# Influence of alternating impulses of pressure on sensory characteristics in fermentation technology

**Iryna Dubovkina**

*Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine, Kyiv, Ukraine*

**Keywords:**

Fermentation
Wine
Alternating impulses
Pressure
Cavitation

**Article history:**

Received 21.05.2022
Received in revised form 17.06.2022
Accepted 2.09.2022

**Corresponding author:**

Iryna Dubovkina
E-mail:
dubovkinai@ukr.net

**DOI:**
10.24263/2310-1008-2022-10-1-6

## Abstract

**Introduction.** The aim of this research was to study the influence of the application of alternating impulses of pressure all through processing in foodstuff production. It was done by the quantitative sensory analysis and tasting evaluation of samples of the wine, fortified wine and associated liquid aqueous systems and solutions.

**Materials and methods.** Wine, fortified wine and associated liquid aqueous systems and solutions were used for investigations and analysing the change of their physical and chemical parameters and properties during the processing by the different methods, approaches, and technological modes.

Electrochemical methods were used for the results analysing. A quantitative sensory analysis and tasting evaluation of the experimental liquid samples of wine, fortified wine and associated liquid aqueous systems and solutions was also conducted.

**Results and discussion**. In general, an effect of the treatment in the conditions of alternating impulses of pressure during uninterrupted mode gave the opportunity to increase the general score of a quantitative sensory analysis of wine and fortified wine by 7.3%.

During treatment in uninterrupted mode of alternating impulses of pressure with flow shear speed $3.0 x 10^5$ $s^{-1}$ and flow shear stress 300 Pa, the general score reached its lowest value 8.4. The verification of the cavitation number from 0.1 to 0.5 gave the possibility to receive the highest general score 8.8 from 10.

It substantiates the technology of obtaining the fortified wine involving grape comminution, crest separation, must infusion on the seeds and skins, pressing, must fermentation, blending, and alcoholization. Wine alcoholization is performed under conditions of hydrodynamic cavitation with cavitation number of 0.3, flow shear rate of $2.6 \cdot 10^5$ $s^{-1}$ and flow shear stress of 260 Pa.

**Conclusions.** The total score of wine and fortified wine samples obtained under the conditions of alternating impulses of pressure had increased quality indicators compared to control samples, which were obtained by the traditional technology. This has a positive effect on the quality of the finished product.

## Introduction

Sensory evaluation is an essential step of food product development. However, when using traditional methods to evaluate the quality of products that have very different sensory characteristics, but do not have defects, they can receive the same quality score. Therefore, such an evaluation does not record differences in sensory characteristics that may be very important for consumer acceptance (Paul et al., 2022).

The use of alternative types of raw materials and innovative technologies lead to a change in taste properties, consistency and other organoleptic indicators of food quality. Organoleptic evaluation tests can be used in product development, research, quality control and shelf life studies (Marjorie et al., 1990).

There are intensively developing novel food processing technologies that are environmentally-friendly and energy-saving ones (Ivanov et al., 2021). The methods of controlled energy impact can influence on structural and energy transformation in multifarious liquid media on micro- and nano- level and give opportunity to begin physical and chemical alteration in these media (Dolinskij et al., 2005).

Consuming of innovative technologies gives the possibilities to reduce the energy and recourses consumption of foodstuff production. The method of the alternating impulses of pressure may be appropriate for technology of the associated liquid aqueous systems and solutions processing for food and foodstuff production. Therefore, further investigations of the influence of alternating impulses of pressure on wine are needed.

The purpose of this research was to study the influence of the application of alternating impulses of pressure all through processing in foodstuff production by the quantitative sensory analysis and tasting evaluation of samples of the wine, fortified wine and associated liquid aqueous systems and solutions.

## Materials and methods

### Materials

Objects of research are different kinds of processing methods and modes of wine, fortified wine and associated liquid aqueous systems and solutions for the application in the food industry.

Subjects of study are the changing of the physical and chemical parameters and properties of wine, fortified wine and associated liquid aqueous systems and solutions (Dubovkina, 2017).

Wine, fortified wine and associated liquid aqueous systems and solutions were used to study the change of their physical and chemical parameters and properties during the processing by the alternating impulses of pressure with verification of the technological modes (Dubovkina et al., 2019).

### Experimental installation

Research was carried out on the experimental unit shown in Figure 1. The main part of this unit is rotary-pulsed apparatus. That’s why the object of this study was rotary-pulsed apparatus in which liquid solutions were processed by alternating impulses of pressure and hydrodynamic effects such as the speeds of shift of a stream and pressures of shift of a stream.

