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Effect of organic compounds on cognac sensory profile

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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

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 stereoiso-merism, etc. [17].

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

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].

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-caffeic, 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: quercetin 3-o-glucuronide, quercetin 3-o-galactoside, quercetin	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

Figure 1 Positive descriptors for brandy and cognacs

samples and standards (0.02 cm³) were introduced in a reversed-phase column at 40°C. The mobile phase was represented by a 0.025 mol/dm³ 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 cm³/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 cm³ 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 cm³/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, isoamilol, 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 sevenplicates, standard deviation ≤ 5%. Each sample in the volume of 5 cm³ (40% vol.) was added to 0.25 cm³ of internal standard solution and placed in 2 cm³ vials. Each component was introduced at a concentration of 2 g/dm³ in absolute alcohol. The vials were hermetically sealed. A sample of 0.002 cm³ 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/dm³	4.0 ± 0.1	4.0 ± 0.1	4.0 ± 0.1
Reduced extract, g/dm³	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

Table 4 Volatile components in cognacs of different ages

Compound	Mass concentration, mg/dm³ (reliability limit p ≥ 0.95)		
	3 years	5 years	7 years
Higher alcohols			
methanol	107.40 ± 11.00	101.80 ± 10.00	100.60 ± 10.00
1-propanol	101.50 ± 10.00	103.60 ± 10.00	101.50 ± 10.10
1-butanol	1.20 ± 0.01	1.30 ± 0.01	1.20 ± 0.01
2- butanol	0.20 ± 0.01	0.20 ± 0.01	0.10 ± 0.01
2-propanol	5.50 ± 0.55	5.70 ± 0.55	4.60 ± 0.04
isobutanol	394.60 ± 40.00	428.90 ± 43.00	394.60 ± 40.00
isoamylol	1138.00 ± 100.00	1168.60 ± 120.00	1138.00 ± 115.00
hexanol	8.80 ± 0.90	10.80 ± 1.00	10.80 ± 1.10
phenylethyl alcohol	17.10 ± 2.00	20.00 ± 2.00	26.50 ± 3.00
Aldehydes and ketones			
acetaldehyde	31.40 ± 3.00	36.30 ± 4.00	59.30 ± 6.00
isobutyraldehyde	20.30 ± 2.00	19.80 ± 2.00	18.30 ± 2.00
acetone	6.90 ± 0.70	9.30 ± 1.00	18.70 ± 2.00
Carboxylic acid ethers			
ethyl formate	4.70 ± 0.50	6.90 ± 0.70	12.80 ± 1.30
diethylformal	0.70 ± 0.01	1.10 ± 0.10	4.10 ± 0.40
ethyl acetate	120.30 ± 12.00	142.70 ± 14.00	261.40 ± 25.00
isoamyl acetate	2.60 ± 0.30	2.40 ± 0.25	2.30 ± 0.25
ethylcaproate	4.40 ± 0.40	5.10 ± 0.50	6.40 ± 0.65
ethyl lactate	74.40 ± 7.00	98.90 ± 10.00	81.10 ± 8.00
ethyl caprylate	16.00 ± 2.00	28.80 ± 3.00	43.70 ± 4.50
ethyl caprate	86.70 ± 9.00	96.20 ± 10.00	155.20 ± 15.00

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 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 sevenplicates. 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 ($P \geq 0.95$) 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 3 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 5 Phenols, furans, and carbohydrates in cognac samples of different ages

