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STUDY OF THE ALCOHOL QUALITY OBTAINED BY FERMENTATION OF HIGHLY CONCENTRATED GRAIN WINE BY DIFFERENT RACES OF YEAST

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The topicality. Requirements for the quality of ethyl alcohol produced for further use in the production of alcoholic beverages are constantly increasing. This is due to the growing competition of producers of alcoholic beverages (improving the range and quality of products) and the revision of standards for products. New directions in the alcohol technology development require increasing the dry matter concentrations of the wort; fermentation at elevated temperatures and concentrations of alcohol in the brew; ensuring the reduction of the cost of alcohol by saving raw materials and energy resources. In such conditions, highly productive breeds of yeast with increased osmophilicity, thermotolerance and fermentation activity are required. Research related to the search for new strains producers of ethyl alcohol, and the technology development for highly concentrated mash from grain raw materials are relevant issues for the alcohol industry. **Purpose and methods.** Investigation of the alcoholic yeast races influence on the synthesis of metabolites during fermentation of highly concentrated wort from grain raw materials. For research methods common to the alcohol and alcoholic beverages have been used. **Results.** The influence of races of alcoholic yeast on the quality indicators of alcohol has been studied. It was found that the selected race of yeast S. cerevisiae DO-16 in the process of life synthesizes significantly fewer side metabolites compared to other studied races DO-11, K-81 and XII. The use of the selected race of S. cerevisiae DO-16 makes it possible to ferment highly concentrated wort from grain raw materials. It has been experimentally proved that at a concentration of DM concentration of the wort 28 %, the selected osmophilic strain of the yeast S. cerevisiae DO-16 provides regulated indicators of the hydrocarbon composition of mature brews and synthesizes up to 14.40 % vol. alcohol, respectively. To improve the qualitative sensory characteristics of ethanol, the possibility of metabolically adjusting the synthesis of volatile alcohol impurities using different races of alcoholic yeast was investigated. **Conclusions and discussions**. Scientific novelty lies in the selection race for the yeast fermentation of corn mash highly concentrated with reduced alcohol content related impurities. The influence of yeast race on the formation of alcohol metabolites has been studied. The practical significance of the obtained results lies in the industrial implementation of the selected race of alcoholic yeast for fermentation of highly con-

centrated wort from grain raw materials. Prospects for further research are the possibility of influencing the quality of alcohol as a raw material for high-quality alcoholic beverages. During the fermentation of wort from grain raw materials, the qualitative and quantitative composition of volatile impurities of alcohol largely depends on the race of alcoholic yeast. The results of research on the biosynthesis of volatile impurities of alcohol allow you to adjust the quality of alcohol for the production of high quality alcoholic beverages.

Keywords: quality, alcoholic beverages, alcohol, industrial alcoholic yeast, volatile alcohol impurities.

The topicality of the problem

The problem formulation. One of the directions of realization of innovative projects is introduction in production of resource and energy saving technologies. One of the areas of implementation of innovative projects is the introduction of resource- and energy-saving technologies in production. One of the areas of implementation of innovative projects is the introduction of resource- and energy-saving technologies in production. Selection and assortment of highly productive breeds of alcoholic yeast make it possible to obtain alcohol as a raw material for high quality alcoholic beverages. One of the ways to reduce the number of ethanol metabolites is to regulate the technological parameters. It is necessary to investigate the effect of the race of alcoholic yeast on the synthesis of alcohol with reduced formation of by-products of fermentation.

The study state of the problem. P. L. Shyian, V. V. Sosnytskyi, S. T. Oliinychuk, V. O. Marynchenko, L. V. Levandovskyi made a significant contribution to the research and the alcohol industry development.

Unresolved issues. Rational selection of the breed of alcoholic yeast is a key factor in obtaining high quality alcohol as a raw material for alcoholic beverages. The question of studying the mechanism of volatile impurities of alcohol formation and the influence of the yeast race during the fermentation of highly concentrated wort has been insufficiently studied. This article is devoted to the study of the impact and scientific substantiation of the adjustment of ethanol quality indicators.

