during champagne and shows a fundamental difference in the cavitation desorption of carbon dioxide from sparkling and carbonated wines.

1. Introduction

Analytical evaluation of liquids with a two-phase “liquid-CO2” system in its various states exhibit the most typical properties caused by carbon dioxide in a dispersed state and forming systems with reversed phases of “CO2-liquid” (emulsion of carbon dioxide bubbles in a liquid) and “liquid-CO2” (foam).

To study the physicochemical properties of food liquids with a two-phase “liquid-CO2” system, we used sparkling and carbonated wines.

A fairly complete description of sparkling wine in equilibrium, especially after disturbance in phase equilibrium, can be obtained only by determining a number of interrelated indicators that determine the stability of the “wine-CO2” system and the kinetics of carbon dioxide evolution [1, 2].

It requires the use of methods that provide measurement of physical and physico-chemical quantities, which allow a quantitative assessment of the state of the two-phase “wine-CO2” system, the phenomena that occur when CO2 is released, the “game” and foaming that determine the typicality of sparkling wines.
Modern normative and technical documentation for table wine materials does not provide a regulation of the quality of the product used for the preparation of sparkling wines [3, 4]. It increases the risks of producing products that do not meet world-class requirements. Another drawback of regulatory documentation is the lack of methods for recognizing the naturalness of products presented to the consumer.

Assessing the initial wine materials only according to their physico-chemical characteristics (GOST RF 32030-2013), we characterize them as wine materials for the production of still wines, without highlighting the main factor determining the quality of the future sparkling wine: the foaming ability of the wine material. At the same time, the champagne qualities of the finished sparkling wine externally defined as “play” and foaming and depend on many factors. Foam collapses quickly in wines that do not ensure its good quality in composition regardless from the duration of gas evolution, i.e. from pressure level. The stability of this foam will be measured in seconds. Two closely related process characteristics of sparkling wines (“play” and foaming) will appear in the finished product with good quality of the initial wine material and a sufficient content of bound forms of carbon dioxide. The duration of preservation of a small layer of foam above the playing wine is the main indicator of the quality of champagne foam and its stability, which directly depends on the foaming ability of wine materials, which in turn is determined solely by the chemical composition and physicochemical properties of wine materials. In our opinion, this indicator can serve as an objective criterion for evaluating wine materials used to prepare wines supersaturated with carbon dioxide; it is necessary the introducing of this indicator into the list of mandatory indicators for evaluating wine materials for sparkling wines. It will allow not to depersonalize the natural component of the future product and to identify attempts to falsify champagne wines by adding additives of surfactants of an unnatural origin in them [5–7].

The aim of our research is to justify the introduction of techniques that allow to assess the quality and authenticity of sparkling and carbonated wines produced in the territory of the Krasnodar Territory and imported into the territory of the Russian Federation.

The development of methods and their hardware design for assessing the quality and authenticity of sparkling wines were carried out at the Kuban State Technological University, Department of Wine Technology and Fermentation named after Professor A.A. Merzhanian.

2. Research Method

2.1. Hardware-software complex "Foaming Analyzer". The method is based on measuring the average maximum foam volume of analyzed sample of wine, formed as a result of passing a controlled flow of carbon dioxide through a specific sample volume.

The analyzer includes sets of carbon dioxide flow meters, actuators, a microcontroller and a personal computer with specially designed software.

Figures 1 and 2 show a diagram of the “Foaming Analyzer”.

Figure 1. Scheme of foaming ability analyzer
The measurement technique on the analyzer of the studied criterion makes possible to record the dynamics of foam formation and destruction in automatic mode, which is displayed on the monitor in the form of a graph (Figure 3) with followed calculation of the foaming ability index.

In addition, the picture of the formation and destruction of the foam of the wine material is displayed in real time during the analysis (Figures 3 and 4), by the nature of which it is possible to predict the state of surface-active substances (surfactants) in wine.

2.2. Method for Determining Sparkling Properties

The method is based on measuring the level of excess pressure of carbon dioxide without violating the conditions of the equilibrium state of the gas in the liquid [5, 8] with followed analysis of the sparkling properties of sample of champagne wine in automatic mode.

Figure 5 shows the hardware complex for determining the sparkling properties of wines supersaturated with carbon dioxide.

