

PHYSICAL, CHEMICAL AND ORGANOLEPTIC CHARACTERISTICS OF LOW ALCOHOL BEVERAGES BASED ON SUGAR SORGHUM

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Abstract. The current market of low-alcohol beverages has been evaluated. The production of alcohol-free beverages is characterized by an extremely wide variety of raw materials. It is allowed to use juices, concentrates, infusions, and extracts of vegetable raw materials, flavours, emulsions, aromatic bases, food acids, vitamins, colourants, stabilizers, preservatives, clarifiers, opacifiers, sweeteners, and other raw materials that meet the requirements of regulations in effect and are authorized by the Ministry of Health. It has been established that the use of natural vegetable raw materials, which are a source of biologically active substances, will help increase the demand for these beverages. As such raw material, it has been suggested to use sugar sorghum, which is a promising agricultural crop and is characterized by a rich component composition. It has been suggested to obtain low-alcohol beverages by wort fermentation on the basis of sugar sorghum juice, with the addition of apple and apple-cherry concentrates. The physicochemical parameters of the wort have been determined, and suggested the modes of its fermentation with dry yeast from the manufacturers Biowin (Brewgo-01) and Fermivin (Gervin GV1), related to brewing and wine yeast races, respectively. The influence of these yeasts on the accumulation of fermentation by-products and on the formation of organoleptic characteristics of beverages has been investigated. It has been found that in the samples studied, most of the fermentation by-products are in quantities close to the perception threshold, and, certainly, they affect the taste and aroma profile of the finished beverages. The profile charts of taste and aroma have been constructed, and the conclusion has been drawn about the prospects of using sugar sorghum juice in the low-alcohol beverages technology based on natural raw materials.

Keywords: low-alcohol beverages, sugar sorghum, wort, dry yeast, fermentation by-products.

Introduction. Formulation of the problem

The low-alcohol beverage market in Ukraine, which had been steadily growing until 2009 (11.4 mln dal of beverages were produced in 2008), has started to lose its position rapidly [1]. Over the last 9 years, the production of these beverages has fallen by almost 70%. Thus, in 2017, only 2147.7 thousand decalitres were produced [2]. There are definitely several reasons for this situation. In particular, these are the directions of state regulation of the market, the economic situation in the country, and the change in consumers' preferences. Nowadays, consumers more and more favour useful

products, that is, those that are not only tasty, but also use natural plant materials. Whereas such low-alcohol beverages are usually produced using sugar syrups, flavours and colourants, which creates a good taste, reduces the cost of production, but does not improve the biological properties of these types of beverages, which is possible only if their composition contains biologically active substances of plant raw material.

Thus, such fermentation products as low-alcohol beverages obtained using vegetable raw materials, which are a source of biologically active substances, is a promising segment of the market.

Analysis of recent research and publications

In order to meet the needs of the population, manufacturers and scientists should pay more and more attention to the development of low-alcohol fermentation technology using non-traditional vegetable raw materials. This technological approach will allow forming new physico-chemical, sensory, and physiological properties of beverages.

Technologies are known of low-alcohol fermentation beverages obtained by fermenting wort from concentrates of fruit and berry raw materials [3-5]. For example, V. Pomozova suggests production of such beverages using fermented fruit and berry raw materials and honey as their base. This allows obtaining a range of low-alcohol beverages of high quality with high nutritional value and original physico-chemical and organoleptic characteristics. In the technology of such beverages, in addition to concentrates of fruit and berry raw materials, it is suggested to use sugar and dried or condensed milk whey. The latter allows you to optimize the composition of the wort with amino nitrogen and reduce the process of fermentation [3].

I. Yakovleva has substantiated the technology of producing fermented beverages based on honey, aromatic raw materials, and kvass wort concentrate. The researcher has experimentally proved the feasibility of using dry baking yeast *Saf Levure* for wort fermentation. The optimum amount of seed material is 1.6 % of the wort volume [6].

However, the search for basic raw materials in the technology of low-alcohol beverages that would satisfy not only the technological requirements, but also provide a high-quality product with excellent organoleptic characteristics, is still in progress.