Purpose and research methods

The purpose of the article is to study the races influence of alcoholic yeast on the synthesis of metabolites during fermentation of highly concentrated wort from grain raw materials of yeast on the synthesis of metabolites during fermentation of highly concentrated wort from grain raw materials.

The methodological basis of the study is the exploration and scientific substantiation of the races influence of alcoholic yeast on the synthesis of ethanol and the formation of concomitant metabolites.

The object of research is the fermentation technology of highly concentrated wort from grain raw materials by different breeds of yeast *Saccharomyces cerevisiae.*

The subject of research is the races influence of alcoholic yeast on the qualitative indicators of ethanol in the fermentation conditions of highly concentrated grain wort.

Research methods. For research methods have been used common to the alcohol and alcoholic beverages.

Information base of research: monographs, scientific articles, patents, author's certificates.

Research results

One of the main tasks of the alcohol industry for Ukraine's accession to the European community is to ensure the competitiveness of domestic products. Requirements for the quality of ethyl alcohol produced for further use in the production of alcoholic beverages are constantly increasing (Shyian & Sosnytskyi, 2017). This is due to the growing competition of producers of alcoholic beverages (improving the range and quality of products) and the revision of standards for products. Therefore, the alcohol industry faces the task of developing and implementing innovative resource- and energy-saving technologies (Shyian et al., 2009). The introduction of the developed technologies will improve the quality of alcohol, reduce energy consumption for distillation and rectification, efficient use of production waste (Khakymova et al., 2016). New directions in the alcohol technology development require increasing the dry matter concentrations of the wort; fermentation at elevated temperatures and concentrations of alcohol in the brew; ensuring the reduction of the cost of alcohol by saving raw materials and energy resources. In such conditions, highly productive breeds of yeast with increased osmophilicity, thermotolerance and fermentation activity are required (Kovalchuk & Mudrak, 2020). Research related to the search for new strains which are producers of ethyl alcohol, and the technology development for highly concentrated mash from grain raw materials are relevant issues for the alcohol industry (Mudrak et al., 2018). Industrial alcoholic yeast synthesizes the main products of fermentation which are alcohol and carbon dioxide, as well as related metabolites (secondary and by-products of fermentation) (Marynchenko et al., 2003). Today, more than 400 compounds have been identified in fermented media from grain raw materials. The presence of by-products and by-products significantly affects the taste and aroma of the finished product (Hunko & Shyian, 2008). Studies have not found a correlation between the quantitative synthesis of ethanol and concomitant metabolites (Rymareva, 2010). Secondary and by-products are synthesized from the corresponding keto acids as a result of biocatalysts of carbohydrates and amino acids (Moyseenko et al., 2004).

Particular attention is paid to volatile impurities that affect the taste and aroma of alcoholic beverages. It has been studied that 90 % of the total amount of volatile impurities are higher alcohols. Higher alcohols have a pungent smell. Organoleptic characteristics depend on the chemical composition and molecular weight, the aroma increases with increasing mass of alcohols. Alcohols with a cyclic structure give a strong aroma to alcoholic beverages. The bouquet of the drink provides a combination of different higher alcohols. It is known that higher alcohols have a pharmacological effect on the human body.

The synthesis of concomitant metabolites during fermentation is associated with the regulatory functions of the yeast cell, which largely depend on the technological processes of preparation and fermentation of wort. The type of raw material, the initial concentration of dry matter of the wort, the fermentation temperature and the pH of the substrate significantly affects the composition of the distillate (Shyian et al., 2015).

There are two main ways of formation of concomitant metabolites: metabolic and technological. The first method depends on the type of raw material, the breed of yeast, the biochemical composition of the wort and the conditions of their cultivation, infection of the nascent environment. The second method depends on the botanical composition, defects in raw materials and technological features of the extraction of metabolites during distillation (Nahurna et al., 2011).

To improve the qualitative sensory characteristics of ethanol, the possibility of metabolically adjusting the synthesis of volatile alcohol impurities using different races of alcoholic yeast was investigated.