The work of the experimental unit was carried out as follows. At first wine or associated liquid aqueous systems and solutions entered the tank 1. After that through the flowmeter 2 wine or associated liquid aqueous systems and solutions followed into rotary-pulsed apparatus 5 for the processing by alternating impulses of pressure. There were two ways of the processing. According to the first, the processing was carried out in a continuous mode from the very beginning, and according to the second, the processing was carried out in a recirculating mode with a variable processing duration. After treatment wine or associated liquid aqueous systems and solutions followed into tank for treatment liquid 9 through the valve 8.

During the treatment temperature by the temperature sensing device 6 and pressure by pressure sensing device 7 were controlled. Other parameters were controlled by analogue-digital transmitter 10 and results were transmitted on personal computer 11.

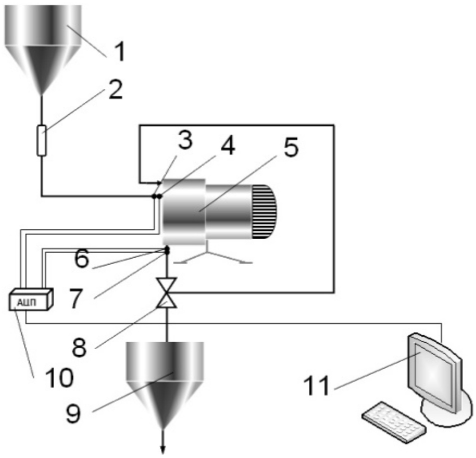


**Figure 1. The scheme of experimental unit:**
1 – tank for liquid; 2 – flowmeter; 3 – temperature sensing device;
4 – pressure sensing device; 5 – rotary-pulsed apparatus; 6 – temperature sensing device;
7 – pressure sensing device; 8 – valve; 9 – tank for treatment liquid;
10 – analogue-digital transmitter; 11 – personal computer.

The rotary-pulsed apparatus was the cylindrical type with the working chamber with two rotors and one stator (Shurchkova et al., 2015). Technical parameters of the experimental equipment such as alternating impulses of pressure:

- $\Delta P$ = 370 kPa near an external surface of an internal rotor;
- $\Delta P$ = 240 kPa near an external surface stator;
- $\Delta P$ = 155 kPa near an internal surface stator;
- $\Delta P$ = 190 kPa near an internal surface of an external rotor.

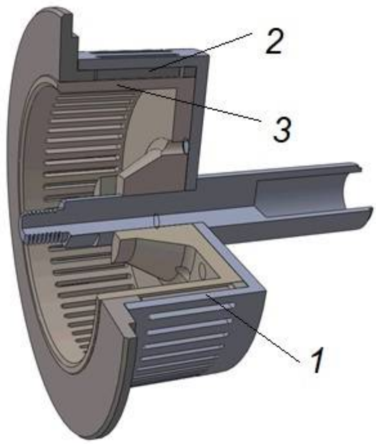


**Figure 2. Scheme of working chamber:**
1 – external rotor; 2 – stator; 3 – internal rotor.

**Methods**

General methods and special methods, such as electrochemical analysis were used for the determination of the results of study (Singh V. P. et al., 2018). For the interpretation of physical and chemical parameters of liquid samples of solutions t al., which obtained through the experimental treatment, chemical methods described in (Sullivan et al., 2005) were used.

The tasting evaluation and quantitative sensory analysis of the experimental liquid samples of wine, fortified wine and associated liquid aqueous systems and solutions was performed. The wines were presented to the panellists for tasting evaluation at 8 to 10 °C in standard wine-tasting glasses (AWWA, 2014) (ISO 3591, 1977).

To obtain related data, liquid samples of wine, fortified wine and associated liquid aqueous systems and solutions were analysed in triplicates with the following statistical procedure (Kenneth, 2007).

## Results and discussion

Recently, researchers, technologists and engineers have turned their interest to employment of the original non-traditional technologies and methods in processing of the liquid mediums, solutions, systems, which consists of the alcohol, water or water solutions.

The physical and chemical properties and parameters of associated liquid aqueous systems, solutions and mediums, such as oxidation-reduction potential, pH value and dissolved oxygen may be changed by the physical methods, particularly by hydrodynamic treatment.

