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## DEVELOPING A TECHNOLOGY OF LOCAL WINES WITH THE ENHANCED AROMATIC PROFILE

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**Abstract.** Different methods of enhancing the aromatic profile of wines are researched throughout the world. One of them consists in adding unsaturated fatty acids to must as the yeast feeding. This work considers how the aromatic profile of dry white table wine made from the local grape variety Aromatny is influenced by the feeding that contains olive oil (a source of oleic acid) and the enzyme lipase and is added to must in combination with rehydrated active dry yeast Anchor Alchemy I (the species *Saccharomyces cerevisiae*). This method has been compared with the two other ones: with the classic method of obtaining dry white table wines by must fermentation (control) and with the sur lie method (when the dry white table wine material is aged on the lees for three months following the end of the must fermentation process). In the wines under study, 19 volatile compounds have been identified and quantified. These compounds, which are the most noticeable and active agents in aroma formation, include higher alcohols, organic acids, complex esters, aldehydes, terpene alcohols. The sample where the feeding was added is substantially higher in aroma-forming compounds than the other samples are. Also, this sample has the highest odour activity value (OAV). Sensory analysis of the wines considered has shown that the feeding containing olive oil and lipase has a positive effect on the aromatic profile of wine: in the aroma, there are distinct floral and fruity notes, more intense than those in the control sample and in the one obtained by ageing the wine material sur lie. This is possible due to a higher concentration of complex esters and a moderate content of higher alcohols. Adding the feeding results in no unpleasant tones in the wine's odour, which are often caused by fatty acids, as their content is low. The advantages of the method suggested to enhance the aromatic profile of wines are its simple production technology and availability of the natural ingredients of the feeding. This research is supposed to help wine manufacturers satisfy consumers' demand for local wines with their site-specific character, because one of the main motivations for tourists to visit the world's wine-producing regions is an opportunity to taste unique wines with a pronounced and attractive floral-fruity aroma.

**Key words:** local wines, unsaturated fatty acids, aromatic profile, odour activity value, oenotourism.

### Introduction. Formulation of the problem

New and non-traditional aromas and flavours of wines are among the main reasons why tourists visit the world's wine-producing regions. Today's travellers choose to take trips to those wine manufacturers who offer a

pleasant and informative "sensory experience." People expect to try a safe product obtained in an eco-friendly way and pleasant in all sensory aspects [1]. Consumers, especially connoisseurs, usually prefer wines from certain regions, which poses new challenges to winemakers: how to impart attractive characteristics to local wines, in

particular a pronounced floral-fruity aroma. It is known from quite a number of publications [2-5] that unsaturated fatty acids are precursors of aroma-forming substances in the course of must fermentation.

#### **Analysis of recent research and publications**

A wine's aroma is formed by employing a lot of techniques both in vineyards and in wineries. Besides the common methods, such as selection of a grape variety [6], winemakers use a great many methods and tools to produce wines with certain aromatic profiles.

The main method to regulate a wine's aroma is the use of special yeast strains in fermentation. There are data that show how a yeast strain can produce quantitative changes in the final chemical composition of wines and determine their sensory profile, irrespective of the grape variety and the year it was harvested in [7]. During alcoholic fermentation, the commercial (adapted, pure) yeast culture *Saccharomyces cerevisiae* effects on the aroma, colour, taste, and chemical composition of the finished product: it modifies some compounds obtained from the grapes, and in the course of sugar and amino acid exchange, it produces quite a number of metabolites of sensory importance that contain organic acids, higher alcohols, complex esters, and, to a lesser extent, aldehydes [2,8-10].

The most significant aroma-forming compounds of wine are complex esters, in particular, ethyl acetate (fruity aroma), isoamyl acetate (pear aroma), isobutyl acetate (banana aroma), ethylhexanoate (apple aroma), and 2 phenylethyl acetate (fruity and floral aroma, a note of honey). In the work [11], synthesis of complex esters by *Saccharomyces cerevisiae* during fermentation is explained by the activity of at least three acetyltransferases that have their genes on a yeast cell chromosome: alcohol acetyltransferase, ethanol acetyltransferase, and isoamyl acetyltransferase.

So, a possible way to intensify the formation of aromatic compounds during fermentation is increasing the activity of acetyltransferases in yeast. Scientists note in their works that acetyltransferase activity is increased by unsaturated fatty acids [3].