Corn with a starch content of 69.0 % was used for the research, which was ground to obtain grindings with a dispersion of 100 % of passage through a sieve with holes with a diameter of 1 mm. The starch content of the original grain was determined by the Evers method and its moisture by the method of drying to constant weight. The particle size distribution of grain grinding was found by scattering on metal and nylon sieves. To determine the dry matter concentration of wort and mature mash used a sugar meter and refractometer (Polygalina, 1999). Preparation of the wort was performed according to the low-temperature scheme of boiling at a temperature of 85-92 °C using concentrated enzyme preparations of α-amylase with exposure to 3 h. The diluted mass was cooled to a temperature of 50-55 ° C and sugared with glucoamylase for 0.5 h. The selected breed of S. cerevisiae DO-16 (Ukrainets et al., 2018) and known breeds of alcoholic yeast S. cerevisiae DO-11, K-81, XII were selected for comparative characterization. To prepare the yeast, the wort was acidified with sulfuric acid to an acidity of 0.5–0.6 degree. Yeast cultivation was performed at a temperature of 30–32 °C, and fermentation was at a temperature of 30–35 °C. For dilution and batches sugaring used enzyme preparations from "Danisco" (Belgium): as α-amylase is Amilex 4T, glucoamylase is Diazyme TGA. Yeast cultivation and fermentation were performed on wort with a concentration of 28 %. In the laboratory conditions, the wort was fermented by the method of "fermentation test" in conical flasks with sulfuric acid gates in a thermostat. The content of volatile impurities in the distillate was determined on a gas chromatograph Crystal 2000M.

During fermentation, corn grain with a starch content of 69 % and wort concentrations of DM concentration of the wort 28 % was used.

The experimental data are shown in table 1 show that the studied races of alcoholic yeast S. cerevisiae XII, K-81, DO-11, DO-16 at a wort concentration of SR 28 % synthesize alcohol to its content of 12.40; 13.55; 14.20; 14.40 % vol. in accordance. It is experimentally proved that at a concentration of DM concentration of the wort 28 %, the selected osmophilic strain of the yeast S. cerevisiae DO-16 provides regulated parameters of the hydrocarbon composition of mature brews and synthesizes up to 14.40 % vol. alcohol, respectively. During the fermentation of wort by races XII and K-81, the content of unfermented carbohydrates significantly exceeded the regulated parameters (*Standard technological regulations for the production of raw ethanol, 2005*).

The synthesis of different groups of organic compounds has been investigated, namely: higher alcohols, aldehydes, esters in the process of wort fermentation with a fixed initial concentration of DM concentration of the wort 28 % by different races of alcoholic yeast. Concentrations of volatile organic compounds in the distillate are associated with changes in biosynthetic processes in the yeast cell, and esterification

reactions (formation of esters due to the interaction of alcohols with acids), which occur in the distillation column (Shiyan et al., 2015).

Table 1. Technological indicators of brewing when using different races of yeast

Indicators	Yeast race S. cerevisiae			
	XII	K-81	DO-11	DO-16
PH value, units	4,95±0,02	4,90±0,02	5,10±0,02	4,90±0,02
Acidity, deg.	0,48±0,02	0,50±0,02	0,48±0,02	0,50±0,02
Alcohol concentration, % vol.	12,40±0,03	13,55±0,03	14,20±0,03	14,40±0,03
Content of unfermented carbohydrates, g / 100 cm^3	2,90±0,02	1,02±0,02	0,48±0,02	0,43±0,02
Content of undissolved starch, g / 100 cm^3	0,25±0,01	0,15±0,01	0,16±0,01	0,12±0,01
Alcohol-soluble carbohydrates, g / 100 cm^3	0,98±0,01	0,87±0,01	0,54±0,01	0,52±0,01
Yeast concentration, million / cm^3	175±17	224±22	298±29	313±31
The proportion of dead cells, %	7,3±0,7	7,6±0,7	4,4±0,4	4,1±0,4

Source: own development

It was found that the concentration of fusel alcohols had the lowest values for distillates obtained by fermentation of starch-containing raw materials by races S. cerevisiae DO-16 and DO-11. The concentration of n-pentanol in the distillate after fermentation by race DO-16 was 8 and 9 times lower compared to race K-81 and XII. The concentration of n-propanol and isobutene in the distillate was almost the same in all samples (within the error of the experiment) (Fig. 1).