Compound	Mass concentration, mg/dm³ (reliability limit $P \geq 0.95$)		
	3 years	5 years	7 years
Phenolic acids			
gallic acid	3.00 ± 0.30	4.60 ± 0.45	8.30 ± 0.80
syringic acid	0.80 ± 0.01	1.50 ± 0.15	3.30 ± 0.30
vanilla acid	0.50 ± 0.05	0.80 ± 0.08	1.50 ± 0.15
sinapic acid	0.10 ± 0.01	0.40 ± 0.04	0.60 ± 0.05
Phenolic aldehydes			
syringaldehyde	2.50 ± 0.25	4.00 ± 0.40	7.70 ± 0.80
vanillin	1.00 ± 0.10	1.60 ± 0.15	3.30 ± 0.30
sinapaldehyde	2.20 ± 0.20	2.90 ± 0.30	3.00 ± 0.30
coniferaldehyde	0.80 ± 0.08	1.30 ± 0.10	1.70 ± 0.15
Furan compounds			
5-hydroxymethylfurfural	37.00 ± 4.00	47.90 ± 5.00	57.40 ± 6.00
furfural, mg/100 cm³ of anhydrous alcohol	2.30 ± 0.20	2.70 ± 0.30	2.90 ± 0.30
5-methylfurfural	0.30 ± 0.03	0.40 ± 0.04	0.50 ± 0.05
syringaldehyde vs. vanillin	2.50 ± 0.25	2.50 ± 0.25	2.40 ± 0.25
Phenols			
o-cresol	0.038 ± 0.001	0.050 ± 0.005	0.065 ± 0.006
Phenolic alcohols			
tyrosol	0.150 ± 0.001	0.235 ± 0.002	0.345 ± 0.004
Volatile phenolic compounds			
guaiacol	1.460 ± 0.010	2.000 ± 0.020	3.420 ± 0.003
eugenol	0.020 ± 0.001	0.118 ± 0.001	0.200 ± 0.002
Volatile terpenoids			
myrcenol	0.255 ± 0.006	0.210 ± 0.002	0.147 ± 0.001
β-terpineol	0.830 ± 0.004	0.645 ± 0.006	0.278 ± 0.003
Carbohydrates			
fructose	1.15 ± 0.10	1.55 ± 0.15	3.02 ± 0.30
glucose	0.99 ± 0.10	1.43 ± 0.15	2.94 ± 0.30
sucrose	6.12 ± 0.60	6.33 ± 0.60	6.45 ± 0.65

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/dm³. 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/dm³), 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 shows that the cognac samples contained typical phenolic acids and aldehydes in quantities that did not exceed those featured in research publications for cognacs of 2.5–15 years of aging [31–33]. The content of syringaldehyde is a marker of aging time. It was in the range of 2.5–7.7 mg/dm³ and increased with aging time, which corresponded with scientific publications on this chemical substance and other simple phenolic acids and aldehydes [31].

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 eluggotannins 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 and Y_7) and the variables. In group Y_1, the variables at X_3 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_x) obtained by the method of pair linear correlation.

The greatest value belonged to variable X_3. 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_4 (resinousness) and Y_7 (chocolate tone) had a greater affect 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
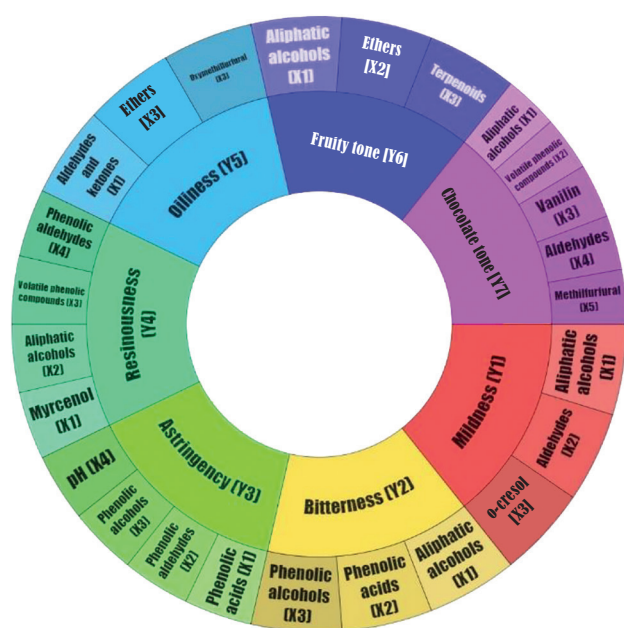

