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RESEARCH OF TECHNOLOGICAL PARAMETERS AND CRITERIA FOR EVALUATING DISTILLATE PRODUCTION FROM DRIED JERUSALEM ARTICHOKE

L.A. Oganesyants[1], V.A. Peschanskaya[1], L.N. Krikunova[1], E.V. Dubinina[1]*

[1]All-Russian Scientific Research Institute of the Brewing, Non-Alcoholic and Wine Industry – Branch of the V.M. Gorbatov Federal Scientific Center of Food Systems of RAS, 7, Rossolimo St., Moscow, Russia, 119021
**elena-vd@yandex.ru*

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ABSTRACT

In this paper, it is proposed to use dried Jerusalem artichoke as a raw material for distillate production. The purpose of the research was to develop a distillate technology from dried Jerusalem artichoke and to determine the criteria for assessing its quality. The work revealed patterns of changes in the concentrations of the main distillate volatile components, depending on the strength of the fermented wort and its composition. It was established that the increase in the strength of fermented wort by 2.0-2.5 %, leads to an increase in the yield of distillate on average by 3.0 % and enriching it with valuable volatile components. A new technical solution was proposed, based on the regulation of the strength of fermented wort from Jerusalem artichoke due to the addition of distillate. A high degree of correlation was established between the tasting evaluation of Jerusalem artichoke distillates and the concentration of 1-propanol, ethyl caproate, ethyl caprylate, the sum of enanthic ethers, the ratio of C_3 and C_4 alcohols, and was found the ratio of the amount of enanthic ethers to ethyl acetate. It is proposed to use the methanol concentration, the content of enanthic ethers, the total content of carbonyl compounds, the ratio of the sum of enanthic ethers to the concentration of ethyl acetate as criteria for assessing the quality of distillates from dried Jerusalem artichoke.

1. Introduction

The unflagging interest in the Jerusalem artichoke use as a raw material in the food industry in the Russian Federation and abroad has been associated with its unique biochemical composition for several decades. The main areas of researches in the field of application of this crop are developments aimed at producing inulin, a polymer of fructose, which is widely used in creating functional foods and dietary supplements (Bekers *et al.*, 2008; Lisovoy *et al.*, 2016; Barkhatova *et al.*, 2015), use of Jerusalem artichoke prepared in various ways as an ingredient of food products (Yakovleva and Arsen'eva, 2012; Shazzo *et al.*, 2013; Baranenko and Borisova, 2014) and pectin production (Toshkov *et al.*, 2015). Known the developments of Russian and foreign experts in obtaining ethyl alcohol by rectification of fermented wort from Jerusalem artichoke (Nakamura *et al.*, 1996; Ponomareva *et al.*, 2009; Pornthap Thanonkeo *et al.*, 2011).

This type of inulin-containing raw material can also be promising in the production of alcoholic drinks based on distillates. The climatic conditions of the Russian Federation make it possible to grow this crop in sufficient quantities for production. Interest in the use of Jerusalem artichoke in the wine industry is also due to its relatively low purchase price compared to fruit raw materials.

It is known, that the tubers of fresh Jerusalem artichoke are difficult to store as raw materials due to the characteristics of the covering tissues (Ilchenko and Patlasov, 2016). In order to increase its storage time, methods have been proposed earlier, involving the use of a controlled gaseous medium or lower temperatures (Khripko and Kozhukhova, 2003). However, these methods require the use of specialized expensive equipment. Therefore, the organization of year-round production of distillate from fresh Jerusalem artichoke tubers is not economically feasible. In this regard, German specialists use Jerusalem artichoke tubers to produce distillates exclusively as seasonal raw materials (Dürr *et al.*, 2010).

As an alternative to fresh raw materials, was conducted research on the use of dried Jerusalem artichoke. The advantages of dried Jerusalem artichoke are possibility of year-round production, the high stability of its biochemical composition and microbiological purity, the partial depolymerization of the main carbohydrate components of the raw material and, consequently, an increase in their accessibility to enzymatic hydrolysis (Krikunova et al., 2016). The use of dried Jerusalem artichoke allows to simplify the technological process, eliminating the stage of washing and crushing.