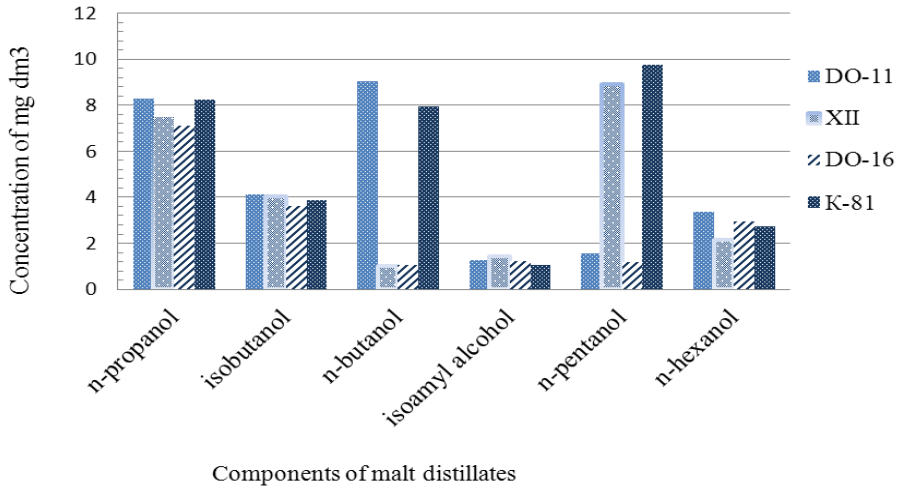

Fig. 1. The concentration of fusel alcohols in fermented distillates depending on the use of different races of alcoholic yeast

During the fermentation of wort from grain raw materials, the qualitative and quantitative composition of volatile impurities of alcohol largely depends on the race of alcoholic yeast. The results of research on the biosynthesis of volatile impurities of alcohol allow you to adjust the alcohol for the production of high quality alcoholic beverages. In fig. 2 the concentrations of volatile organic impurities in the distillate are shown.

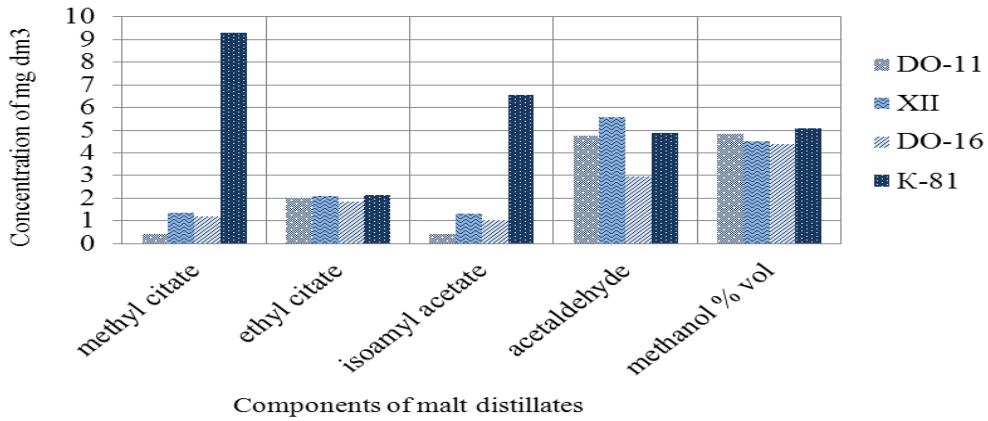

Fig. 2. Concentration of volatile organic impurities of alcohol when using different races of alcoholic yeast

Complex esters in alcohol are synthesized due to enzymatic processes in the yeast cell. Indicators of ethyl acetate and isoamyl acetate for malt distillates, where S. cerevisiae DO-16 and XII were used for wort fermentation, were at the same level. However, for the K-81 race, this figure was 6 times higher. Methanol was almost at the same level for all test samples. The concentration of acetaldehyde was lowest in the distillate, where *S. cerevisiae* DO-16 was used.