Figure 2 Descriptors for sensory evaluation of cognac samples

Table 6 Sensory evaluation of cognac samples of different aging

Aging time, years	Descriptor (point ± 0.2)									
	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_n) on descriptor (Y) depending on the aging time, years		
	3	5	7
Mildness (Y_1)	$Y_{1/3}=3\times10^{-3}+2.45\times10^{-7}\times X_1-6\times10^4\times X_2+1{,}703\times X_3$	$Y_{1/5}=11\times10^{-4}\times X_1-0.23\times X_2-7.4\times X_3+7\times10^{-3}$	$Y_{1/7}=42\times10^{-5}\times X_1+0.1\times X_2-22.9\times X_3-0.05$
Bitterness (Y_2)	$Y_{2/3}=2.8\times X_3-1\times10^{-5}\times X_1-7.4\times10^{-4}\times X_2+12.9\times10^{-5}$	$Y_{2/5}=5\times10^{-3}\times X_1+0.1\times X_2-2.85\times X_3-2\times10^{-5}$	$Y_{2/7}=2\times10^{-6}\times X_1-4\times10^{-6}\times X_2+X_3+17\times10^{-4}$
Astringency (Y_3)	$Y_{3/3}=-0.3\times X-0.25\times X_2+17.3\times X_3+0.25\times X_4+0.011$	$Y_{3/5}=3\times10^{-3}+0.31\times X_1-0.12\times X_2+0.66\times X_3-0.13\times X_4$	$Y_{3/7}=-75\times10^{-4}\times X_1+0.133\times X_2-0.403\times X_3-0.07\times X_4-0.01$
Resinousness (Y_4)	$Y_{4/3}=-10\times10^{-4}\times X_1+16.9\times10^{-4}\times X_2+0.98\times X_4-0.75$	$Y_{4/5}=2\times10^{-2}+27.4\times X_1-36\times10^{-4}\times X_2+0.65\times X_4$	$Y_{4/7}=89\times10^{-4}-4.5\times X_1+44\times10^{-4}\times X_2-0.128\times X_4$
Oiliness (Y_5)	$Y_{5/3}=11.7\times10^{-5}-16.5\times10^{-6}\times X_1-20.8\times10^{-6}\times X_2+0.6\times X_3$	$Y_{5/5}=-72.6\times X_1+37.6\times X_2-214\times X_3-1.57$	$Y_{5/7}=8\times10^{-2}+84\times10^{-4}\times X_1-7\times10^{-6}\times X_2-0.162\times X_3$
Fruity tone (Y_6)	$Y_{6/3}=0.265-6.85\times10^{-3}\times X_1+6\times10^{-3}\times X_2-0.734\times X_3$	$Y_{6/5}=8.25\times10^{-3}+2.6\times10^{-3}\times X_1-0.7\times10^{-3}\times X_2+2.25\times X_3$	$Y_{6/7}=26\times10^{-3}-0.12\times X_1+0.44\times X_2+1.42\times X_3$
Chocolate tone (Y_7)	$Y_{7/3}=41\times10^{-3}+25\times10^{-4}\times X_1+24\times10^{-4}\times X_2+4.4\times X_3-0.17\times X_4$	$Y_{7/5}=17\times10^{-3}-7\times10^{-3}\times X_1-1.42\times X_2+3.8\times X_3+0.23\times X_4$	$Y_{7/7}=46\times10^{-4}\times X_1-2.35\times X_2+2.77\times X_3-0.03\times X_4$

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

Effect of aging period (Y_n) on the content of the compound (X_n)	Equation
o-cresol (X_1) and (Y_1)	$Y_1=4.7+3\times10^{-4}\times X_1$
phenolic alcohols (X_2) and (Y_2)	$Y_2=1.4+13.3\times X_2$
volatile phenolic compounds (X_3) и (Y_3)	$Y_3=2+18\times X_3$
phenolic aldehydes (X_4) и (Y_4)	$Y_4=1.8+0.27\times X_4$
oxymethylfurfural (X_5) и (Y_5)	$Y_5=5\times X_5-1.183$
terpene compounds (X_6) и (Y_6)	$Y_6=-0.05+6\times X_6$
vanillin (X_7) и (Y_7)	$Y_7=82\times10^{-4}+2.35\times X_7$

in the development of taste profiles for cognac samples of different ages. The paper introduced equations of multivariate models that describe the effect of organic compounds on the descriptors of cognac products. Linear regression equations revealed that phenolic compounds of various classes played a major role in the taste profile formation. The obtained data will make it possible to form a list of additional criteria for sensory evaluation of cognac products.

CONTRIBUTION

M.N. Eliseev supervised the research project. O.A. Kosareva developed the research plan, I.N. Gribkova and O.M. Alexeyeva performed the experimental research, obtained the data, and analyzed them.

CONFLICT OF INTEREST

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

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