Effect of organic compounds on cognac sensory profile

Mikhail N. Eliseev¹, Irina N. Gribkova²*, Olga A. Kosareva³, Olga M. Alexeyeva¹

¹ Plekhanov Russian University of Economics, Moscow, Russia
² All-Russian Research Institute of Brewing, Non-alcoholic and Wine Industry, Moscow, Russia
³ Moscow University for Industry and Finance “Synergy”, Moscow, Russia

* e-mail: beer_institut@mail.ru

Received March 22, 2021; Accepted in revised form April 24, 2021; Published online July 09, 2021

Abstract:

**Introduction.** The present research featured the effect of carbonyls, phenols, furans, fatty alcohols, ethers, and other chemical compounds on the sensory properties of cognac distillates of different ages. The research objective was to identify additional criteria of sensory evaluation by measuring the effect of various compounds on perception intensity.

**Study objects and methods.** The study featured cognac samples of different ages. The experiment involved standard methods, including high-performance liquid and gas chromatography and a mathematical analysis based on Microsoft software.

**Results and discussion.** The content of fatty alcohols, ethers, and carbonyl compounds that formed as a result of fermentation demonstrated little change during the aging period in oak casks. A longer extraction increased the content of phenolic and furan compounds and sugars. The content of terpene compounds decreased due to their high lability. The study revealed the effect of organic compounds on taste descriptors. The article introduces multivariate equations that calculate the dependences of the descriptor intensity on the content of organic compounds. A correlation and regression analysis revealed that phenolic compounds had a significant effect on the taste formation of cognac samples, depending on the aging time.

**Conclusion.** Organic compounds proved to affect the taste profiles of cognac samples of different ages, as well as sensory evaluation descriptors.

**Keywords:** Sensory profile, cognac, organic compounds, fatty alcohols, ethers, volatile compounds, polyphenolic compounds, descriptors

Please cite this article in press as: Eliseev MN, Gribkova IN, Kosareva OA, Alexeyeva OM. Effect of organic compounds on cognac sensory profile. Foods and Raw Materials. 2021;9(2):244–253. https://doi.org/10.21603/2308-4057-2021-2-244-253.

INTRODUCTION

Formation of the flavor profile of cognac and brandy is a complex multistage process. Their aroma, taste, and color depend on too many factors, including the quality of raw materials, the technology of fermentation and distillation, etc. One of the most important factors is the aging in oak casks: its time and conditions are responsible for the numerous transformations of organic compounds, such as extraction, synthesis, biosynthesis, oxidation, etc. [1].

Different classes of compounds contribute to the formation of the sensory profile of cognacs with different aging periods (Tables 1 and 2) [2–9].

Figure 1 shows descriptors that make up the sensory profile of cognac [15].

The gustatory sensation formation is a complex process, where a single shade of flavor may result from a whole complex of compounds [16]. People are able to perceive five basic tastes: sweet, sour, bitter, salty, and “umami”, which was discovered in the early XX century.

In fact, the taste sensation forms in the brain as protein structures trigger its response to a combination of external stimuli. Several sensory stimuli shape perceptions from several descriptors. For instance, spicy tones are formed by compounds of mustard and pepper because carbon dioxide is responsible for this taste. Fresh tones depend on several compounds of plant raw materials, e.g. mint, or on individual substances, e.g. xylitol. A sense of astringency appears when saliva proteins interact with food polyphenols. How panelists evaluate one particular descriptor depends on a complex of organic compounds that enhance or minimize their effect on taste receptors due to spatial stereoisomerism, etc. [17].
Therefore, the present research objective was to study the effect that compounds in cognacs of different ages produce on the intensity of perception of individual descriptors in order to reveal extra quality assessment criteria.

**STUDY OBJECTS AND METHODS**

The present research featured cognac samples of various ages purchased in a network supermarket. Cognacs were stored in a dark room at 20 ± 1°C.

The reduced extract was analyzed by distillation followed by a pycnometric analysis of solids [18].

| Table 1 | Compounds that affect the sensory profile of cognacs |
|---------|-----------------------------------------------------|
| **Compounds** | **Source** | **Effect on cognac quality** |
| Fatty alcohols | Amino acids of raw materials during fermentation | Resinous, honey, floral, and ripe fruity tones |
| Ethers | Raw materials; fermentation and aging in oak casks | Fruity tones; ethyl acetate is responsible for floral and anis aroma |
| Aldehydes and ketones | Raw materials; fermentation and aging in oak casks | Unpleasant unripe tones; nutty and floral tones |
| Norizoprenoids and terpenes | Fermentation of plant raw materials | Resinous tones, e.g. myrcene; fruity and floral tones; caryophylenes are responsible for the tone of cedar pine nuts |
| Polyphenols and phenols | Oak wood during aging | A wide range of flavors and colors |

The pH of the samples was measured in sevenplicates using a pH meter (METTLER TOLEDO, USA).