Sugar sorghum is one of the promising plants for production of alcoholic and low-alcohol beverages. Research in the technology of fermentation of sugar sorghum juice (SSJ) was carried out by foreign scientists, such as M. Chekmaryova. [7], S. J. Hawke, S. Panter, M. Hayes, M. H. Nguyen [8]. The following yeast strains were selected and recommended for fermentation of SSJ: *sacch. cerevisiae*, *diastaticus*, *carlsbergensis*, *chevalier* [7,8].

Sugar sorghum, a vegetable raw material, is a promising beverage technology. The main economically valuable features of this crop are its fast recovery, drought resistance, high and stable yields (80–120 t/ha of green mass), universal use in agriculture and food industry [9,10]. Sugar sorghum juice is used in the technologies of glucose-fructose syrups [11], alcohol [12,13], spirits [7], strong alcoholic beverages [14], confectionery [15], caramel [16], and ice cream [17]. Due to the biologically active substances of sugar sorghum (such as vitamin C, B vitamins, macro and microelements), the obtained foods based on it are healthy [14].

In the State Register of plant varieties suitable for distribution in Ukraine, 2017, there are 16 varieties and hybrids of sugar sorghum. Such varieties as *Favoryt*, *Medovyy FI*, *Tsukrove I*, *Afonya*, *Mamont* are characterized by a high sugar content of 16–24%, and are promising in the technology of complex processing of this plant to make food products, to be used as animal feed, or as a valuable source of fuel [18,19]. The study of the characteristics of the wort fermentation process on the basis of sugar sorghum and fruit and berry concentrates will allow obtaining high-quality low-alcohol beverages on the basis of natural raw materials.

However, sugar sorghum has never been used in the technology of low-alcohol beverages, so it is advisable to study wort fermentation based on sugar sorghum and the formation of organoleptic properties of low-alcohol beverages with different yeast races applied.

The purpose of the work was to study the physical, chemical and organoleptic characteristics of low-alcohol beverages made by wort fermentation on the basis of sugar sorghum juice and apple and apple-cherry concentrates, and assess the influence of different yeasts on the formation of organoleptic properties of the beverages obtained.

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

- to choose a sugar sorghum variety that will allow obtaining high-quality juice as a basis for preparation of wort in the technology of low-alcohol beverages;
- to choose fruit and berry concentrates from natural raw materials, namely, apple and apple-cherry, which will contribute to the production of ready-made beverages with excellent organoleptic characteristics;
- to investigate the conditions of wort fermentation on the basis of sugar sorghum juice and fruit and berry concentrates using dry yeast *Brewgo-01* and *Fermivin – Gervin GVI Universal Wine Yeast*, which belong, respectively, to brewery and wine races of yeast;
- to determine the component composition of fermentation by-products in the beverages tested, and build their taste profiles (profile charts).

Research materials and methods

Materials. The following materials were used in the studies.

Juice made from Sugar sorghum of the *Mamont* variety, with the DS content $24.8 \pm 0.2\%$. The main components of the dry substances of the juice were ($\text{g}/100 \text{ cm}^3$): total sugars – 17.8 ± 0.2 , of them, reducing sugars – 4.1 ± 0.1 ; starch – 1.5 ± 0.1 ; cellulose and hemicellulose – 0.80 ± 0.05 .

The apple and apple-cherry concentrates of the domestic producer *T. B. Fruit*, which were used in the studies, had the DS content $65 \pm 1\%$.

Brewgo-01 dry yeast made in Poland, which is a low fermentation strain used mainly for lager beer, has the optimum fermentation temperature 11–16°C. It provides good clarification of the beverage. Also, a strain of dry wine yeast of the brand *Fermivin – Gervin GVI Universal Wine Yeast* is selected for comparison. It is the *S. cerevisia Bordeaux* strain 7013 from the

Bordeaux region. This yeast provides a quick start of fermentation, a pure aromatic bouquet, and good clarification of the drink. The optimum fermentation temperature for the strain is up to 15°C.

The enzymic preparations (EP) *Xyladol* and *Tegamyl FAL*, the characteristics of which are shown in Table 1.