To a large extent, the level of aldehyde formation depends on the metabolic state and fermentation activity of alcoholic breeds of yeast. The use of a selected breed of yeast S. cerevisiae DO-16 makes it possible to intensify the fermentation of highly concentrated wort and to obtain distillates with a lower content of metabolic products. The results of studies of biochemical parameters of mature mash and volatile impurities of alcohol confirm the advantages of the selected race during the fermentation of highly concentrated grain wort.

Conclusions and results discussion

A study of the influence of the yeast race on the formation of alcohol metabolites as raw materials for alcoholic beverages has been made. To improve the qualitative sensory characteristics of ethanol, the possibility of metabolically adjusting the synthesis of volatile alcohol impurities using different races of alcoholic yeast was investigated.

The practical significance of the obtained results lies in the industrial implementation of the selected race of alcoholic yeast to obtain high quality alcohol.

The scientific novelty of the work is the selection of a yeast race for the fermentation of highly concentrated grain wort with a reduced content of concomitant alcohol impurities. A promising race for the fermentation of highly concentrated wort from grain raw materials is a selected osmophilic thermotolerant race of alcoholic yeast S. cerevisiae DO-16.

Prospects for further research are the ability to adjust the quality of alcohol as a raw material for high quality alcoholic beverages. During the fermentation of wort from grain raw materials, the qualitative and quantitative composition of volatile impurities of alcohol largely depends on the race of alcoholic yeast. The results of research on the biosynthesis of volatile alcohol impurities allow adjusting the indicators of alcohol for the production of high quality alcoholic beverages, which, in turn, will improve the quality of restaurant products (beverages, confectionery, etc.).

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ДОСЛІДЖЕННЯ ЯКОСТІ СПИРТУ, ОТРИМАНОГО ШЛЯХОМ ЗБРОДЖУВАННЯ ВИСОКОКОНЦЕНТРОВАНОГО ЗЕРНОВОГО СУСЛА РІЗНИМИ РАСАМИ ДРІЖДЖІВ

Актуальність. Вимоги до якості етилового спирту, що виробляється для подальшого застосування у виробництві алкогольних напоїв, постійно підвищуються. Це пов'язано зі зростаючою конкурентної боротьбою виробників алкогольних напоїв (удосконалюються асортимент і якість продукції) і з переглядом стандартів на продукцію, що випускається. Нові напрямки розвитку технології спирту вимагають підвищення концентрацій сухих речовин сусла; проведення бродіння за підвищених температур та концентрацій спирту в бражці; забезпечення зменшення собівартості спирту за рахунок економії сировини та енергоресурсів. У таких умовах необхідні високопродуктивні раси дріжджів із підвищеною осмофільністю, термотолерантністю та бродильною активністю. Дослідження, пов'язані з пошуком нових штамів – продуцентів етилового спирту, та розробка технології висококонцентрованих бражок із зернової сировини є актуальними питаннями для спиртової галузі. **Мета і методи.** Дослідження впливу рас спиртових дріжджів на синтез метаболітів при зброджуванні висококонцентрованого сусла із зернової сировини. Для досліджень застосовували методики, загальноприйняті для спиртової та лікеро-горілчаної галузі. **Результати. Досліджено вплив рас спиртових дріжджів на якісні показники спирту.** Встановлено, що селекціонована раса дріжджів *S. cerevisiae* ДО-16 у процесі життєдіяльності синтезує значно менше побічних метаболітів у порівнянні з іншими досліджуваними расами ДО-11, К-81 та XII. Застосування селекціонованої раси *S. cerevisiae* ДО-16 дає можливість зброджувати висококонцентроване сусло із зернової сировини. Експериментально доведено, що при концентрації сусла СР 28 % селекціонований осмофільний штам дріжджів *S. cerevisiae* ДО-16 забезпечує регламентовані показники вуглеводневого складу зрілих бражок та синтезує до 14,40 % об. спирту відповідно. Для підвищення якісних сенсорних характеристик етанолу досліджено можливість метаболічним шляхом корегувати синтез летких домішок спирту, застосовуючи різні раси спиртових дріжджів. **Висновки та обговорення**. Наукова новизна роботи полягає в підборі раси дріжджів для зброджування висококонцентрованого зернового сусла зі зменшеним вмістом супутніх домішок спирту. Досліджено вплив раси дріжджів на утворення метаболітів спирту. Практичне зна-