The list of phenolic and furan compounds included gallic, syringic, vanilla and sinapic acids, vanillin, syringaldehyde, coniferaldehyde, sinapaldehyde, 5-hydroxymetifurfural, furfural, and 5-methylfurfural. Their content was analyzed by high performance liquid chromatography (HPLC) using a diode array detector Agilent Technologies 1200 (Agilent, USA). We also used a Hypersil 5 um C18 250×4.6 mm column (Thermo, USA) with wavelengths of 270 and 310 nm. The test

| Table 2 | Polyphenolic compounds extracted from oak wood |
|---------|------------------------------------------------|
| **Compounds** | **Effect on cognac** |
| Low molecular benzoic phenolic acids: gallic, p-hydroxybenzoic, protocatechuic, syringic, vanilla | Bitterness and astringency |
| Low molecular hydroxycinnamic phenolic acids: ellagic, trans-cafeic, ferulic, coniferic, p-coumaric, sinapic, caffeic | Color stabilization [10] |
| Furan compounds: 5-OH-methyl-furfural, furfural | Pentoses and hexoses, thermal transformation products; almond, grainy, spicy-alcoholic taste during aging in oak casks |
| Low molecular phenolic aldehydes: syringaldehyde, coniferaldehyde, sinapaldehyde, protocatechuic aldehyde | Woody and roasted tones that appear due to thermal transformation of oak wood lignin by decarboxylation, followed by breaking the aryl-alkyl ether bonds of the end links [6] |
| Oxidation products of simple acids: vanillin | Vanilla tone |
| Oxycoumarins: scopoletin | New extract tones due to intermediate products of conversion of lignin to coniferyl alcohol |
| Ellagotannins: vescalagin, castalagin, grandinin, Roburin A, B, C, D, E | Orange color that appear as anthocyano-ellagitannin compounds react with purple or red pigments of grape raw materials [11] |
| Phenolic compounds: cis- and trans-p-coumaric acids, cis- and trans-coumaric acids, derivatives of cis- and trans-p-coumaric acids | Woody tone |
| Flavonoids: (+)-catechin, (−)-epicatechin, Myricetin, myricetin 3-o-glycoside; Flavanols: queretin 3-o-glucuronide, queretin 3-o-galactoside, queretin | Yellow and orange shades |
| Volatile phenolic compounds: guaiacol, ethyl guaiacol, eugenol, methoxyevgenol | Vanilla, nutty, caramel, and spicy-clove tones; guaiacol is responsible for smoky, spicy, clove, and oak tones [12, 13] |
| Octalactones: cis- and trans-octalactone | Coconut, fresh wood, sweet, spicy, and celery tones [14] |
| Phenols: o-, p-cresol, 2,6-dimethoxyphenol | Milder and better taste by interacting with other aromatic components |
| Polyphenols: resveratrol, trans-resveratrol, trans-, cis-3-o-glucoside resveratrol | Responsible for antioxidant properties |
| Gallic acid ethers (tannins): methyl and ethyl gallates | Astringency |
| Phenolic alcohols: tyrosol, tryptopol | Bitter tones |
samples and standards (0.02 cm$^3$) were introduced in a reversed-phase column at 40°C. The mobile phase was represented by a 0.025 mol/dm$^3$ solution of potassium dihydrogen phosphate (A) with pH = 2.5, and a solution of acetonitrile (B) in the ratio of A:B = 87:13. The elution rate was 1.3 cm$^3$/min.

The mass concentration of sugars, i.e. fructose, glucose, and sucrose, was analyzed by HPLC using an Agilent Technologies 1200 diode array detector (Agilent, USA). A Hypersil 5 um C18 250×4.6 mm column (Thermo, USA) had wavelengths of 440 and 540 nm. The test samples and standard solutions were injected in a volume of 0.02 cm$^3$ of a reversed-phase column at 40°C. The mobile phase was represented by distilled water (A) and acetonitrile solution (B) in the ratio of A:B = 87:13. The elution rate was 600 cm$^3$/min.

The mass concentration of higher alcohols, ethers, and hydrocarbons was assessed using gas chromatography (HPHC). A flame ionization detector (GC-FID) was used to detect various volatile components, including methanol, ethanol, 1-, 2-propanol, 1-, 2-butanol, isobutanol, isoamylol, hexanol, phenylethyl alcohol, acetaldehyde, isobutyl aldehyde, acetone, ethyl formate, diethyl formate, ethyl acetate, isoamyl acetate, ethyl caproate, ethyl lactate, ethyl caprylate, ethyl caprate, guaiacol, and eugenol. The analysis also involved such non-volatile components as o-cresol, tyrosol, myrcene, and β-terpineol.