Besides, unsaturated fatty acids activate the growth of yeast and help it survive, as they form part of the plasma membrane and regulate the exchange of compounds between the inner cell and its environment. They play an important role not only in keeping the yeast membranes whole and functional, but also in adapting to the stresses of fermentation, such as the high toxicity of sugars and ethanol [12-14].

By squalene cyclisation, yeast cells can synthesise their own sterol (ergosterol) in the endoplasmic reticulum membrane, from where, through Golgi bodies, it is transported to the plasma membrane under aerobic conditions. The enzyme that regulates sterol synthesis is hydroxymethylglutaryl-CoA reductase. Its activity depends on oxygen. That is why under

anaerobic conditions, yeast can no longer synthesise sterols and long-chain fatty acids [15]. However, it is anaerobic conditions that are the best for obtaining unoxidised white table wines with a pronounced aroma.

On the other hand, unsaturated fatty acids are precursors of aroma-forming substances. In a grape berry, metabolism involving fatty acids precursors the biosynthesis of volatile aromatic components. It is proved that during fermentation, they have a strong effect on the formation of volatile metabolites, including complex esters, acetates, ethyl esters, higher alcohols, and medium chain fatty acids [2-5].

During enzymatic oxidative reactions involving fatty acids, not only can the fresh "green" aroma be formed, but the fruity one as well. The fatty acid oxidation mechanism involves the action of four endogenous enzymes. Lipase extracts fatty acids from the fatlike substances of plant cell membranes, then lipoxygenase catalyses molecule fixation by oxygen on these unsaturated (C18) fatty acids. These enzymes form hydroxyperoxides (C13), mainly from linoleic and linolenic acids, and the hydroperoxydes break down to 6-atom aldehydes with the "green" aroma (in particular, 3 hexenal). This is not the end of the reaction, though. Acted upon by hexenal isomerise, the 6-atom aldehydes can turn into 2 hexenal with the sweet aroma of underripe fruit. Or, when acted upon by alcohol dehydrogenase of grapes, these aldehydes can break down to higher alcohols with an intense aroma [16,17]. Higher alcohols, too, are important precursors for synthesis of esters.

To sum up the above, it can be noted that the yeast *Saccharomyces cerevisiae*, during its propagation under anaerobic conditions, needs exogenous unsaturated fatty acids. An alternative to biosynthesis is adding unsaturated fatty acids directly to grape must during fermentation, not only as a practical method to increase the yeast fermentation activity, but also as a possible way to manipulate the wine aroma.

Thus, in the work by Duan L. et al. [3], it is pointed out that unsaturated fatty acids (namely linoleic, oleic, and  $\alpha$ -linolenic acids) added to synthetic grape juice significantly improved the yeast growth and activated the fermentation. In particular, this increased the concentration of most volatile compounds in the wine, including higher alcohols (2-phenylethanol, 2-methyl-1-propanol, and 3-methyl-1-propanol), medium chain fatty acids (butanoic acid, hexanoic acid, and octanoic acid), complex esters of acetic acid (isoamyl acetate and 2-phenylacetate), and all ethyl esters. Besides, linear relationship was found between ethyl esters and the concentration of the unsaturated fatty acids added, which greatly enhanced the wine's floral-fruity aroma. On the other hand, other authors proved in their works that linoleic and linolenic acids started affecting adversely the formation of esters and medium chain fatty acids at a certain concentration of fatty acids in the yeast. It was also established how

linoleic and linolenic acids influenced the increase in fusel alcohols [18].

That is why for this research, oleic acid was chosen as yeast feeding. It is known that during fermentation, unsaturated fatty acids can be added to must in the form of capsules of the preparation Tween 80 containing 70% of oleic acid [5]. The same is the content of oleic acid in olive oil (64–85%). However, as olive oil contains oleic acid in the bound form, the enzyme lipase should be used to obtain free oleic acid.

It is known that another source of unsaturated fatty acids and of other chemical compounds that help aroma formation in wines is yeast autolysis products [19,20].

In yeast lees, fatty acids make up 1–6% of the total dry weight of the biomass. The most common fatty acids in the lees are palmitic (29%), linoleic (28%), oleic (15.3%), stearic (10%), and linolenic (9.2%) acids. Lipids released during autolysis can participate in the formation of certain volatile components, such as esters, ketones, and aldehydes [21]. It was shown that at the end of long autolysis, the amount of diglycerides decreased due to the action of enzymes (probably of lipases). These compounds later revealed themselves as free fatty acids (palmitoleic, palmitic, stearic, and oleic acids) and glycerol [22].