The method of alternating impulses of pressure is one of the methods to control energy impact with many hydrodynamic effects, such as power of pressure of shift, cavitation, the effect of explosive boiling, collective effects in assembly of vials, crossness of an interphase surface in gas-liquid bubbly medium, action of hydrodynamic oscillations, alternating impulses of pressure, effects which associated with acceleration of movement of a continuous phase.

The most important effects of the alternating impulses of pressure are associated with increase of velocity of association of a continuous phase of medium. The fundamental nature of alternating impulses of pressure comprises in that preliminary permanently entered and any rank the energy distributed in working volume to accumulate in locally disconnected discrete points of system and further pulse to realise for achievement of necessary physical effects:

- forcing and dumping of pressure,
- adiabatic boiling,
- hydraulic blow,
- shock waves of pressure or depression,
- pressure of shift, local turbulence,
- cavitation and many other effects (Dolinskij and Basok, 2005).

Three-dimensional and period concentration of energy gives the possibility to receive the big capacity of pulsation power accomplishment, to release internal energy of substance, to create active energetic processes which take place at microlevel and also at nanolevel.

The development of different microliquid devices for some last decades has caused growth of interest to microscale streams. Rotary pulse apparatus is characterised by small enough sizes of width of channels which gives the possibility to consider them as microchannels with effects of slippage of a watercourse on walls and surfaces. A number of heat and mass technological processes (structuring, crushing, dispersion, emulsification, homogenization, and mixing) are spent in rotary pulse apparatus of cylindrical type, which realise principles of alternating impulses of pressure.

Wine is a multicomponent system consisting of volatile components such as higher alcohols, aldehydes, ethers, acetals, ketones, terpenes and various acids. Monoterpenes are isoprene compounds currently found in aromatic plants such as hydrocarbons, aldehydes, alcohols, acids or esters (Marcon et al., 2019). Hydration processes in such complex systems differ in their essence from hydration in water-alcohol mixtures, so it is impossible to apply the same processing methods for water-alcohol mixtures, wine and wine materials, since its quality depends on the bouquet and aroma of the wine. The study of sensory space can also demonstrate the influence on the perceived sensory characteristics of products, helping to characterize the tasting learning in oenology (Caissie et al., 2021).

Technological factors will define the complexity of wine aroma but numerous viticulture, ethnological techniques significantly influence the types and concentrations of volatile compounds (Zhou et al., 1996). Cavitation is used to intensify the process of assimilation of wine with alcohol in the process of distilling wine materials.

Since water is an ampholyte, preliminary activation of water systems is suggested to increase the degree of hydration, i.e. to initiate the formation of hydrogen bonds and proton transfer in the system, during the processing of wine materials and wine, preliminary treatment is not desirable, because during the intensive action of cavitation a decrease in the amount of aldehydes may occur, which in turn leads to a deterioration of the bouquet and taste of the wine. In order to intensify the assimilation of wine with alcohol, it is proposed to use not only cavitation, but also flow shear stresses and flow shear velocities, which together allow to improve the quality of wine.

Sensory evaluation is a key method to assess the flavor quality of foods because it measures what consumers really perceive; however, it is a subjective method. Several factors must be controlled in conducting a sensory evaluation test to minimize experimental error in the data. Sensory tests may be divided into three groups based on the type of information that they provide. The three types are discrimination, descriptive, and affective. Descriptive sensory analysis of wines related to methodology and vocabulary, tasting room and taster selection and training (ISO-11035, 2007).

Therefore, descriptive sensory evaluation methods give an additional tool for application in research, product development, and marketing. In addition, descriptive sensory evaluation methods use a panel of assessors, rather than one expert, and therefore the result obtained represents a consensus that is less subjective, and less susceptible to bias, than the result obtained when one expert performs the evaluation. To avoid errors in the sensory evaluation in daily quality control, it is necessary to follow well-defined grading systems or guidelines and standards (Martinsdóttir, 2010).

The techniques of descriptive sensory analysis allow obtaining an objective description of the wine based on its attributes of aroma and perceived taste and can be both qualitative and quantitative (Sánchez-Palomo et al., 2018).

Wine critics are clarity, tone, pure aroma, aroma concentration, aroma quality, pure taste, taste concentration, lasting taste, taste quality, overall assessment (Hou et al., 2020).