All measurements were conducted in seven replicates, standard deviation ≤ 5%. Each sample in the volume of 5 cm$^3$ (40% vol.) was added to 0.25 cm$^3$ of internal standard solution and placed in 2 cm$^3$ vials. Each component was introduced at a concentration of 2 g/dm$^3$ in absolute alcohol. The vials were hermetically sealed. A sample of 0.002 cm$^3$ was introduced into the chromatograph inlet. The column thermostat

Table 3 Indicators of cognac samples of different ages

| Indicator      | Content (reliability limit $P \geq 0.95$) |
|---------------|----------------------------------------|
|               | 3 years | 5 years | 7 years |
| Ethanol, g/dm$^3$ | 4.0 ± 0.1 | 4.0 ± 0.1 | 4.0 ± 0.1 |
| Reduced extract, g/dm$^3$ | 2.80 ± 0.03 | 4.00 ± 0.04 | 4.70 ± 0.50 |
| Active acidity (pH) | 3.70 ± 0.04 | 3.50 ± 0.35 | 3.60 ± 0.36 |
temperature was 220°C, and the carrier gas velocity was 1.3 cm³/min.

The sensory evaluation of the cognac samples involved seven panelists with an extensive experience in cognac industry and sensory tests. The panelists worked in separate booths, isolated from external factors. The cognac samples were served chilled to 18 ± 1°C in testing glasses at room temperature 20 ± 1°C under white diffused light. The samples were evaluated according to a set of descriptors in comparison with the reference sample. The result was expressed in points from 0 to 10 (0 – impossible to evaluate; 1–2 – unsatisfactory (demonstrates a severe flaw); 3–4 – satisfactory (demonstrates an obvious flaw); 5–6 – satisfactory (violates the quality standard); 7–8 – very satisfactory (slightly violates the quality standard); 9–10 – excellent (corresponds with the quality standard).

The statistical analysis was performed in triplicates. The descriptive statistics and values were expressed as mean ± standard deviation (SD). The Student-Fisher method provided multivariate models of the correlation and regression dependence of the parameters. The reliability limit of the obtained data (P ≥ 0.95) was used to assess various factors that affected the content of polyphenols in all the experiments. The obtained statistical data were processed using the Statistics program (Microsoft Corporation, Redmond, WA, USA, 2006).

RESULTS AND DISCUSSION

Tables 3–5 show the content of ethanol, reduced extract, carbohydrates, volatiles, furans, and phenols in the cognac samples of different ages.

The data are representatives of seven independent experiments, and values are expressed in mean (± SD).

Table 3 shows that the content of ethanol stayed within the permissible values for cognac products specified in State Standard 31732-2014 “Brandy. General specifications” and did not fall below 40.0 ± 0.3% or 4.00 ± 0.03 g/dm³. The content of volatile compounds in the samples increased together with the aging time, which correlates with the previously published scientific data [19, 20].

Table 4 clearly demonstrates that the active acidity decreased insignificantly as the aging time increased. The total acidity index depended on the origin of the wood. However, it increased as a result of long-term aging in oak casks due to the oxidation of ethanol as compounds passed from the wood to the cognac [21, 22].

The pH value is known to depend on the amount of acids and the strength of the distillate. As the content of alcohol in the distillate increases, the dissociation of carboxyl groups decreases, and acidity drops. As tannins dissolve, volatile acids appear, and the strength decreases during aging, the pH decreases [23]. The pH value also depends on the amount of dissolved tannins with an acidic pH, which increases the acidity of the distillates [23]. The experimental data in Table 5 confirmed these trends.

The data are representatives of seven independent experiments, and values are expressed in mean (± SD).
Table 4 shows that the content of volatile fractions in the cognac samples increased together with the aging period, as reported in [19]. The total of higher alcohols was 1.774–2.092 mg/dm$^3$. A longer aging period triggered the process of oxidation in higher alcohols (Table 4). Since the content of these alcohols in the cognac distillate was low, the oxidation of each alcohol was insignificant, in comparison with the oxidative processes of ethyl alcohol. The amounts of aldehydes, acids, and ethers formed by higher alcohols were also insignificant. Nevertheless, even in such small quantities that are elusive for conventional analysis methods, these substances still affect the taste of cognac due to the sheer fact of their existence [24–26]. If the cognac composition is well-balanced, higher alcohols form the basis of its sensory profile [27].

Undesirable tones may result from excessive acetaldehyde that form during oxidation, especially in the samples with a longer aging period, depending on the characteristics of oak wood [22, 28]. However, if other volatile compounds are present, the excessive acetaldehyde in these samples does not disrupt the taste balance.

Ethers also affect the flavor profile of cognacs. Their content depends on the aging time [29]. If ethyl acetate exceeds the sensitivity threshold (180 mg/dm$^3$), it affects the sensory profile of the distillate, giving it undesirable tones [30].