The simplest and best-studied method of autolysis is the *sur lie* method. It consists in long (3–6 months) ageing of wine on a thin layer of the lees after alcoholic fermentation is over [23,24].

Thus, today's knowledge of the biochemistry of wines' aromatic profile formation, the existing techniques involving the use of yeast, and auxiliary winemaking materials allow manipulating the aroma of wines to make it more pronounced.

That is why, in this research, two methods of enhancing the aromatic profile of wines have been compared for their effectiveness: adding olive oil in the yeast feeding composition as a source of oleic acid and the *sur lie* method.

**The purpose** of the research was to study how formation of the aromatic profile of wines from the grape variety Aromatny (selection by Tairov National Science Centre of Viticulture and Winemaking) depended on oleic acid, a precursor of wine's aroma-forming compounds, introduced as a component of olive oil into the must prior to its fermentation, and how it depended on employing the *sur lie* method.

To achieve the purpose, the following **objectives** were set:

- to develop a method of adding olive oil to the must prior to fermentation;
- to produce dry white table wine materials from the local grape variety Aromatny using olive oil and the *sur lie* method (ageing the wine materials on the thin layer of the yeast lees);
- to carry out physicochemical and sensory analyses of the wine materials obtained;
- to determine the composition of volatile aroma-forming compounds in the wine samples produced;

- to compare the effectiveness of the suggested method of enhancing the aromatic profile of wine and that of other methods by determining the indices of odour activity values (OAV) in the wines under study.

### Research materials and methods

**Selection of the grapes.** The object of research is grapes of the variety Aromatny selected by Tairov National Science Centre of Viticulture and Winemaking, Ukraine.

The variety Aromatny is an interspecific hybrid (Vertes Csillaga x Romulus). In 2009, the variety was included in the Register of Plant Varieties of Ukraine. It is an early and midseason-ripening wine grape variety. The bush growth is strong, the ripening of stems is good, the winter hardiness is high. The frost tolerance is –26°C. The variety is resistant to mildew, oidium, berry rot, and blackspot. Grape clusters are large or medium-sized, cylindroconical, sometimes having a twig, and of medium density. A berry is medium-sized, roundish, pink-coloured. The flesh is juicy. The taste is caramel-like, with tinges of strawberry.

The grapes of the variety Aromatny was grown in an experimental field in the town of Velyky Dalnyk, Odessa Region (46°27'57" north latitude, 30°33'30" east longitude). The soil under the vines was southern chernozem, highly loamy and low-humic.

The vines were planted in 2013. The row width was 3 m, the row spacing between the vines was 1.5 m. The training system was a bilateral one-storey vertical cordon. To irrigate the field, a drip irrigation system was used.

The grapes selected for the research were harvested in the years 2017, 2018, and 2019, as soon as they were industrially ripe (mass concentration of sugars 200–230 g/dm<sup>3</sup> (20–23°Bx), mass concentration of titrated acids 6–7 g/dm<sup>3</sup>). The grape clusters had no physical damage and were not infected.

Yeast strains. The active dry yeast (ADY) used for the research was Anchor Alchemy I developed by the company Anchor Wine Yeast (France) in association with Australian Wine Research Institute. It is a blend of yeast strains of the species *Saccharomyces cerevisiae*, with high sugar and alcohol tolerance, fermentable at low temperatures, and capable of optimising the aromatic potential of grapes (by increasing the content of aromatic esters in white wines).

The ADY was preliminarily activated. It was diluted in 10 volumes of prepared water at 36–37°C, and continuously stirred until a homogeneous suspension was obtained. After dilution, it was left for rehydration for 15–20 min. Then, to acclimatise the yeast starter to the thermal conditions of the must, the cooled must was gradually (during 25–30 min) introduced into it, the mixture being stirred throughout the process. The difference in the temperatures of the must and the yeast starter added did not exceed 10°C.

Feeding the yeast. To develop a method of adding olive oil to the must before fermentation, it was taken

into consideration that a distinctive feature of lipase hydrolysis of fats is the action of the enzyme at the interface of the hydrolysed ester and water. Note that the enzyme is water-soluble, and the substrate (olive oil) emulsified in water forms the insoluble phase. For this reason, the olive oil and powdered lipase were added to the rehydrated ADY, and then to the must, as follows: 2 g of the enzyme preparation was mixed in a mortar with 1 cm<sup>3</sup> of crude olive oil. The pulverised preparation was placed into a 500 cm<sup>3</sup> conical flask, the residue was flushed into the flask by means of 5 cm<sup>3</sup> of distilled water and thoroughly stirred. Then, 150 cm<sup>3</sup> of the ADY starter was poured into the flask, stirred, and added to the must proportionally to the must's volume.