Earlier, the main regularities of changes in the carbohydrate complex of dried Jerusalem artichoke in the preparation of the saccharified wort were identified and technological modes of preparation of raw materials for distillation were developed (Oganesyants et al., 2016). Was showed the advantages of using Fermiol alcohol yeast, as compared to the use of wine and brewing yeast, allowing to intensify the fermentation process, to get a wort with a maximum strength and a minimum content of acetaldehyde and methanol (Oganesyants et al., 2017).

The purpose of this work was to identify patterns of changes in the main volatile component concentrations of distillate from Jerusalem artichoke, depending on the strength of the fermented wort and its composition, to develop a new technological method, aimed at increasing the yield of distillate and improving its organoleptic characteristics.

2.Materials and methods

2.1. Materials

Dried Jerusalem artichoke from the tubers of the Skorospelka variety was obtained from Topinambur LLC (Tver Region, Russian Federation). The method of dried Jerusalem artichoke production involves washing, sorting, inspection, calibration, cleaning, additional cleaning, cutting, blanching, drying and subsequent grinding (Golubev and Volkova, 1995). The biochemical composition of dried Jerusalem artichoke we studied previously (Krikunova *et al.*, 2016).

Samples of fermented wort from dried Jerusalem artichoke, obtained by two-and one-stage methods (control); wort samples prepared for distillation (experimental); distillate fractions, selected by strength and organoleptic characteristics; samples of distillate were used in this study.

2.1.1. Obtaining a fermented wort

The control sample C 1 of fermented wort from dried Jerusalem artichoke was obtained according to the previously developed two-stage method, namely:

- *at the saccharified wort obtaining stage:* hydronic module 1÷4.5; enzymatic hydrolysis of raw materials polymers due to its own Jerusalem artichoke enzymes and microbial inulinases (3.0 units/g of inulin raw material) and proteases (0.01 units/g of protein raw material); the duration of hydrolysis is 3 hours at 50 °C.
- *at the saccharified wort fermentation stage:* the use of dry Fermiol alcoholic yeast with an application rate of 100 mg/100 g of wort; fermentation at a temperature of 28-30 °C for 48 hours.

A control sample of C 2 fermented wort from dried Jerusalem artichoke was obtained by a one-step method, including mixing the raw material with water at a water ratio of 1÷4.5, acidifying the wort with H_2SO_4 solution to pH 4.5; the use of microbial inulinase with a dosage of 4.0 units/g of inulin raw materials; the introduction of a fermentation activator; the use of Fermiol dry alcoholic yeast with an application rate of 100 mg/100 g of wort; fermentation at a temperature of 28-30 °C for 72 hours. At the same time, Vitamon Kombi (Erbsloeh, Germany), which is a mixture of pure ammonium phosphate and thiamine (vitamin B_1), was used as a fermentation activator.

2.1.2. Experimental samples preparation

The experimental samples of wort were prepared by introducing into the control samples a certain volume of distillate, obtained as a result of fractionated distillation of control samples previous batches. The amount of introduced distillate was determined on the basis of increasing the strength of the fermented wort by 1.0-4.0 % by volume. The increase in the strength of samples S 1.1 and S 2.1 was 0.9–1.1% vol.; samples S 1.2 and S 2.2 - 1.9-2.1% vol.; samples S 1.3 and S 2.3 - 2.9-3.1% vol.; samples S 1.4 and S 2.4 - 3.9-4.1% vol.

2.1.3. Obtaining distillates

Control and experimental samples of fermented wort were subjected to single fractionated distillation in a direct distillation unit with a strengthening column and a reflux condenser (Kothe Destillationstechnik, Germany). The temperature of the heating vapor was maintained from 102 °C (at the beginning of the distillation) to 105 °C (at the end of the distillation). The heating vapor pressure in the distillation process was 0.2-0.5 mPa. The selection of the head, average (heart) and tail fractions of the distillate was carried out according to organoleptic characteristics and strength.