The operation of the hardware complex is as follow. The test sample is fixed in the apparatus to achieve the tightness of the puncture site of the champagne cork. A standard cavitation center is placed in the gas channel of the probe; it is a glass ball with an air-dry micro-rough surface [9].

The champagne cork is punctured by the probe on the operator instructions; the carbon dioxide (CO₂) pressure level measured by a pressure sensor in kPa to the third digit is displayed on the touch panel.

The cavitation center is introduced into the wine by the input mechanism without removing the pressure; the sparkling properties of the wine are analyzed, which is carried out using a pressure measuring circuit operating in the CO₂ reset-set mode released from the wine (Figures 6 and 7).
We can propose a criterion for determining the level of the indicator of the sparkling properties of wine based on the measurement of these values for a particular wine sample; it has the following mathematical expression:

$$m_i = \left( dP_i^+ \right) \sum_{k=1}^{i-1} \left( dP_k^- \right)$$

(1)

where \(m_i\) is an indicator of sparkling properties at the current \(i\)-th step of work; \(P_i\) is the pressure level at the current \(i\)-th operation cycle at the “set” mode, [kPa]; \(P_k\) is the pressure level at the current \(i\)-th operation cycle in the “reset” mode, [kPa].

The general methodology for evaluating the sparkling properties when using the proposed hardware complex is as follows: when the champagne process is better conducted, the concentration of carbon dioxide and its connected forms in the sample are higher. Consequently, the process of its gas evolution from wine is longer and more intensive. The analysis of the initial pressure level and the subsequent determination of pressure in the “reset-set” mode adequately reflects the kinetic characteristics of desorption of carbon dioxide from wine and, therefore, its sparkling properties.
2.3. Methodology for Determining the Quantitative Content of Carbon Dioxide in the Finished Product

The method is based on measuring the level of excess pressure of carbon dioxide without violating the conditions of an equilibrium state of gas in a liquid in a sample of champagne wine at automatic mode. Figure 8 shows the hardware complex for determining the carbon dioxide content of wines supersaturated with carbon dioxide.

![Figure 8. General view of the carbon dioxide analyzer in the finished product](image)

![Figure 7. Graphical representation of the dynamics of changes in sparkling properties during cavitation desorption of carbon dioxide from sparkling wine](image)

This technique will allow to recognize the nature of carbon dioxide due to the sum of the pressures with followed calculation of the amount of energy needed to release carbon dioxide from the “gas-wine” system. When energy is more expended on the release of carbon dioxide, the concentration of carbon dioxide and its associated forms in the sample are higher. Thanks to this, we can talk about the production technology of wines supersaturated with carbon dioxide.

3. Results and Discussion

The wine was saturated in an acratophore equipped with a finely porous bubbler at a temperature of 0°C and a pressure of 0.22 MPa during 1 hour to assess the typical properties of carbonated wines at the experimental-experimental installation of the department from a bottling-resistant wine material. Filling of carbonated wine was carried out according to technology that ensures the preservation of the phase balance of the “wine-gas” system during bottling.

The number of tests to determine the champagne properties in the test samples was carried out at three repetitions.

The obtained average values of the research results, shown in Table 1, indicate that the numerical value of the indicator of sparkling properties m does not exceed unity, unlike values of m in samples of sparkling and champagne wines despite the high carbon dioxide content in carbonated wine samples, as evidenced by the pressure level in the gas chamber of the bottle.

This dramatic difference in the values of the indicator of sparkling properties in sparkling and carbonated wines is indirect evidence of the influence of the biochemical factor of yeast on the binding of carbon dioxide to wine components at the process of champagne [10–12].

The revealed difference makes it possible to determine the authenticity of sparkling wines on the basis of the main principle “whether or not there was” and the quality of the process of champagne in the test sample. The numerical value of the pressure increase ΔPCO2 in carbonated wine is additional evidence, it exceeds the pressure increase ΔPCO2 in samples of champagne and sparkling wines by two or more times. This position indicates an unstable state of CO2 in carbonated wine, as a result of
which a more intensive transition of carbon dioxide from the dissolved form to the gaseous one occurs when the sample is shaken.