Crude virgin olive oil from the firm Minerva (Crete, Greece) was used as the source of oleic acid. The enzyme lipase used (dietary supplement E 1104) was made in China (the firm RUGAO CHANGJIANG FOOD). Its enzymatic activity was > 160,000 nkat/g, and it was manufactured in the form of powder.

Fermentation experiments. The dry table wine materials were obtained, according to the classical white wine technology, by must fermentation. The grapes were harvested by hand. They were carefully stemmed and crushed. The crushed mass was sulphited with SO<sub>2</sub> to 30 mg/dm<sup>3</sup> and pressed with a hand-operated basket press. The must was clarified by resting for 18–24 hours at 10–12°C, with addition of 0.03 g/dm<sup>3</sup> of the enzyme preparation Depectil clarification (from the firm Martin Vialatte, France). The enzymatic activity of Depectil clarification: endo and exopolysaccharuronase >29,000 nkat/g, pectin-methyl-esterase >15,000 nkat/g, pectinlyase >1,600 nkat/g. The form: microgranules.

Completely clarified, the must was racked off and fermented in 10 dm<sup>3</sup> glass bottles that were cotton-plugged tightly.

Into two bottles with the must (variants 1 and 3), the ADY starter was added at a rate of 2 g/dm<sup>3</sup>. Into the last bottle (variant 2), 2 g/dm<sup>3</sup> of the ADY starter was added in combination with the feeding (olive oil with lipase).

Alcoholic fermentation was carried out at 17–18°C. During the process, the fermentation temperature and the must density were periodically checked. The fermentation was performed as long as the mass concentration of sugars in wine did not exceed 20 g/dm<sup>3</sup>.

After the alcoholic fermentation, wine material samples 1 and 2 were decanted into secondary vessels filling them up to the top. There, the wine materials went on being fermented for 3 weeks until the sugar concentration reached 2 g/dm<sup>3</sup>. Then they were separated from the lees, bottled, and kept at 4°C.

After wine material sample 3 was fermented, it was placed, along with the yeast, into secondary vessels, which were filled up to the top. There, the wine material continued its fermentation. It was left on the thin layer of the fine lees (according to the sur lie method) at 15°C for 3 months. Once a week, the wine material was stirred for 5 min (the operation termed *bâtonnage* in French).

Then it was decanted (racked off the lees), bottled, and kept at 4°C.

General enological parameters. In the research, standard methods of analysis were used [25]. The following wine parameters have been determined: ethanol by volume, pH, sugar mass concentration, mass concentration of titrated acids, and mass concentration of free sulphuric acid.

Volatile aroma compounds analysis. The mass concentration of aroma-forming compounds was determined by high-performance gas-liquid chromatography on a chromatograph Kristall 2000 M.

Evaluation of the aromatic profile of the wines. The wines' aromatic profiles were evaluated on the basis of their odour activity values (OAV). This aromatic index allows determining how much each compound is involved in the formation of the final aroma. In this respect, the compounds were considered to be active aroma formers only if their OAV was > 1. The OAV were calculated by the equation  $OAV=c/t$  [26], where *c* is a compound's concentration in the wine, and *t* is the threshold of olfactory perception of a compound in the wine.

Sensory evaluation. For the sensory analysis of the wine, the descriptive testing method was used, in compliance with ISO 6658:2005 "Sensory analysis – Methodology – General guidance." The descriptive analysis was performed by a panel of wine experts.

Statistical analysis. The experimental data of the research were statistically processed according to ISO 5725 6:1994/Cor. 1:2001 "Accuracy (trueness and precision) of measurement methods. Part 6. Use of accuracy values in practice." All the experiments were carried out in no fewer than three replications. The confidence interval was 0.95%. The statistical analysis was performed using the software Microsoft Excel 2010 and Statistika V. 10.1.