The data are representatives of seven independent experiments, and values are expressed in mean (± SD).

Table 5 illustrates the ratio of syringaldehyde and vanillin, which is also a marker of aging time. This ratio stayed within the range of 2–4, established for collection samples, and was 2.4–2.5 [31, 34].

Phenolic acids are involved in the complex biochemical processes of aging and affect the sensory profile of cognacs [35]. For instance, gallic acid, a product of hydrolysis of soluble gallotannins and ellagitannins of oak wood, affects the aging processes, acts as an oxidation catalyst, and removes sulfides [36, 37].
As alcohol comes in contact with oak bark during aging, it triggers solubilization with the subsequent cleavage of the covalent alkylaryl ether. This reaction leads to the cleavage of lignins and produces vanillin, syringaldehyde, and their acids, which affect the taste profile of cognac distillates [38]. Table 5 shows that phenolic acids and aldehydes increased with aging, which is consistent with the previously published research data [38].

Furan compounds appear as the temperature increases during the decomposition of non-starch polysaccharides of oak bark or during distillation from five-membered sugars [39]. The amount of furan compounds is known to affect the number of distillations [26]. The content of furan compounds increased after a prolonged contact of oak bark and cognac distillate.

Reducing sugars, i.e. glucose, arabinose, and fructose, were also registered in the distillate samples. During aging, the contact of alcohol and oak wood led to the hydrolysis of hemicelluloses and hydrolyzable tannins [40]. Sugars affected the sensory profile of cognacs, and their quantity increased with aging (Table 5).

Volatile phenolic compounds, phenols, and terpene compounds are responsible for some characteristic tones in the cognac bouquet. The content of phenolic compounds increases with aging, while the concentration of terpene compounds decreases as a result of their lability (Table 5).

The cognac samples underwent a sensory evaluation (Table 6) using the descriptors presented in Fig. 2, which demonstrates how certain organic compounds compose particular descriptors.

In low alcohol drinks, bitterness is known to depend on alcohol content [41]. This study proved that bitterness depends not only on aliphatic alcohols, but also on phenolic compounds.

Aldehydes are responsible for mildness [42]. However, aliphatic alcohols with their different tones also might help make the taste of cognac milder, and the content of o-cresol might also produce a certain effect on the mildness [2]. Astringency appears when phenolic compounds are released during aging as a result of contact with oak wood, depending on the aging time and pH [5, 6].

The resinous tones result from the combined action of organic compounds in the distillate; it defines the quality of the finished product [33]. This descriptor is formed during fermentation, distillation, and aging [1, 33]. As a result, resinousness may depend on the content of aliphatic alcohols, phenolic compounds, and terpenoids [5, 7, 33].

Oiliness, another cognac descriptor, appears mainly due to secondary fermentation products that remain after distillation, and partly due to the contact of alcohol with oak [33]. Fruity tones depend on such secondary fermentation products as aldehydes and alcohols, as well as on terpene compounds, which is associated with the fermentation of fruit raw materials [9].

Chocolate tones are more difficult to form than the rest of the descriptors. Chocolate tones are known to depend on secondary fermentation products, volatile phenolic compounds, vanillin, and methylfurfural, the latter also being responsible for sweet-nutty tones [26].

The intensity indicators for each descriptor were quantitatively correlated with the results of the sensory evaluation (Tables 3–5). They were processed in order to obtain correlation and regression equations that made it possible to calculate the dependence of the tones on particular compounds (Table 7).

The values of the coefficients were analyzed in modulus in each group of the dependencies (\( Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7, Y_8 \) and \( Y_9 \)) and the variables. In group \( Y_1 \), the variables at \( X_1 \) had a larger coefficient because o-cresol had a greater effect on descriptor \( Y_1 \); in groups \( Y_2 \) and \( Y_3 \), phenolic alcohols contributed; in \( Y_4 \) – volatile phenolic compounds and aldehydes; in \( Y_5 \) – oxymethylfurfural; in \( Y_6 \) – terpene compounds, and in \( Y_7 \) – vanillin.

Table 8 demonstrates equations for the dependence of the compounds (\( X \)) on the aging period (\( Y_1 \) ) obtained by the method of pair linear correlation.

The greatest value belonged to variable \( X_1 \). Therefore, the change in the content of volatile phenolic compounds affected the sensory profile of the cognac samples more than other compounds. Probably, descriptor groups \( Y_1 \) (resinousness) and \( Y_6 \) (chocolate tone) had a greater effect on the taste perception in comparison with other descriptor groups. Phenolic compounds, i.e. acids, aldehydes, alcohols, and volatile compounds, were especially important for the development of the sensory profile of the cognac samples.