2.2. Methods

The qualitative and quantitative composition of volatile components in the objects of research was determined by gas chromatography using a Thermo Trace GC Ultra gas chromatograph (Thermo, USA) with a flame ionization detector (detection limit not more than 3•10-12 g/s). Chromatography column HP FFAP: length 50 m, internal diameter 0.32 mm with a membrane thickness of the stationary phase of 0.5 µm (State Standart, 2016). In order to conduct a comparative analysis of the samples studied, the concentration of volatile components was expressed in mg/dm^3 of absolut alcohol (mg/dm^3 of a.a.). For processing the research results, a statistical method for processing experimental data was used, during which the average values of measured values from 3-5 replications, the standard deviation and the confidence interval were determined (Borovikov, 2003; Grachev and Plaksin, 2005). Data in tables and figures are presented as averages of 3-5 dimensions. Mathematical planning and processing of experimental data was carried out using the methods of mathematical statistics using Excell 2007. The results of the correlation analysis were evaluated using tabular data on the critical values of the Pearson's code. For p=0.05 with the number of degrees of freedom 18, r=0.44.

3. Results and discussions

At the first stage of researches, was made a comparative assessment of volatile components composition and concentration in the control samples of fermented wort from dried Jerusalem artichoke, depending on the method of preparing raw materials for distillation (Table 1).

Table 1. The Main Control Samples Volatile Components Content of Fermented Wort from Dried Jerusalem Artichoke

Volatile Components Content, mg/dm^3 of a.a.	C 1 (7,31 % vol.)	C 2 (7,58 % vol.)
Acetaldehyde	685	565
Ethyl acetate	114	126
Methanol	1181	971
Higher alcohols, including:	2254	2191
- 1-propanol	588	577
- isobutanol	536	497
- isoamylol	1130	1117
Enanthic ether	28	22
Phenylethyl alcohol	224	214
The sum of the components*	**4532**	**4146**

* In this table and in the subsequent when calculating the amount of volatile components, all identified impurities were taken into account, some of them are not included in the illustrative material.

It was established that the method of obtaining fermented wort from dried Jerusalem artichoke affected on the total content of volatile components and the concentration of individual substances. In sample C 2, there was a decrease in acetaldehyde and methanol compared to sample C 1 by 17.5 and 17.8%, respectively. The concentration of higher alcohols did not depend on the method of producing wort.

When comparing the data, presented in Table 1, and in a previously published paper (Krikunova *et al.*, 2017), significant differences were found in the control samples of fermented wort from dried Jerusalem artichoke and samples of fermented wort from fresh tubers. Concentrations of higher alcohols and methanol in fermented wort from fresh raw materials, compared with the wort from dried Jerusalem artichoke, exceeded their values by 1.4–1.9 and 4–5 times, respectively. Therefore, it can be concluded that in terms of methanol content, an indicator characterizing the safety of alcoholic drinks, dried Jerusalem artichoke has significant advantages over fresh raw materials. At the same time, the marked lower content of higher alcohols, components that form the basis of the aroma of distillate-based alcoholic drinks, could adversely affect on the intensity of the aromatic characteristics of the finished product, which should be considered when developing a new distillate technology from dried Jerusalem artichoke.

In order to increase the mass concentration of aroma-forming components and the possibility of changing their volatility in the distillation process, wort prototypes (experimental samples) were obtained. They were prepared from control wort samples by adding distillate as described above.

The conditions for the transition of volatile components to distillate depend on many factors, including their solubility in ethyl alcohol and aqueous-alcoholic solutions of various concentrations, on their mutual miscibility and the type of distillate plant (Prado-Ramirez *et al.*, 2005). Differences in the behavior of volatile components affect the organoleptic characteristics of individual fractions, selected during the distillation process and their yield (Claus and Berglund, 2005). On this basis, the addition of distillate to the fermented wort from dried Jerusalem artichoke could be a significant factor influencing the processes occurring during distillation. The content of the main volatile components of the experimental samples of wort is presented in Table 2.