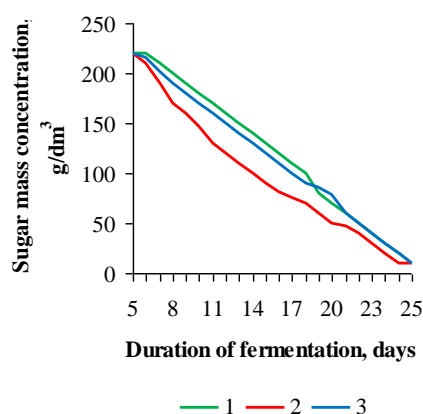
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### Results of the research and their discussion

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The research was carried out to respond the topical demand of the oenotouristic business. The studies were limited to the winemaking technology. In the work, a method of enhancing wines' aromatic profile has been suggested, which consists in adding olive oil, as a source of oleic acid, to grape must prior to its fermentation. The wines analysed were considered to be local from the oenotouristic point of view, because they had been made from the grape variety *Aromatny* (selection by Tairov National Science Centre of Viticulture and Winemaking) adapted to the climate of the Odessa Region.

Fig. 1 shows the dynamics of fermentation of the samples under study and makes it clear that the fastest absorption of sugars by yeast was in sample 2. This can be explained by the effect the feeding has on the yeast activity. The fermentation processes in samples 1 and 3 were similar, for these two samples had the same fermentation conditions.



**Fig. 1. Fermentation dynamics in the must of the samples under study:** 1 – control (no yeast feeding added, no ageing *sur lie*); 2 – with the yeast feeding added (olive oil + lipase); 3 – no yeast feeding added, the wine material aged on the fine lees for 3 months (the *sur lie* method)

In the wines analysed, the main physicochemical parameters conformed to the regulatory requirements.

The ethanol by volume was 11.85-13.0%. The pH value ranged 3.4-3.6%. The mass concentration of titrated acids was 8.4-8.8 g/dm<sup>3</sup>, and that of free sulphuric acid was 5.33–5.42 mg/dm<sup>3</sup>.

Table 1 presents the results of analysis of aroma-forming compounds in the dry white wine samples under study (made from the grape variety Aromatny), including the descriptors of aromas and their threshold concentrations (mg/dm<sup>3</sup>).

Compounds that determine the aroma of wine include higher alcohols (aromatic, aliphatic), acids (acetic acid, higher acids), complex esters, aldehydes, terpene alcohols. In Table 1, these compounds are ranked by decreasing concentration.

Higher alcohols have been found to be the largest group of aroma-forming compounds in all the three wine samples analysed. Table 1 lists some of the most noticeable higher alcohols formed by yeast during fermentation.

**Table 1 – Content of aroma-forming compounds in the wines under study**

Aromatic compounds	Mass concentration, mg/dm <sup>3</sup>			Aroma descriptors	Threshold concentrations, mg/dm <sup>3</sup>
	Experimental variants*				
	1	2	3		
Phenylethyl alcohol (2-phenylethanol)	99.542	118.381	110.474	Roses	10.000 [3]
1-Butanol, 3-methyl- (isoamyl alcohol)	66.203	76.138	70.091	Floral	30.000 [3]
1-Butanol, 2-methyl- (active amyl alcohol)	38.764	42.162	35.991	Ether, fresh	1.200 [27]
Octanoic acid	16.055	23.790	16.533	Light Fatty, weak Fruity	13.000 [8]
1-Propanol, 2-methyl- (isobutanol)	9.022	9.506	12.661	Alcohol	40.000 [3]
n-Decanoic acid	7.598	9.312	8.754	Fatty	10.000 [8]
1-Butanol, 3-methyl-, acetate (isoamil acetate)	6.534	9.949	4.862	Banana, Pear	0.030 [3]
Octanoic acid, ethyl ester (ethyl octanoate)	4.218	7.175	4.704	Floral-Fruity	0.002 [29]
Hexanoic acid, ethyl ester (ethyl hexanoate)	3.342	4.897	3.071	Pineapple, Green Apple	0.005 [29]
Acetic acid	3.080	4.090	13.488	Acetic	700.000 [8]
Hexanoic acid	2.783	4.892	3.218	Fatty, Fruity	8.000 [8]
Acetic acid, 2-phenylethyl ester (2-phenylethyl acetate)	2.125	3.430	2.254	Floral, Sweet	0.250 [3]
Decanoic acid, ethyl ester (ethyl decanoate)	1.390	1.790	1.733	Fruity, Sweet Apple	0.200 [29]
Butanoic acid, ethyl ester (ethyl butyrate)	1.164	1.412	1.215	Fruity	0.0200 [29]
1,6-Octadien-3-ol, 3,7-dimethyl- (linalool)	1.033	1.494	1.128	Bergamot, Lavender	0.015 [29]
Benzene acetaldehyde (acetaldehyde)	0.966	1.875	1.372	Fruity	7.500 [3]
1-Hexanol	0.519	0.541	0.603	Freshly cut grass	8.000 [3]
1-Propanol	0.411	0.457	0.485	Fresh, Alcohol	500.000 [28]
L-alpha-Terpineol	0.348	0.512	0.338	Sweet, Floral	1.000 [29]

Note\*. Experimental variants: 1 – control (no yeast feeding added, no ageing *sur lie*); 2 – with the yeast feeding added (olive oil + lipase); 3 – no yeast feeding added, the wine material aged on the fine lees for 3 months (the *sur lie* method).