The following samples of sparkling and carbonated wines were investigated, 1 is semi-sweet carbonated white wine; 2 is sparkling wine brut white; 3 is brut white sparkling wine; 4 is dry white sparkling wine; 5 is sparkling wine semi-dry white; 6 is semi-sweet white sparkling wine; 7 is semi-sweet white sparkling wine; 8 is sparkling wine of geographical indication brut white; 9 is sparkling wine of geographical indication dry white; 10 is sparkling wine of geographical indication extra brut white.

There is a correlation in the values of the indicator m and the duration of the “game” in wines supersaturated with carbon dioxide in all cases. When the value of the indicator m is the higher, the "play" of champagne is longer; therefore, its typical properties are better.

There is no correlation between the values of the “game” indicator of wine m and the indicator of its foaming ability $F$, [s]. It cannot be, because we are comparing disparate indicators in this case. The “foaming ability” of wine material and the “foamy properties” of sparkling wine cannot be taken as same indicator; now the methodology of determining is imperfect and requires a special solution [1].

We argue that the analysis of the indicators $F$, [s] and m in everyday practice allows to identify the strengths and weaknesses in the production technology of champagne wines, summarizing the conclusions of the Table 1. Analysis of the sparkling properties showed a fundamental difference of the cavitation desorption of carbon dioxide of samples of sparkling and carbonated wines. This circumstance can serve as the basis for identifying the type of wine and recognizing its counterfeit.

The quality scale obtained as a result of research (Table 1) shows the possibility of identifying the authenticity of different types of wines by the indicator of sparkling properties m due to the significant separation of the regions of carbonated and sparkling wines from each other.

**Table 1. Typical qualities of wines supersaturated with carbon dioxide**

| Sample name | Height of the gas chamber, [cm] | Pressure level, kPa | Sparkling properties index, m | Foaming index $F$, [s] | Carbon dioxide content, [l] |
|-------------|---------------------------------|---------------------|-------------------------------|------------------------|---------------------------|
| 1           | 9.0                             | 370                 | 51                            | 0.69                   | 14.7                      | 0.908                     |
| 2           | 8.1                             | 471                 | 39                            | 4.27                   | 22.7                      | 1.704                     |
| 3           | 8.2                             | 410                 | 8                             | 10.86                  | 23.1                      | 1.835                     |
| 4           | 8.1                             | 405                 | 10                            | 1.33                   | 26.8                      | 1.627                     |
| 5           | 7.8                             | 388                 | 17                            | 0.38                   | 26.1                      | 1.956                     |
| 6           | 8.3                             | 495                 | 22                            | 2.7                    | 16.8                      | 1.369                     |
| 7           | 7.3                             | 389                 | 29                            | 5.31                   | 34.8                      | 1.978                     |
| 8           | 8.1                             | 358                 | 12                            | 6.07                   | 29.1                      | 2.065                     |
| 9           | 7.8                             | 402                 | 19                            | 4.99                   | 21.3                      | 1.989                     |
| 10          | 8.2                             | 397                 | 13                            | 3.56                   | 18.9                      | 2.061                     |

When a sample of champagne wine falls into the region of carbonated wine ($m < 1$), it should be considered effervescent even if they are prepared by the secondary fermentation method. The latter may be if de-champanization takes place during the production process.

Summarizing the foregoing, we can say that this set of methods will determine the quality indicators of sparkling and carbonated wines, as well as analyze the applicable technological methods of production and identify the authenticity of the analyzed object.

4. Conclusion

An analysis of the sparkling properties of wine confirms the influence of the biochemical factor of yeast biomass on the binding of CO$_2$ to wine components during champagne and shows a fundamental difference in the cavitation desorption of carbon dioxide from sparkling and carbonated wines.

Identification of the quality and authenticity of wines supersaturated with carbon dioxide is possible by determining in the sample the pressure level $P$, [kPa] and the indicator of sparkling properties m.
The range of values of the foaming ability index \( F, [s] \) provides recognition of surfactant additives introduced into the blend of wine.

Thus, the manufacturer can evaluate the state of his products inside factory batches and determine his position on the developed, over time, quality scale of sparkling wines produced in the Russian Federation using the hardware-software complex, according to the developed methods.

Acknowledgments
This study was carried out in framework of scientific research (agreement No 6.29.02.32, September 1, 2017, No 6.29.02.33, September 1, 2017 and No 6.29.02.37, May 18, 2018) and assignments of the Department of Viticulture, Winemaking and Alcohol Industry Krasnodar Territory.

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