Table 2. Volatile Composition of Experimental Wort Sampels

Volatile Components Content, mg/dm^3 of a.a.	**S 1.1**	**S 1.2**	**S 1.3**	**S 1.4**	**S 2.1**	**S 2.2**	**S 2.3**	**S 2.4**
Acetaldehyde	706	725	747	765	583	598	614	630
Ethyl acetate	122	129	137	144	134	141	148	156
Methanol	1346	1508	1668	1825	1118	1262	1404	1544
Higher alcohols, including:	2583	2906	3224	3536	2478	2752	3023	3291
- 1-propanol	650	711	771	830	639	698	757	814
- isobutanol	620	702	783	862	568	636	701	768
- isoamylol	1313	1493	1670	1844	1271	1418	1565	1709
Enanthic ether	34	40	46	51	29	35	42	48
Phenylethyl alcohol	223	223	222	222	214	213	213	212
The sum of the components	**5065**	**5589**	**6105**	**6612**	**4652**	**5073**	**5525**	**6171**

As can be seen from the obtained data, the increase in the strength of the fermented wort due to the introduction of a certain volume of distillate led to a change, as compared with the control, of both the total concentration and the content of individual volatile components. The total concentration of volatile components in the test samples increased on average by 10-30 %. At the same time, the mass concentration of acetaldehyde, a component that gives rigidity to taste and aroma of distillates, increased, depending on the amount of distillate introduced, by 3.0 - 12.0 %. However, its relative content in the amount of volatile components decreased by 1.0-4.0%. The absolute content of higher alcohols in the test samples of the wort increased by 13-57 % compared with the control ones. The concentration of the components of enanthic ether, represented by ethyl caprate, ethyl caprylate, ethyl caproate, increased in the wort samples by 30-120 %. It is believed, that these volatile components give specific floral shades to the distillates aroma and harmonize the organoleptic characteristics of alcoholic drinks (Li *et al.*, 2012; Kostik and Memeti, 2013).

It was estimated the effectiveness of a new method of preparing of dried Jerusalem artichoke to distillation on the basis of experimental data by the yield of distillate (average fraction or heart) calculated on anhydrous alcohol when processing 10 kg of prepared wort. The initial data for the calculation of the fractions yield presented in Table 3. While the strength of fermented wort increased from 7.31% to 11.15% (sample 1) and from 7.58 % to 11.48 % (sample 2) revealed a clear tendency to increase the volume of all fractions. The head ranged from 6 to 50 %, heart - from 13 to 34 %, tail - from 5 to 30 %. At the same time, no regularities were revealed for changing the strength of individual fractions. The strength of heart (final distillate) averaged 84-85% vol., that is, it practically did not depend on the strength of the distilled wort.

Table 3. Baseline Data for Calculating the Yield of Distillate Fractions Depending on the Strength of the Fermented Wort

Indicator Name	C 1	S 1.1	S 1.2	S 1.3	S 1.4	S 2	S 2.1	S 2.2	S 2.3	S 2.4
Volume of a.a. from 10 kg of fermented wort. cm^3	730	830	925	1020	1115	760	860	955	1050	1150
Fraction volume. cm^3:										
- head	75	80	90	110	145	70	75	75	100	135
- heart	655	750	850	925	990	690	800	900	970	1030
- tail	850	900	950	1000	1210	900	950	950	1115	1200
Alcohol volume proportion in the fraction. %:										
- head	84.7	85.0	85.1	85.0	84.8	84.1	84.4	84.7	84.0	84.2
- heart	84.2	84.5	84.7	84.5	84.2	83.9	84.0	84.1	83.7	84.0
- tail	10.7	11.4	10.5	11.2	10.0	11.4	10.4	11.7	10.9	11.6
Losses of a.a.. %	3.3	3.0	3.1	3.2	3.3	2.6	2.9	2.4	3.1	2.8

The data, presented in Table 3 allowed us to calculate the yield of fractions by absolut alcohol (Figures 1, 2).

It was established that with an increase in the strength of the wort by 1-2%, the share of the head fraction decreased by 0.3-1.0%, and a further increase in the strength of the wort (by 3-4%) led to an increase in the yield of the head fraction by 0.3-2.3%, depending on the method of Jerusalem artichoke preparation for distillation. The yield of the tail fraction on the contrary was characterized by a tendency to decrease.