Alcohols are known to be formed by degradation of amino acids, carbohydrates, and lipids [30]. Phenylethyl alcohol, also known as 2-phenylethanol, is an aromatic alcohol [31] which smells of roses, so it helps the formation of floral tones in a wine's bouquet. It has been reported that the level of 2-phenylethanol depends both on the grape variety and on the yeast metabolism [32]. Phenylethanol has been found in all the three samples in concentrations far exceeding the threshold. Its highest concentration (118.381 mg/dm<sup>3</sup>) was observed in the sample with the feeding added (olive oil + lipase), that is in variant 2. There, its content in wine was by 16% higher than it was in the control sample where no yeast feeding was used. Even ageing on the lees for 3 months did not result in such an effect: in this case, the phenylethyl alcohol content only increased by 10%.

2-Methyl-1-butanol, 3-methyl-1-butanol, isobutanol, and 1-hexanol are higher alcohols that have a significant effect on wine's aromatic composition. When in high concentrations, they have a sharp odour [33], but in concentrations below 300 mg/dm<sup>3</sup>, they impart a pleasant aroma to wines [34].

The total concentrations of the compounds of this group are: 114.490 mg/dm<sup>3</sup> (variant 1) and 128.347 mg/dm<sup>3</sup> (variant 2) – after alcoholic fermentation; and 119.346 mg/dm<sup>3</sup> (variant 3) – after ageing on the fine lees. The highest concentration of higher alcohols was observed in sample 2, but it remains within the limits of unpleasant odours.

In all the three samples, 1-propanol has been found in concentrations far below the threshold, thus it

has no effect on the aroma of the wines under study (Table 2).

C<sub>6</sub> alcohols normally impart vegetable and herbal accents to the aroma of wine, which affects adversely its sensory characteristics [35]. In the samples analysed, the C<sub>6</sub> alcohol 1-hexanol has been identified, but its concentration is very low and practically does not exceed the threshold (Table 2).

In all the three samples, four volatile acids have been identified (acetic acid, hexanoic acid, octanoic acid, and decanoic acid). In above-threshold concentrations (0.7–1.1 g/dm<sup>3</sup>), acetic acid smells of vinegar, and wine where it is present is considered defective [36]. However, it can be seen from Table 2 that in the samples analysed, the acetic acid concentrations are low, close to the threshold ones (the OAV is 0), and thus this acid has no significant effect on the aroma of the wines. The two other fatty acids, decanoic and hexanoic, can make the aroma of wine mild and pleasant (despite the fact that fatty acids are usually associated with odours of grease [37]) when their concentrations range 4 to 10 mg/dm<sup>3</sup> [38].

In sample 2, adding the feeding to the must (olive oil + lipase) resulted in an increase in octanoic acid: in this sample, its concentration is higher than it is in the control (variant 1) and in sample 3. However, it should be pointed out that normally, the average octanoic acid concentration in wines can be as high as 41 mg/dm<sup>3</sup> [8], which is almost twice as high as its concentration in sample 2. That is why increasing the octanoic acid content by adding olive oil cannot affect adversely the aromatic profile of wine.