Table 1 – Characteristics of the enzymic preparations

Name of the EP	Producer, supplier company	Characteristics of the enzymic preparation	Activity of the EP, units/g	Temperature optimum, °C
<i>Tegamyl FAL</i>	<i>TegafermHoldingGmbH</i> , Austria. The supplier company is LLC <i>Biotest</i> .	α -amylase for deliquation and saccharification, fungal	39944 – α -amylase 12546 – glucoamylase	30–55
<i>Ksylolad</i>	<i>ENZYM</i> : Ladyzhyn Plant of bio and enzyme preparations, Ukraine.	endo-1.4-xylanase for cleavage of non-starch polysaccharides, fungal	2000 – xylanase	40–50

Preparation of beverages. The preparation of beverages included the following steps: obtaining sugar juice by the pressing method, enzymic hydrolysis of the macromolecular compounds of the juice, obtaining the wort on its basis using fruit and berry concentrates, pasteurization of the wort and its fermentation.

Research methods.

In the experimental part, the methods were used that are commonly applied for chemical and technological control of the sugar, alcohol, and brewing industries. Thus, the mass fraction of dry substances (DS) in the juice, wort, and finished beverages was determined by the refractometric method [20]; the pH of the medium by the potentiometric method using the universal ionometer EB-74 [21]; the concentration of reducing substances and total sugars by the Luff–Schoorl method [20]; the amino nitrogen by the Pope and Stevens iodometric method [20]; the alcohol content by the refractometric method [20]. The content of fermentation by-products was determined on a gas chromatograph *Khromatek-Krystall* 5000 [22]. The results of these studies were processed using *Khromatek Analytyk* software. The profile charts of the taste and aroma of the low-alcohol fermented beverages were constructed using the profiling method [23, 24].

Results of the research and their discussion

Due to the fact that sugar sorghum juice contained cellulose, hemicelluloses, and a significant amount of starch, we used technologies for making wort from SSJ using enzyme preparations (EP) with amylolytic and cytolytic effects, namely *Tegamyl FAL*, in an amount of 140 cm³/t of starch (which is equivalent to 5.5±0.1 units/g AA and 1.6±0.1 units/g HLA), and *EP Xylolad*, in an amount of 20 cm³/t of raw material (which is equivalent to 0.4 units/g of xylanase activity) [14]. This made it possible to increase the amount of reducing and total sugars, to increase the

filtration rate of the wort, to reduce its viscosity, and to accelerate the clarification process [25].

For the preparation of wort, to create the optimum values of its acidity and ensure high consumer properties of the beverages, apple and apple-cherry concentrates were used.

The hydrolyzed and filtered SSJ was diluted with prepared water to a 10% DS content, and blended with the apple concentrate (sample 1) or the apple-cherry concentrate (sample 2), both diluted up to a 10% DS content, in the ratio 70:30. This ratio of wort obtained from sugar sorghum juice and diluted concentrates provides the optimum acidity of the wort to be fermented [26]. The wort samples were pasteurized at 80±2°C for 15 min, cooled, and filtered. This pasteurization mode minimizes the loss of biologically active substances of the raw material and helps obtain wort with the optimum physico-chemical and microbiological parameters [26]. The physico-chemical parameters of the obtained wort samples are shown in Table 2.

Table 2 – Physico-chemical characteristics of the wort on the basis of SSJ

Parameters	Sample 1	Sample 2
The content of dry substances, %	10.0±0.2	10.0±0.2
Total sugars, g/100 cm ³	8.6±0.1	8.8±0.1
Reducing substances, g/100 cm ³	2.2±0.1	2.3±0.1
Starch, %	0.0±0.1	0.0±0.1
Cellulose and hemicellulose, %	0.0±0.1	0.0±0.1
Pectin substances, %	0.0±0.1	0.0±0.1
Total nitrogen, mg/100 cm ³	38.0±1.0	40.5±1.0
Amino nitrogen, mg/100 cm ³	18.8±1.0	21.2±1.0
Total acidity, cm ³ 1 mol/dm ³ NaOH per 100 cm ³	1.90±0.1	2.10±0.1
pH	4.50±0.1	4.40±0.1

Describing the data obtained, it can be noted that in the wort prepared for fermentation, there is no starch completely hydrolyzed as a result of the pre-enzymic treatment of SSJ. The wort has the optimum acidity of the yeast and contains a sufficient amount of sugars and amino nitrogen, which in the future, will provide full nutrition of the yeast cells.