*The control example of the* ***red wine*** *obtained by traditional technology:*

- alcohol content is 14,2%;
- characteristics of the sample: transparent, deep ruby colour, the aroma is vaguely expressed, the perceptible smell of ethyl alcohol, the taste is harmonious with sharp notes, incomplete;
- tasting ball is 8.2.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.5:*

- alcohol content is 14,2 %;
- characteristics of the sample: transparent, rich dark ruby colour, simple aroma, harmonious taste, but noticeable astringent tones;
- tasting ball is 8.35.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.4:*

- alcohol content is 14.1 %;
- characteristics of the sample: transparent, dark ruby colour, rich, the aroma is complex, the taste is harmonious, but astringent tones are felt;
- tasting ball is 8.4.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.3:*

- alcohol content is 14.1 %;
- characteristics of the sample: transparent, dark ruby, velvety, the aroma is complex, the taste is full-rounded, velvet;
- tasting ball is 8.8.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.2:*

- alcohol content is 14.0 %;
- characteristics of the sample: weak opalescence, the colour is dark with a ruby-new velvet shade complex aroma with a side tone, the taste is full, not harmonious enough;
- tasting ball is 8.4.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.1:*

- alcohol content is 14.0 %;
- characteristics of the sample: pronounced opalescence, dark velvet colour, complex aroma with a side tone, the taste is full and not harmonious enough with astringent tones;
- tasting ball is 8.25.

The general score (tasting ball) of control samples was 8.2 and the general score of wine which was processed by alternating impulses of pressure was 8.8.

The results of the tasting evaluation are given in the Figure 3.

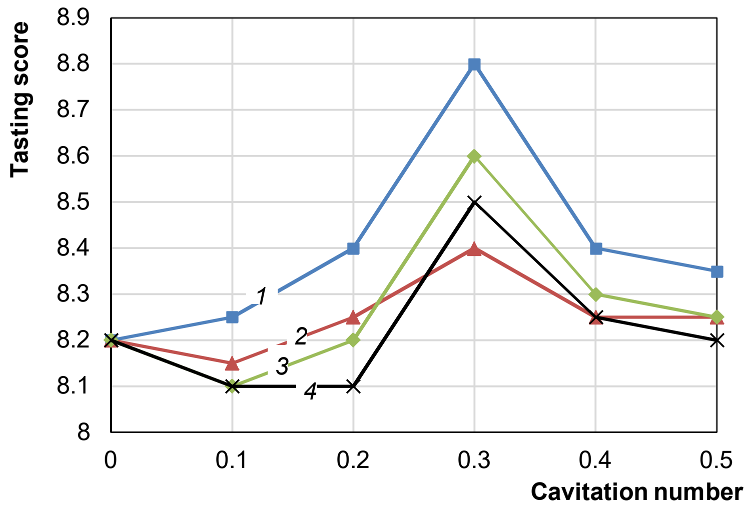


**Figure 3. Dependence of the tasting score of red wine on the number of cavitation number the influence of different flow shear stresses and flow shear rates:**

1 – flow shear rate $2.6 \times 10^5\ s^{-1}$, flow shear stress 260 Pa;
2 – flow shear rate $2.5 \times 10^5\ s^{-1}$, flow shear stress 250 Pa;
3 – flow shear rate $2.8 \times 10^5\ s^{-1}$, flow shear stress 280 Pa;
4 – flow shear rate $3.0 \times 10^5\ s^{-1}$, flow shear stress 300 Pa.

*The control example of the* ***white wine*** *obtained by traditional technology:*

- alcohol content is 16.3 %;
- characteristics of the sample: transparent, light-golden colour, aroma thin, vaguely pronounced, noticeable smell of ethyl alcohol, the taste is bitter with sharp notes, incomplete;
- tasting ball is 8.15.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.5:*

- alcohol content is 16.2 %;
- characteristics of the sample: transparent, light golden colour, weak aroma developed, taste developed, but bitter-cotton tones are noticeable;
- tasting ball is 8.30.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.4:*

- alcohol content is 16.2 %;
- characteristics of the sample: transparent, light golden colour, subtle aroma, noticeable floral notes the taste is harmonious and slightly velvety;
- tasting ball is 8.45.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.3:*

- alcohol content is 16.0 %;
- characteristics of the sample: transparent, golden colour, the aroma is subtle, complex, with floral notes, the taste is light, full and soft;
- tasting ball is 8.75.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.2:*

- alcohol content is 16.0 %;
- characteristics of the sample: pronounced opalescence, rich golden colour, the aroma is complex with an extraneous tone, the taste is light and not harmonious enough;
- tasting ball is 8.5.