**CONCLUSION**

The correlation and regression analysis made it possible to assess the role of various organic compounds...
Table 6 Sensory evaluation of cognac samples of different aging

| Aging time, years | Palate fullness | Balance | Aftertaste | Mildness | Bitterness | Astringency | Resinousness | Oiliness | Fruity tones | Chocolate tones |
|-------------------|----------------|---------|------------|----------|------------|-------------|-------------|----------|-------------|-----------------|
| 3                 | 7.8            | 6.4     | 4.8        | 6.5      | 0.4        | 0.7         | 3.8         | 2.2      | 5.2         | 0.2              |
| 5                 | 8.2            | 8.2     | 7.2        | 7.2      | 1.0        | 0.8         | 5.8         | 5.8      | 6.4         | 3.4              |
| 7                 | 9.4            | 9.4     | 8.4        | 8.4      | 0.4        | 1.6         | 6.4         | 6.6      | 7.0         | 4.6              |

Table 7 Mathematical assessment of the effect of various compounds on the formation of sensory profiles of cognac samples

| Descriptor (Y) | Equation of multivariate variable dependence (X_i) on descriptor (Y) depending on the aging time, years |
|---------------|--------------------------------------------------------------------------------------------------|
|               | 3                                                                                               | 5                                                                 | 7                                                                 |
| Mildness (Y_1) | Y_1 = 3 \times 10^{-3} + 2.45 \times 10^{-7} \times X_1 - 6 \times 10^{4} \times X_1 + 1.703 \times X_1 + 7 \times 10^{-3} | Y_1 = 11 \times 10^{-4} \times X_1 - 0.23 \times X_1 - 7 \times 10^{-4} \times X_1 + 7 \times 10^{-3} | Y_1 = 42 \times 10^{-5} \times X_1 + 0.1 \times X_1 - 22.9 \times X_1 + 7 \times 10^{-1} |
| Bitterness (Y_2) | Y_2 = 2.8 \times X_1 - 10^{4} \times X_1 - 7.4 \times 10^{4} \times X_1 + 12.9 \times 10^{-3} \times X_1 + 2 \times 10^{-5} | Y_2 = 5 \times 10^{-5} \times X_1 + 0.1 \times X_1 - 2.85 \times X_1 + 10^{-5} \times X_1 + 17 \times 10^{-4} | Y_2 = 2 \times 10^{-4} \times X_1 + 4 \times 10^{-4} \times X_1 + 10^{-4} \times X_1 + 17 \times 10^{-4} |
| Astringency (Y_3) | Y_3 = -0.3 \times X_1 - 0.25 \times X_1 + 17.3 \times X_1 + 0.25 \times X_1 + 0.11 | Y_3 = 3 \times 10^{-3} \times X_1 - 0.12 \times X_1 + 0.66 \times X_1 - 0.13 \times X_1 + 0.01 | Y_3 = 75 \times 10^{-4} \\times X_1 + 0.133 \times X_1 - 40 \times 0.07 \times X_1 - 0.01 |
| Resinousness (Y_4) | Y_4 = -10^{-4} \times X_1 + 16.9 \times 10^{-4} \times X_1 + 0.98 \times X_1 - 0.75 | Y_4 = 2 \times 10^{-2} \times X_1 - 3.6 \times 10^{-4} \times X_1 + 0.65 \times X_1 + 0.128 \times X_1 | Y_4 = 89 \times 10^{-4} \times X_1 + 44 \times 10^{-4} \times X_1 + 0.128 \times X_1 |
| Oiliness (Y_5) | Y_5 = 11 \times 10^{-5} - 16.5 \times 10^{-6} \times X_1 - 20.8 \times 10^{-5} \times X_1 + 0.6 \times X_1 | Y_5 = -72 \times 10^{-5} \times X_1 + 37.6 \times X_1 - 214 \times X_1 - 1.57 | Y_5 = 8 \times 10^{-8} \times X_1 - 84 \times 10^{-4} \times X_1 + 2 \times 10^{-4} \times X_1 - 0.162 \times X_1 |
| Fruity tone (Y_6) | Y_6 = 0.265 - 6.85 \times 10^{-3} \times X_1 + 6 \times 10^{-3} \times X_1 - 0.734 \times X_1 | Y_6 = 8.25 \times 10^{-3} + 2.6 \times 10^{-3} \times X_1 - 0.7 \times X_1 + 2.25 \times X_1 + 1.42 \times X_1 | Y_6 = 26 \times 10^{-4} \times X_1 + 0.12 \times X_1 + 0.44 \times X_1 + X_1 + 1.42 \times X_1 |
| Chocolate tone (Y_7) | Y_7 = 4 \times 10^{-3} + 2.5 \times 10^{-4} \times X_1 + 24 \times 10^{-6} \times X_1 + 4.4 \times 10^{-6} \times X_1 - 0.17 \times X_1 + 3.8 \times X_1 + 0.23 \times X_1 | Y_7 = 17 \times 10^{-3} - 7 \times 10^{-3} \times X_1 - 1.42 \times X_1 + 2.77 \times X_1 - 0.03 \times X_1 |