In order to obtain low-alcohol fermented beverages, the wort samples were fermented with beer and wine races of yeast introduced in the amount 10 ± 0.5 mln/cm³. The following parameters of the fermentation process were established: duration of the basic fermentation – 3.5–4.0 days at the temperatures 12–15 °C; duration of fermentation – 3.0–3.5 days at 1–2 °C. With such technological parameters, ethyl alcohol that accumulates in the beverages is 4.91–5.06% a.b.v., the acidity increases to 2.75–2.93 cm³ of the NaOH solution with the concentration 1 mol/dm³ per 100 cm³, the DS content decreases to 4.3–4.8 %.

In order to evaluate the effect of the component composition of the wort and yeast on the content of volatile fermentation by-products, the following beverage samples were investigated:

- sample 1 – wort made from SSJ and diluted by apple concentrate, fermented with dry Brewgo-01 brewery yeast;
- sample 2 – wort made from SSJ and diluted by apple concentrate, fermented with dry Gervin GV1 wine yeast;
- sample 3 – wort made from SSJ and diluted by the apple concentrate, fermented with dry *Brewgo-01* brewery yeast;
- sample 4 – wort made from SSJ and diluted by the apple concentrate, fermented with dry *Gervin GV1* wine yeast.

The data of the chromatographic studies of the accumulation of volatile fermentation by-products in the samples of beverages are shown in Table 3.

Table 3 – The content of volatile fermentation by-products in the samples of low-alcohol beverages based on SSJ and fruit and berry concentrates

The name of the component	The concentration of the beverage component, mg/dm ³			
	Sample No.1	Sample No.2	Sample No.3	Sample No.4
acetaldehyde	19.3923±3.8785	23.2169±4.6434	14.6421±2.9284	17.4217±3.4843
2-phenylethanol	20.5115±4.1023	12.8961±2.5792	13.1246±2.6249	12.1034±2.4207
ethyl-acetate	4.4369±0.8874	3.391±0.6782	3.4717±0.6943	3.5166±0.7033
isoamyl acetate	0.1958±0.0392	0.1388±0.0278	0.2161±0.0432	0.1845±0.0369
Σ of esters	4.6329±0.9266	3.5298±0.7060	3.6876±0.7375	3.7011±0.7402
methanol	0.0003±0.0001	0.0004±0.0001	0.0004±0.0001	0.0004±0.0001
2-propanol	0.0306±0.0061	–	0.0678±0.0136	–
1-propanol	14.6845±2.2027	14.1585±2.1238	14.9485±2.2423	13.9835±2.0975
isobutanol	14.5655±2.9131	12.2286±2.4457	12.2078±2.4416	10.9744±2.1949
1-butanol	0.5683±0.1137	–	0.4998±0.1000	–
isopentanol	48.0464±9.6093	53.9855±10.7971	38.8058±7.7612	42.7356±8.5471
1-pentanol	0.0713±0.0143	–	0.0586±0.0117	–
Σ of fusel alcohols	77.9669±13.2544	80.3718±14.4669	66.5871±11.9857	67.6935±12.1848
acetic acid	46.3743±9.2749	20.9446±4.1889	40.6541±8.1308	23.5431±4.7086
propionic acid	0.7511±0.1502	0.1808±0.0362	0.4766±0.0953	0.09971±0.0199
isobutyric acid	1.3704±0.2056	1.1199±0.1680	0.7985±0.1198	0.5611±0.0842
hexanoic acid	1.5638±0.2346	2.9246±0.4387	2.2076±0.3311	2.3457±0.3519
octanoic acid	2.1956±0.3293	1.0566±0.1585	3.1570±0.4736	1.8433±0.2765
butyric acid	2.6018±0.3903	1.2778±0.1917	1.7211±0.2582	0.5708±0.0856
isovaleric acid	0.7939±0.1191	0.6648±0.0997	0.5203±0.0780	0.3217±0.0483
valeric acid	–	0.7333±0.1100	–	0.8102±0.1215
Σ of acids	55.6502±10.5735	28.9024±5.4915	49.5352±9.4571	29.2854±5.6082