*The example of the wine obtained by alternating impulses of pressure with cavitation number 0.1:*

- alcohol content is 15.9 %;
- characteristics of the sample: strong opalescence with shimmer, golden-straw color, the aroma is complex with a herbal tone, the taste is full of roughness;
- tasting ball is 8.5.

The general score (tasting ball) of control samples of white wine was 8.15 and the general score of wine which was processed by alternating impulses of pressure was 8.75.

The results of the tasting evaluation are given on Figure 4.

A quantitative sensory general score (tasting ball) of red wine which was processed by alternating impulses of pressure depending on the processing time or the duration and from the cavitation number. This sensory approach provides a global sensory image of a product and can give an overall assessment of a sensory concept (Barbe et al., 2021).

Two main descriptive methodologies are generally considered according to the way data are gathered (generation of marks on a scale or determination of descriptor citation frequencies), but modified approaches have also been developed. It is a very useful technique to establish a solid knowledge for the identification of the wines based on evidence and facts of their aromatic characteristics (Magalios et al., 2019).

Control liquid samples of wine and fortified wine were used for qualified analysis. These were samples of wine which were obtained according to the traditional standard methodology. In general, an effect of the treatment in the conditions of alternating impulses of pressure during uninterrupted mode gave the opportunity to increase the general score of a quantitative sensory analysis of wine and fortified wine by 7.3%.

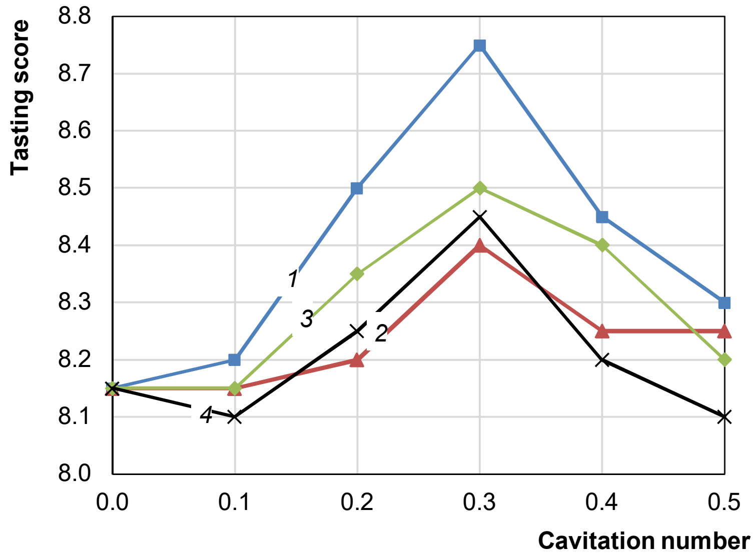


**Figure 4. Dependence of the tasting score of white wine on the number of cavitation under the action of different flow shear stresses and flow shear rates:**
1 – flow shear rate $2.6x10^5 s^{-1}$, flow shear stress 260 Pa;
2 – flow shear rate $2.5x10^5 s^{-1}$, flow shear stress 250 Pa;
3 – flow shear rate $2.8x10^5 s^{-1}$, flow shear stress 280 Pa;
4 – flow shear rate $3.0x10^5 s^{-1}$, flow shear stress 300 Pa.

As a result of study the new technology was created. The invention relates to a process for fortified wine producing involving grape comminution, crest separation, must infusion on the seeds and skins, pressing, must fermentation, blending, and alcoholization. Wine alcoholization was performed under conditions of hydrodynamic cavitation with cavitation number of 0.3, flow shear rate of $2.6 \cdot 10^5$ $s^{-1}$ and flow shear stress of 260 Pa.

## Conclusions

At the present time one of original and innovative methods and equipment that were used for the advancement of processing by samples of wine, fortified wine and associated liquid aqueous systems and solutions is the method of alternating impulses of pressure.

New experimental and theoretical studies and modeling have shown that the method of alternating impulses of pressure may possibly be suitable for processing in food industry and foodstuff production, where hydrodynamic effects are found to be an substitute to traditional methods and modes in technological lines, equipment and processes of wine, fortified wine and associated liquid aqueous systems and solutions.

According to the general results of sensory analysis and tasting evaluation, it was established that wine and fortified wine has a higher general tasting score and improved parameters, which has a positive effect on the quality of the finished product, as compared to the control samples, which were obtained by the traditional technology.

## References


AWWA (2014), *Simplified procedures for water examination*, Laboratory manuals of American Water Works Association, Denver.