Table 8 Equations of linear correlation of accumulation of organic compounds in cognacs of different ages

| Effect of aging period (Y_1) on the content of the compound (X_i) | Equation |
|---------------------------------------------------------------|----------|
| o-cresol (X_1) and (Y_1) with phenolic alcohols (X_2) and (Y_2) | Y_1 = 4.7 + 3 \times 10^{4} \times X_1 |
| phenolic alcohols (X_3) and (Y_3) | Y_3 = 2.18 \times X_1 |
| volatile phenolic compounds (X_4) with phenolic aldehydes (X_5) and (Y_5) | Y_5 = 1.8 + 0.27 \times X_1 |
| oxyethylfurfural (X_6) and (Y_6) | Y_6 = 5 \times X_1 - 1.183 |
| terpene compounds (X_7) and (Y_7) | Y_7 = -0.05 + 6 \times X_6 |
| vanillin (X_8) and (Y_8) | Y_8 = 82 \times 10^{-4} + 2.35 \times X_1 |

The authors declare that there is not conflict of interests regarding the publication of this article.

REFERENCES
1. Song L, Wei Y, Bergiel BJ. COGNAC consumption: A comparative study on American and Chinese consumers. Wine Economics and Policy. 2018;7(1):24–34. https://doi.org/10.1016/j.wep.2018.01.001.
2. Awad P, Athès V, Decloux ME, Ferrari G, Snakkers G, Raguenaud P, et al. The evolution of volatile compounds during the distillation of cognac spirit. Journal of Agricultural and Food Chemistry. 2017;65(35):7736–7748. https://doi.org/10.1021/acs.jafc.7b02406.
3. Inui T, Tsuchiya F, Ishimaru M, Oka K, Komura H. Different beers with different hops. Relevant compounds for their aroma characteristics. Journal of Agricultural and Food Chemistry. 2013;61(20):4758–4764. https://doi.org/10.1021/jf3053737.
4. Rettberg N, Biendl M, Garbe L-A. Hop aroma and hoppy beer flavor: chemical backgrounds and analytical tools – A review. Journal of the American Society of Brewing Chemists. 2018;76(1):1–20. https://doi.org/10.1080/03610470.2017.1402574.

5. De Simón BF, Martínez J, Sanz M, Cadahía E, Estreuselas E, Muñoz AM. Volatile compounds and sensorial characterisation of red wine aged in cherry, chestnut, false acacia, ash and oak wood barrels. Food Chemistry. 2014;147:346–356. https://doi.org/10.1016/j.foodchem.2013.09.158.

6. Delia L, Jordão AM, Ricardo-Da-Silva JM. Influence of different wood chips species (oak, acacia and cherry) used in a short period of aging on the quality of “Encruzado” white wines. Mittelungen Klosterneuburg. 2017;67(2):84–96.

7. Coldea TE, Socaciu C, Mudura E, Socaci SA, Ranga F, Pop CR et al. Volatile and phenolic profiles of traditional Romanian apple brandy after rapid aging with different wood chips. Food Chemistry. 2020;320. https://doi.org/10.1016/j.foodchem.2020.126643.

8. Ianni F, Segoloni E, Blasi F, Di Maria F. Low-molecular-weight phenols recovery by eco-friendly extraction from Quercus spp. wastes: An analytical and biomass-sustainability evaluation. Processes. 2020;8(4). https://doi.org/10.3390/pr8040387.

9. Ruiz J, Kiene F, Belda I, Fracassetti D, Marquina D, Navascués E et al. Effects on varietal aromas during wine making: a review of the impact of varietal aromas on the flavor of wine. Applied Microbiology and Biotechnology. 2019;103(18):7425–7450. https://doi.org/10.1007/s00253-019-10008-9.

10. Hu Y, Ma Y, Wu S, Chen T, He Y, Sun J, et al. Protective effect of Cyanidin-3-O-glucoside against ultraviolet B radiation-induced cell damage in human HaCaT Keratinocytes. Front Pharmacology. 2016;7. https://doi.org/10.3389/fphar.2016.00301.

11. Escudero-Gilete ML, Hernanz D, Galán-Lorente C, Heredia FJ, Jara-Palacios MJ. Potential of coopperage byproducts rich in ellagitannins to improve the antioxidant activity and color expression of red wine anthocyanins. Foods. 2019;8(8). https://doi.org/10.3390/foods8080336.