Analyzing the data obtained, it can be noted that the studied beverage samples have differences in the amount of accumulated by-products that belong to different groups of substances. For instance, the total amount of acids in samples 1 and 3 (wort fermented with brewery yeast) is 1.4–1.9 times as high as their content in samples 2 and 4 (wort fermented with wine yeast). The highest relative content of acids in all beverages is that of acetic acid, and it ranges from 70.82% to 91.33%. It should also be noted that in the samples of beverages obtained by fermenting the wort with the apple-cherry concentrate, the relative amount of acetic acid accumulated is slightly greater than the

corresponding percentage of this acid in the samples based on the apple-sorghum wort. The results of studies show that in all the samples, the acetic acid content does not exceed the perception threshold, which, according to various data, is in the range from 30.0 to 93.0 mg/dm³ [27]. In such small amounts, acetic acid influences the formation of a certain fruity accent in the taste of the beverage. In turn, the presence of all other acids can adversely affect the sensory characteristics. For instance, butyric and isovaleric acids can impart a cheesy taste, octane a butyric one. However, according to the chromatographic studies, the content of all other acids does not exceed the

perception threshold, which, for example, for butyric acid, is approximately 0.2–3.0 mg/dm³, for octane, 3.0–13.0 mg/dm³, for isovaleric, 0.5–1.5 mg/dm³ [27].

Characterizing the total content of higher aliphatic alcohols in the samples, it can be noted that it is within the limits typical of most yeast strains formed during fermentation, that is, from 60.0 to 90.0 mg/dm³ [27]. However, as can be seen from Table 2, in samples 3 and 4 obtained by fermentation of the wort with the apple-cherry concentrate, the amount of higher alcohols accumulated was by 15.8–19.8% lower than in samples 1 and 2. Moreover, higher alcohols in all samples are represented predominantly by isopentanol, 1-propanol, and isobutanol contained in amounts that are within the ranges 57.9–67.2%, 17.6–22.5%, and 15.2–18.3% of the total higher alcohols, respectively. It should be noted that in samples 3 and 4 obtained by fermentation of the wort with the apple-cherry concentrate, the amount of 1-propanol accumulated, of the total amount of fusible alcohols, was approximately by 3.0–4.0% larger. However, the presence of up to 50.0 mg/dm³ of propanol, according to the researchers' data, does not impair the taste of the beverages. Of the higher alcohols that were identified in the samples, isobutanol can have the most adverse effect. This component can impart unpleasant bitterness to the beverage, but its amount in the samples tested is within the perception threshold, which for this component ranges from 5.0 to 20 mg/dm³ [24].

In the formation of the organoleptic properties of beverages, along with higher alcohols and acids, of great importance are esters that are present in all samples as ethyl acetate and isoamyl acetate. In general, esters are positive components of beverages that can impart pleasant flavours to them when contained in moderate concentrations. Thus, ethyl acetate, when it is present in an amount significantly exceeding the perception threshold, can impart fruit or caramel flavours; isomethyl acetate, in concentrations substantially more than 0.5–2.5 mg/dm³, also gives the product a fruity, in particular, banana flavour. The esters present in the test samples are in quantities close to the perception thresholds, and therefore cannot have a negative effect on the taste of the beverages.

Researchers have proved that one of the factors in providing and preserving the bouquet of a beverage is the presence of carbonyl compounds, mainly aldehydes [27]. The main aldehyde in fermentation beverages, for example, in beer is acetaldehyde, the content of which can be in the range from 10.0 to 35.0 mg/dm³. Being in beverages in high concentrations, acetaldehyde creates flavours that are characterized by the terms “green,” “grassy,” “marinade,” as well as the taste of filter paper [28]. In the beverages produced by the above technology, the amount of acetaldehyde is slightly higher in samples 2 and 4 obtained by fermenting the wort with wine yeast.