Table 2 – Odour activity values (OAV) in the wines under study

Aromatic compounds	Odour activity values (OAV)		
	Experimental variants*		
	1	2	3
Phenylethyl alcohol (2-phenylethanol)	9.95	11.84	11.05
1-Butanol, 3-methyl- (isoamyl alcohol)	2.21	2.53	2.34
1-Butanol, 2-methyl- (active amyl alcohol)	32.30	35.13	29.99
Octanoic acid	1.24	1.83	1.27
1-Propanol, 2-methyl- (isobutanol)	0.23	0.24	0.32
n-Decanoic acid	0.76	0.93	0.88
1-Butanol, 3-methyl-, acetate (isoamil acetate)	217.80	331.6	162.1
Octanoic acid, ethyl ester (ethyl octanoate)	2109.00	3587.50	2352.00
Hexanoic acid, ethyl ester (ethyl hexanoate)	668.40	979.40	614.20
Acetic acid	0.00	0.00	0.00
Hexanoic acid	0.35	0.61	3.218
Acetic acid, 2-phenylethyl ester (2-phenylethyl acetate)	8.5	13.73	9.02
Decanoic acid, ethyl ester (ethyl decanoate)	6.95	8.95	8.67
Butanoic acid, ethyl ester (ethyl butyrate)	58.20	70.60	60.75
1,6-Octadien-3-ol, 3,7-dimethyl- (linalool)	68.67	99.60	75.20
Benzene acetaldehyde (acetaldehyde)	0.13	0.25	0.18
1-Hexanol	0.06	0.07	0.08
1-Propanol	0.00	0.00	0.00
L-alpha-Terpineol	0.35	0.51	0.34

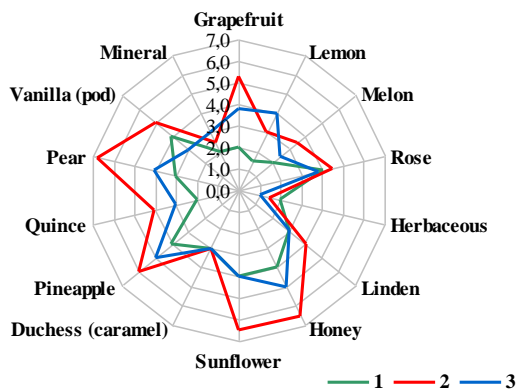
Note\*. Experimental variants: 1 – control (no yeast feeding added, no ageing *sur lie*); 2 – with the yeast feeding added (olive oil + lipase); 3 – no yeast feeding added, the wine material aged on the fine lees for 3 months (the *sur lie* method).

Esters, which are one of the largest and most important groups of chemical compounds determining the aroma of wines, are represented by isoamyl acetate, ethyl octanoate, ethyl hexanoate, ethyl decanoate, ethyl butyrate (ethyl butanoate), and 2-phenylethyl acetate (Table 1). The odour detection thresholds of these esters are quite low, and they add fruity and floral notes to the aroma of wine. Isoamyl acetate is the highest in sample 2, where it, along with ethyl octanoate, forms floral-fruity aromas. Its lowest concentration is in sample 3, which may be due to senescence of wine [8]: this sample was aged at a higher temperature than the other two, and was periodically accessed by oxygen from the air when stirred. The highest content of the sum of complex esters is in the control sample (variant 1) – 28.653 mg/dm<sup>3</sup>. The lowest is in variant 3, where it is 17.839 mg/dm<sup>3</sup>.

Terpene compounds are secondary plant metabolites. Terpene alcohols are important components of a varietal aroma, and they are not affected by yeast metabolism during fermentation [39,40]. In Table 1, they are represented by linalool and terpineol. Only linalool is present in above-threshold concentrations, but its contents in the samples analysed do not differ significantly.

Aldehydes are important for the aroma because of their low threshold sensory values. Acetaldehyde is the main component, it makes up more than 90% of the total aldehyde content in wines. In the samples analysed, its concentration is very small, far below the threshold (< 7.5 mg/dm<sup>3</sup>).

Sensory analysis of the samples has shown that adding the feeding that contains olive oil and lipase has a positive effect on the aroma of wine (fig. 2).



**Fig. 2. Aromatic sensory profile of the wine samples under study:** 1 – control (no yeast feeding added, no ageing sur lie); 2 – with the yeast feeding added (olive oil + lipase); 3 – no yeast feeding added, the wine material aged on the fine lees for 3 months (the sur lie method)

It is visualised in the aromatic sensory profile plot (Fig. 2): the distinct notes of the aroma are the floral ones (sunflower, honey, rose, lime-tree) and the fruity ones (pear, pineapple, grapefruit). These notes are more intense in variant 2 than in the control sample (variant 1) and in

the one aged sur lie (variant 3). The aromatic sensory profile of the wines under study consistently correlates with the odour activity values (OAV) of the volatile aroma-forming substances they contain. Thus, in all the wine samples studied, the substances with the highest OAV are: ethyl octanoate (floral-fruity aroma), ethylhexanoate (pineapple aroma), and isoamyl acetate (pear aroma) (Table 2). In sample 2, the OAV for these compounds is 1.5–2 times as high as it is in samples 1 and 3, which can be seen from the plot (Fig. 2).