12. Noestheden M, Thiessen K, Dennis EG, Tiet B, Zandberg WF. Quantitating organoleptic volatile phenols in smoke-exposed Vitis vinifera berries. Journal of Agricultural and Food chemistry. 2017;65(38):8418–8425. https://doi.org/10.1021/acs.jafc.7b03225.

13. Del Fresno JM, Morata A, Ricardo-da-Silva JM, Escott C, Loira I, Lepe JAS. Modification of the polyphenolic and aromatic fractions of red wines assisted with ultrasound. International Journal of Food Science and Technology. 2019;54(9):2690–2699. https://doi.org/10.1111/ijfs.14179.

14. Călugără A, Coldea TE, Pop CR, Pop TI, Babeș AC, Bunea CI, et al. Evaluation of volatile compounds during ageing with oak chips and oak barrel of Muscat Ottonel Wine. Processes. 2020;8(8). https://doi.org/10.3390/pr80801000.

15. Tsakiris A, Kallithraka S, Koukoutas Y. Grape brandy production, composition and sensory evaluation. Journal of Food and Science Agricultural. 2014;94(3):404–414. https://doi.org/10.1002/jsfa.6377.

16. Aprotosoaie AC, Luca SV, Miron A. Flavor chemistry of cocoa and cocoa products – An overview. Comprehensive Reviews in Food Science and Food Safety. 2016;15(1):73–91. https://doi.org/10.1111/1541-4337.12180.

17. Delompré T, Salles C, Briand L. Taste perception: from molecule to eating behaviour. Correspondances en MHND. 2020;24(3):88–92.

18. Peschanskaya VA, Osipova VP, Trofinchenko VA, Tochilina RP, Goncharova SA. On the determination of the total extract and given not less than 35.0 % strength in wine production. Food Industry. 2016;(9):36–38. (In Russ.).

19. Rodríguez-Solana R, Rodríguez-Freigedo S, Salgado JM, Domínguez JM, Cortés-Díezgue S. Optimisation of accelerated ageing of grape marc distillate on a micro-scale process using a Box-Benhken design: influence of oak origin, fragment size and toast level on the composition of the final product. Australian Journal of Grape and Wine Research2017;23(1):5–14. https://doi.org/10.1111/ajgw.12180.

20. Giannetti V, Mariani MB, Marini F, Torrelli P, Biancolillo A. Flavour fingerprint for the differentiation of Grappa from other Italian distillates by GC-MS and chemometrics. Food Control. 2019;105:123–130. https://doi.org/10.1016/j.foodcont.2019.05.028.

21. Herrera P, Durán-Guerrero E, Sánchez-Guillén MM, García-Moreno MV, Guillén DA, Barroso CG, et al. Effect of the type of wood used for ageing on the volatile composition of Pedro Ximénez sweet wine. Journal of the Science of Food and Agriculture. 2020;100(6):2512–2521. https://doi.org/10.1002/jsfa.10276.

22. Viana EJ, de Carvalho Tavares IM, Rodrigues LMA, das Graças Cardoso M, Júnior JCB, Gualberto SA, et al. Evaluation of toxic compounds and quality parameters on the aged Brazilian sugarcane spirit. Research, Society and Development. 2020;9(8). https://doi.org/10.33448/rsd-v9i8.5544.

23. Cherkashina YuA. Identifikatsiya kon’yakov s primeneniem organolepticheskogo analiza i fiziko-khimicheskih metodov: opredelenie khromaticheskikh pokazateley, dubil’nykh veshchestv i pokazatelya pH [Identification of
cognacs using sensory evaluation and physicochemical methods: determination of chromatic indicators, tannins, and pH]. Bulletin of the Technological University. 2011;(7):198–204. (In Russ.).

24. Botelho G, Anjos O, Estevinho LM, Caldeira I. Methanol in grape derived, fruit and honey spirits: A critical review on source, quality control, and legal limits. Processes. 2020;8(12). https://doi.org/10.3390/pr8121609.

25. Oseledzova IV, Kipricleva LS. Assessment of the influence of long factor on variation of parameters of the fractions volatile cognac wine materials and young brandy distillate. Agricultural Bulletin of Stavropol Region. 2015;17(1):246–252. (In Russ.).

26. Puentes C, Joulia X, Vidal J-P, Esteban-Decloix M. Simulation of spirits distillation for a better understanding of volatile aroma compounds behavior: Application to Armagnac production. Food and Bioproducts Processing. 2018;112:31–62. https://doi.org/10.1016/j.fbp.2018.08.010.

27. Santos F, Correia AC, Ortega-Heras M, García-Lomillo J, González-Sanjose ML, Jordão AM, et al. Acacia, cherry and oak wood chips used for a short aging period of rosé wines: effects on general phenolic parameters, volatile composition and sensory profile. Journal of the Science of Food and Agriculture. 2019;99(7):3588–3603. https://doi.org/10.1002/jfsa.9580.