The 2-phenylethanol is another component in the samples that can significantly affect the taste and aroma. The perception threshold for it is, on average, 10.0–50.0 mg/dm³. The 2-phenylethanol can give a beverage a floral taste, in particular, that of rose. In the alcoholic beverages under study, its content ranges from 12.1034 mg/dm³ to 20.5115 mg/dm³, that is, within the perception threshold.

To determine the effect of the component composition of the original wort and the yeast race used for fermentation, a sensory evaluation of the beverages was conducted, and the taste and aroma profile charts were constructed [24]. By the quality characteristics (transparency, colour, and appearance; taste and aroma; carbon dioxide saturation), all the beverage samples received 23–25 points, which corresponds to the *Excellent* rating on a 25-point scale of organoleptic quality assessment of low-alcohol beverages.

The following descriptors (features) were used to construct the taste and aroma profile charts of low-alcohol fermented beverages: harmonious taste and aroma, sour taste, apple taste, cherry taste, herbal taste, pure aroma, fruity aroma, yeast taste and aroma. In order to make a profile chart of the finished product, the tasting panel was asked to quantify the values of the selected descriptors by the following scale: 0 – no feature; 1 – the feature is barely felt; 2 – the feature has low intensity; 3 – moderate intensity of the feature; 4 – a marked feature; 5 – a pronounced feature. The profile charts of the taste and aroma of the samples are shown in Fig. 1, 2.