чення одержаних результатів полягає у промисловому впровадженні селекціонованої раси спиртових дріжджів для зброджування висококонцентрованого сусла із зернової сировини. Перспективи подальших наукових розробок полягають у можливості впливу на якісні показники спирту як сировини для високоякісних алкогольних напоїв. При зброджуванні сусла із зернової сировини якісний та кількісний склад летких домішок спирту значною мірою залежить від раси спиртових дріжджів. Результати досліджень біосинтезу летких домішок спирту дозволяє корегувати якісні показники спирту для виробництва алкогольних напоїв високої якості.

Ключові слова: якість, алкогольні напої, спирт, виробничі спиртові дріжджі, леткі домішки спирту.

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ИССЛЕДОВАНИЕ КАЧЕСТВА СПИРТА, ПОЛУЧЕННОГО ПУТЕМ СБРАЖИВАНИЯ ВЫСОКОКОНЦЕНТРИРОВАННОГО ЗЕРНОВОГО СУСЛА РАЗЛИЧНЫМИ РАСАМИ ДРОЖЖЕЙ

Актуальность. Требования к качеству этилового спирта для дальнейшего применения в производстве алкогольных напитков постоянно повышаются. Это связано с растущей конкурентной борьбой производителей алкогольных напитков (совершенствуются ассортимент и качество продукции) и с просмотром стандартов на выпускаемую продукцию. Новые направления развития технологии спирта требуют повышения концентраций сухих веществ сусла; проведения брожения при повышенных температурах и концентраций спирта в бражке; обеспечение уменьшения себестоимости спирта за счет экономии сырья и энергоресурсов. В таких условиях необходимы высокопроизводительные расы дрожжей с повышенной осмофильностью, термотолерантностью и бродильной активностью. Исследования, связанные с поиском новых штаммов – продуцентов этилового спирта, и разработка технологии высококонцентрированных бражек из зернового сырья являются актуальными вопросами для спиртовой отрасли.

Цель и методы. Исследование влияния рас спиртовых дрожжей на синтез метаболитов при сбраживании высококонцентрированного сусла из зернового сырья. Для исследований применяли методики, общепринятые для спиртовой и ликеро-водочной отрасли.

Результаты. Исследовано влияние рас спиртовых дрожжей на качественные показатели спирта. Установлено, что селекционированная раса дрожжей *S. cerevisiae* ДО-16 в процессе жизнедеятельности синтезирует гораздо меньше побочных метаболитов по сравнению с другими исследуемыми расами ДО-11, К-81 и XII. Применение селекционированной расы *S. cerevisiae* ДО-16 дает возможность сбраживать высококонцентрированное сусло из зернового сырья. Экспериментально доказано, что при концентрации сусла СВ 28 % селекционированный осмофильный штамм дрожжей *S. cerevisiae* ДО-16 обеспечивает регламентированные показатели углеводородного состава зрелых бражек и синтезирует спирт до 14,40 % об. Для повышения качественных сенсорных характеристик этанола исследована возможность метаболическим путем корректировать синтез летучих примесей спирта, применяя различные расы спиртовых дрожжей.

Выводы и обсуждение. Научная новизна работы заключается в подборе расы дрожжей для сбраживания высококонцентрированного зернового сусла с уменьшенным содержанием сопутствующих примесей спирта. Исследовано влияние расы дрожжей на образование метаболитов спирта. Практическое значение полученных результатов заключается в промышленном внедрении селекционированной расы спиртовых дрожжей для сбраживания высококонцентрированного сусла из зернового сырья. Перспективы дальнейших научных разработок заключаются в возможности моделирования качественных показателей спирта как сырья для высококачественных алкогольных напитков. При сбраживании сусла из зернового сырья качественный и количественный состав летучих примесей спирта в значительной степени зависит от расы спиртовых дрожжей. Результаты исследований биосинтеза летучих примесей спирта позволяют корректировать качественные показатели спирта для производства алкогольных напитков высокого качества.

Ключевые слова: качество, алкогольные напитки, спирт, производственные спиртовые дрожжи, летучие примеси спирта.