Barbe J.C., Garbay J., Tempère S. (2021), The sensory space of wines: From concept to evaluation and description. A review, *Foods,* 10(6), pp. 1424, DOI: 10.3390/foods10061424.

Caissie A., Riquier L., de Revel G., Tempere S. (2021), Representational and sensory cues asdrivers of individual differences in expert quality assessment of red wines*, Food Quality and Preference,* 87, pp. 104032, DOI:10.1016/j.foodqual.2020.104032.

Dolinskij A.A., Basok B.I. (2005), Nanoscale effects by discrete-pulsed transformation of energy, *Journal of Engineering Physics and Thermophysics,* 78(1), pp. 15–23. DOI:10.1007/s10891-005-0025-6

Dubovkina I. (2017), Change of physical and chemical parameters of the liquid binary systems by alternating impulses of pressure, *Ukrainian Food Journal*, 6(1), pp. 142–154, DOI: 10.24263/2304-974X-2017-6-1-16.

Dubovkina I., Davydenko B., Rikhter V. (2019), Modelling of the hydrodynamic conditions throughout liquid system treatment by alternating impulses of pressure, *Ukrainian Food Journal*, 8(2), p. 343–354, DOI: 10.24263/2304-974X-2019-8-2-13.

Ozomwna K.I. (2007), *Recent Advances in Analytical Electrochemistry. Transword Research Network,* Available at: http://www.ressign.com/UserBookDetail.aspx?bkid=605&catid=160.

Hou G.L., Ge B., Sun L.L., Xing K.X. (2020), A study on wine sensory evaluation by the statistical analysis, *Czech Journal of Food Sciences*, 38(1), pp. 1–10. DOI: 10.17221/438/2017-CJFS.

Ivanov V., Shevchenko O., Marynin A., Stabnikov V., Gubenia O., Stabnikova O., Shevchenko A., Gavva O., Saliuk A. (2021), Trends and expected benefits of the breaking edge food technologies in 2021–2030, *Ukrainian Food Journal,* 10(1), pp. 7–36, DOI: 10.24263/2304-974X-2021-10-1-3.

Magalios P., Kosmas P. C., Tsakiris A., Theocharous A. L. (2019), Sensory evaluation of wine through correspondence analysis: a theoretical and empirical rationale, *Journal of Wine Research,* 30(1), pp. 62–77,. DOI: 10.1080/09571264.2019.1573357.

Marcon Â.R., Schwarz L.V., Dutra S.V., Delamare A.P.L., Gottardi F., Parpinello G.P., Echeverrigaray S. (2019), Chemical composition and sensory evaluation of wines produced withdi different Moscato varieties, *41st World Congress of Vine and Wine, BIO Web Conference,* 12, pp. 5, DOI: 10.1051/bioconf/20191202033.

Marjorie P. Penfield, Ada Marie Campbel (1990), *Experimental Food Science* (Third Edition), Elsevier Inc.

Martinsdóttir E. (2010*), Sensory analysis for food and beverage quality control*, Woodhead Publishing.

Paul L.H. McSweeney, John P. McNamara (2022), *Encyclopedia of Dairy Sciences (Third Edition)*, 2, Elsevier Ltd, pp. 572–576

Sullivan P.J., Agardy F.J., Clark J.J. (2005), *The environmental science of drinking water*, Elsevier, Burlington.

Sánchez-Palomo E., Izquierdo Cañas P.M., Delgado J.A., González Viñas M.A. (2018), Sensory characterization of wines obtained by blending cencibel grapesand minority grape varieties cultivated in La Mancha region, *Journal of Food Quality*, 2018, 2832095, DOI:10.1155/2018/2832095.

Shurchkova J., Dubovkina I. (2015), Research parameters of the water-ethanol mixture obtained under conditions of alternating impulses of pressure, *Bulletin of NTU "KPI". Series: New solutions in modern technologies*, 46(1155), pp. 171–176.

Singh V.P., Shalini Ya., Ram N. Ya. (2018), Water quality management: select proceedings of ICWEES-2016, *Water science and technology library*, 79, Springer Singapore.

Zhou Y., Riesen R., Gilpin C. (1996), Comparison of amberliteXAD-2/freon 11 extraction with liquid/liquid extraction forthe determination of wine flavor components, *Journal of Agricultural and Food Chemistry*, 44(3), pp. 818–822, DOI: 10.1021/JF950593A.