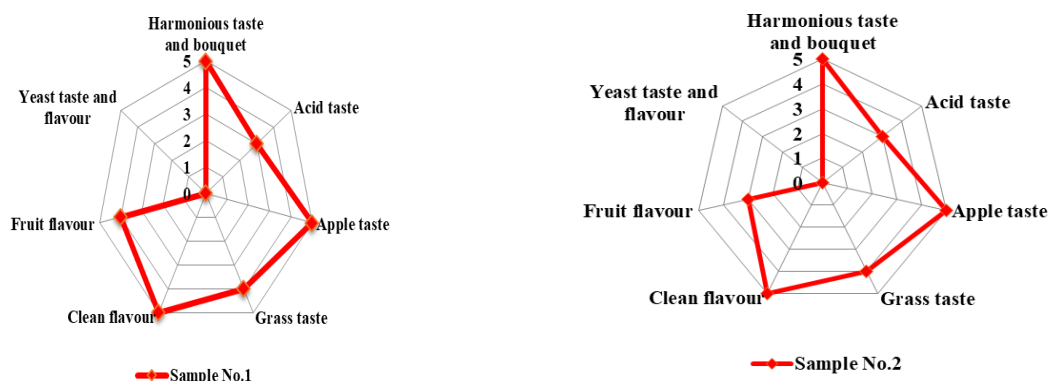


Fig. 1. Profile charts of the taste and aroma of beverage samples 1 and 2

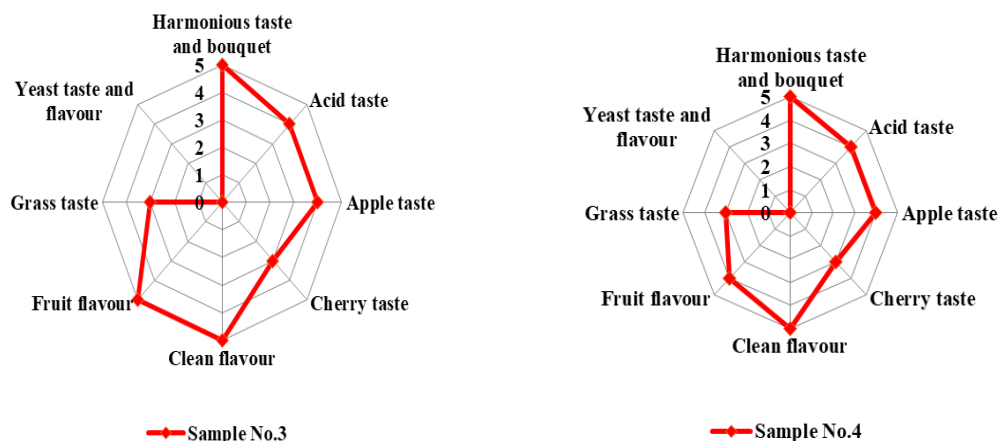


Fig. 2. Profile charts of the taste and aroma of beverage samples 3 and 4

According to the profile charts formed, we can conclude that all the beverage samples were characterized by a harmonious taste and aroma, a pronounced apple taste, a moderate herbal taste, a pure aroma, and non of the samples showed a yeast taste and aroma. It should also be noted that beverage samples 3 and 4 on the descriptor scale have a moderately pronounced cherry taste characteristic.

Evaluation of the research results. The results of the research can be implemented at beer and non-alcoholic industry enterprises of high, medium, and low capacity.

Conclusion

Summing up the results of the research, we can conclude that the suggested wort composition in the technology of low-alcohol beverages based on SSJ and fruit concentrates, as well as the modes of its fermentation by brewery and wine yeast races allow

obtaining beverages with high flavour characteristics and enriched with useful natural components of vegetable raw materials.

The samples of low-alcohol beverages obtained after the apple-sorghum wort and the wort containing an apple-cherry concentrate were fermented with brewery and wine yeast have, in general, a similar component composition of their by-products. However, most of the components that can significantly affect the taste of the beverage are in quantities close to the perception threshold, and, of course, form the organoleptic properties of the resulting low-alcohol beverages. Thus, the technology of fermenting wort based on sugar sorghum juice and fruit and berry concentrates by means of dry yeast of the races *Brewgo-01* and *Gervin GVI* allows obtaining low-alcohol beverages characterized by a harmonious apple or apple-cherry flavour, with a grassy flavour, and with a pure, fruity flavour.

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ФІЗИКО-ХІМІЧНІ ТА ОРГАНОЛЕПТИЧНІ ХАРАКТЕРИСТИКИ СЛАБОАЛКОГОЛЬНИХ НАПОЇВ НА ОСНОВІ ЦУКРОВОГО СОРГО

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Анотація. У роботі оцінено сучасний ринок слабоалкогольних напоїв. Виробництво безалкогольних напоїв характеризується надзвичайно широким розмаїттям сировини. Допускається використання соків, концентратів, настоїв і екстрактів рослинної сировини, ароматизаторів, емульсій, ароматичних основ, харчових кислот, вітамінів, барвників, стабілізаторів, консервантів, освітлювачів, замутнювачів, підсолоджувачів та іншої сировини та матеріалів, які відповідають вимогам чинних нормативних документів і мають дозвіл Міністерства охорони здоров'я. Встановлено, що підвищенню попиту на ці напої буде сприяти використання в технології натуральної рослинної сировини, яка є джерелом біологічно активних речовин. В якості такої сировини пропонується цукрове сорго, яке є перспективною сільськогосподарською культурою та характеризується багатим компонентним складом. Пропонується отримувати слабоалкогольні напої шляхом зброджування сусла на основі соку цукрового сорго з додаванням яблучного та яблучно-вишневого концентратів. Визначено фізико-хімічні показники сусла та запропоновано режими його зброджування сухими дріжджами виробника «Biowin» – Brewgo-01 та виробника «Fermivin» – Gervin GV1, які відносяться до пивоварних та винних рас дріжджів відповідно. Досліджено вплив цих рас дріжджів на накопичення побічних продуктів бродіння та формування органолептичних характеристик напоїв. Встановлено, що в досліджених зразках більшість побічних продуктів бродіння знаходяться в кількостях, близьких до порогу відчуття і, безумовно, впливають на смаковий та ароматичний профіль готових напоїв. Побудовано профілограми смаку і аромату та зроблено висновок про перспективність використання соку цукрового сорго в технології слабоалкогольних напоїв на основі натуральної сировини.

Ключові слова: слабоалкогольні напої, цукрове сорго, сусло, сухі дріжджі, побічні продукти бродіння.

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