This research is supposed to help wine manufacturers satisfy consumers' demand for local wines with their site-specific character. The results of the study can be introduced in small craft wineries and in individual rural households and farms.

### Conclusion

A method has been developed consisting in adding olive oil (a source of oleic acid), in combination with the enzyme lipase to grape must, as the yeast feeding. It has been established that oleic acid formed in the course of olive oil fats breakdown by lipase intensifies the fermentation activity of the yeast *Anchor Alchemy I* of the species *Saccharomyces cerevisiae* and influences the formation of the aromatic profile of dry white table wine made from the local grape variety *Aromatny*.

The method that involves addition of the feeding (olive oil + lipase) has been compared with the classic method of obtaining dry white table wines by must fermentation (control) and with the method of ageing dry white table wine materials on the fine lees for 3 months after the must fermentation is over (the sur lie method). It has been established that application of the feeding in the technology of dry white table wines increases the concentration of most volatile compounds in wine, including higher alcohols (2-phenylethanol, 3-methyl-1-butanol, 2-methyl-1-butanol), medium chain fatty acids (hexanoic, octanoic, and decanoic acids), complex acetate esters (isoamil acetate and 2-phenylethyl acetate), and a number of fatty acid ethyl esters (ethyl butyrate, ethyl hexanoate, ethyl octanoate, ethyl decanoate). A higher concentration of complex esters and a moderate content of higher alcohols intensify the floral and fruity notes in the aroma of wine. This has been evaluated by calculating the odour activity values (OAV) and confirmed by sensory analysis. Adding the feeding results in no unpleasant tones in the wine's odour, which are often caused by fatty acids, because their content is low and close to the threshold values.

The research results prove that using the feeding (olive oil + lipase) in the dry white table wines technology will help wine manufacturers satisfy consumers' demand for local wines with the pronounced floral-fruity aroma.

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## РОЗРОБКА ТЕХНОЛОГІЇ ЛОКАЛЬНИХ ВИН З ПОСИЛЕНИМ АРОМАТИЧНИМ ПРОФІЛЕМ

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**Анотація.** Для посилення ароматичного профілю вин в світі досліджуються різноманітні методи, зокрема внесення ненасичених жирних кислот в сушло, як живлення для дріжджів. Робота присвячена дослідженню впливу живлення, яке містить оливкову олію, як джерело олеїнової кислоти, та фермент ліпазу, і вноситься в сушло разом з регідратованими активними сухими дріжджами Anchor Alchemy I виду *Saccharomyces cerevisiae*, на ароматичний профіль білого столового сухого вина, виготовленого з винограду локального сорту Ароматний. Цей метод порівнювався з двома іншими: з класичним методом отримання білих столових сухих вин шляхом бродіння сусла (контроль) і з витримкою білого столового сухого виноматеріалу на тонкому шарі осаду дріжджів протягом 3 місяців після закінчення бродіння сусла (метод «sur lie»). В досліджуваних винах ідентифіковано та кількісно оцінено 19 найбільш помітних та активних з точки зору ароматоутворення летких сполук: вищі спирти, органічні кислоти, складні естери, альдегіди, терпенові спирти. Вміст ароматоутворюючих сполук є істотно більшим у зразка, отриманого з внесенням живлення, порівняно з іншими варіантами. Цей зразок також має найвище значення активності запаху (OAV). Сенсорний аналіз досліджуваних вин показав, що внесення живлення з оливковою олією і ліпазою позитивно впливає на ароматичний профіль вина: в ароматі чітко відчувуються квіткові та фруктові ноти, які переважають за інтенсивністю, ніж в контрольному зразку та в зразку, який витримувався на дріжджовому осаді. Цьому сприяє збільшення концентрації складних естерів та помірний вміст вищих спиртів. Внесення живлення не призводить до формування непріємних тонів запахів у вині, які можуть обумовлювати жирні кислоти, тому що їх вміст є невисоким. Однією з переваг запропонованого способу посилення ароматичного профілю вин є простота отримання живлення і натуральні доступні інгредієнти. Це дослідження допоможе виноробам задовольнити попит споживачів на локальні вина з неповторним місцевим характером, адже однією з головних мотивацій для туристів відвідати виноробні регіони світу є унікальні вина з привабливим, яскраво вираженим квітково-фруктовим ароматом.

**Ключові слова:** локальні вина, ненасичені жирні кислоти, ароматичний профіль, значення активності запаху, енотуризм.

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