28. Fernandes OWB, Silva DF, Sanson AL, Coultrim MX, Afonso RJDCF, Eichler P, et al. Influence of harvest season and maturation of different sugarcane (Saccharum spp.) cultivars on the chemical composition of alembic Brazilian sugarcane spirit. OALib Journal. 2017;4. https://doi.org/10.4236/oalib.1103266.

29. Garcia-Moreno MV, Sánchez-Guillén MM, de Mier MR, Delgado-González MJ, Rodriguez-Dodero MC, García-Barroso C, et al. Use of alternative wood for the ageing of brandy de Jerez. Foods. 2020;9(3). https://doi.org/10.3390/foods9030250.

30. Xu ML, Yu Y, Ramaswamy HS, Zhu SM. Characterization of Chinese liquor aroma components during aging process and liquor age discrimination using gas chromatography combined with multivariable statistics. Scientific Reports. 2017;7. https://doi.org/10.1038/srep39671.

31. Egorova EYu, Morozhenko YuV, Reznichenko IYu. Identification of aromatic aldehydes in the express assessment of quality of herbal distilled drinks. Foods and Raw Materials. 2017;5(1):144–113. https://doi.org/10.21179/2308-4057-2017-1-144-153.

32. Cernišev S. Analysis of lignin-derived phenolic compounds and their transformations in aged wine distillates. Food Control. 2017;73:281–290. https://doi.org/10.1016/j.foodcont.2016.08.015.

33. Lukinan A, Sidorenko A. Criteria for determination of age of cognac spirits. Bulletin of Agricultural Science. 2016(10):51–60. (In Russ.). https://doi.org/10.31073/agrovisnyk201610-10.

34. Savchuk SA, Vlasov VN, Appolonova SA, Arbusov VN, Vedenin AN, Mezinov AB, et al. Application of chromatography and spectrometry to the authentication of alcoholic beverages. Journal of Analytical Chemistry. 2011;56(3):214–231. https://doi.org/10.1023/A:1009446221123.

35. Chira K, Anguelle L, Da Costa G, Richard T, Pedrot E, Jourdes M, et al. New C-glycosidic ellagitannins formed upon oak wood toasting; identification and sensory evaluation. Foods. 2020;9(10). https://doi.org/10.3390/foods9101477.

36. Payab M, Chaichi MJ, Nazari OL, Maleki FY. Tannin extraction from oak gall and evaluation of anti-oxidant activity and tannin iron chelation compared with deferoxamine drug. Journal of Drug Design and Medicinal Chemistry. 2019;5(2):18–25. https://doi.org/10.11648/j.jddmc.20190502.11.

37. Marchal A, Pons A, Lavigne V, Dubourdieu D. Contribution of oak wood ageing to the sweet perception of dry wines. Australian Journal of Grape and Wine Research. 2013;19(1):11–19. https://doi.org/10.1111/agw.12013.

38. Rasines-Perea Z, Jacquet R, Jourdes M, Quideau S, Teissedre PL. Ellagitannins and flavano-ellagitannins: Red wines tendency in different areas, barrel origin and ageing time in barrel and bottle. Biomolecules. 2019;9(8). https://doi.org/10.3390/biom9080316.

39. Phetxumphou K, Miller G, Ashmore PL, Collins T, Lahne J. Mashbill and barrel aging effects on the sensory and chemometric profiles of American whiskies. Journal of the Institute of Brewing. 2020;126(2):194–205. https://doi.org/10.1002/jib.596.

40. Kumar V, Joshi VK, Thakur NS, Sharma N, Gupta RK. Effect of artificial ageing using different wood chips on physicochemical, sensory and antimicrobial properties of apple tea wine. Brazilian Archives of Biology and Technology. 2020;63. https://doi.org/10.1590/1678-4324-2020180413.

41. Paixão JA, Filho ET, Bolini HMA. Investigation of alcohol factor influence in quantitative descriptive analysis and in the time-intensity profile of alcoholic and non-alcoholic commercial pilsen beers samples. Beverages. 2020;6(4). https://doi.org/10.3390/beverages6040073.

42. Cvetković D, Stojiliković P, Zvezdanović J, Stanojević J, Stanojević L, Karabegović I. The identification of volatile aroma compounds from local fruit based spirits using a headspace solid-phase microextraction technique coupled
with the gas chromatography-mass spectrometry. Advanced Technologies. 2020;9(2):19–28. https://doi.org/10.5937/savteh2002019C.

**ORCID IDs**
Mikhail N. Eliseev https://orcid.org/0000-0001-8636-4468
Irina N. Gribkova https://orcid.org/0000-0002-4373-5387
Olga A. Kosareva https://orcid.org/0000-0002-9639-8302
Olga M. Alexeyeva https://orcid.org/0000-0001-8254-6987