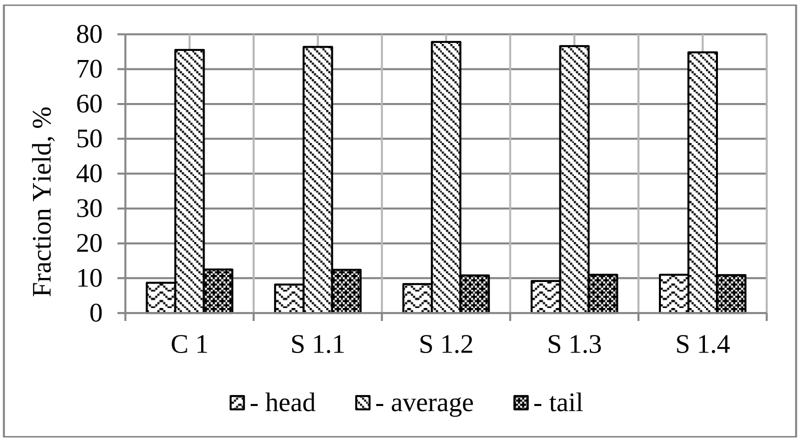

Figure 1. Fractions Yield by Absolut Alcohol during the Wort Samples Distillation, Obtained by the Two-Stage Method (Sample 1)

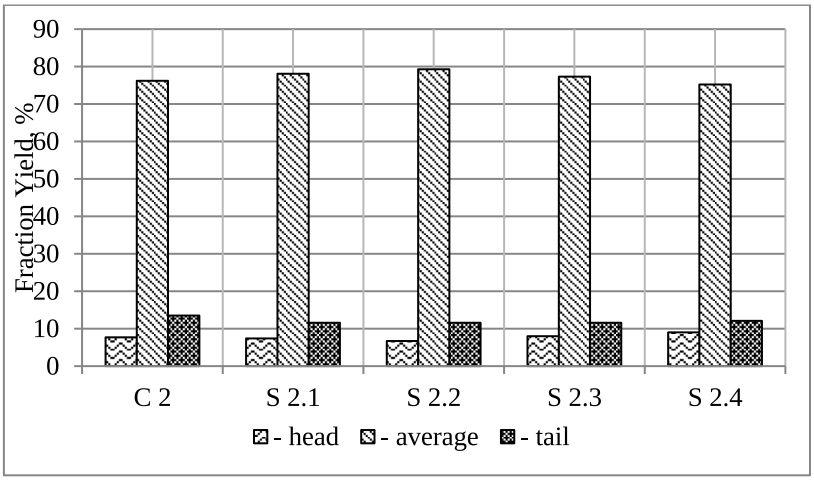

Figure 2. Fractions Yield by Absolut Alcohol during the Wort Samples Distillation, Obtained by the Single-Stage Method (Sample 2)

The data presented in Figures 1 and 2 showed that to achieve the maximum yield of the average fraction (distillate from dried Jerusalem artichoke), increasing the strength of the original wort by adding additional distillate volume, obtained from fractional distillation of previous batches of control samples should be 2-2.5 %. For example, the yield of distillate in test samples S 1.2 and S 2.2 was maximum compared with the control and increased by 2.8 and 3.1%, respectively.

Distillate-based alcoholic drinks are a special group of elite expensive products. In its production of these spirits, it is necessary to take into account not only the economic aspects, determined by the output of products from a unit of raw materials, but first and foremost consumer properties. In this case, the concept of consumer properties includes safety indicators and organoleptic characteristics of the product. The organoleptic characteristics of distilled drispirits, produced without exposure in contact with the wood of oak or other wood species are determined by the composition of the fragrance forming volatile components.

The study of content of volatile components in experimental samples of distillates have shown that the qualitative composition and quantitative content of volatile components in the distillate prototypes from dried Jerusalem artichoke differed significantly in dependence on the level of increase in the initial strength of the wort. These changes were reflected in the results of organoleptic analysis. As a rule, when distillates and distilled drinks sensory evaluation, tasters use a system of descriptive descriptors and an intensity scale. The choice of descriptors system is a fundamental element in preparation for an organoleptic analysis and includes a descriptive characteristic of appearance (color, transparency, the presence of sediment), flavor, its shades and taste (Brochet, Dobourdieu, 2001).

To characterize a new type of product (distillates from dried Jerusalem artichoke), we used certain descriptors for flavor and taste evaluation.

The following descriptors were used to evaluate the flavor: intensity: bright, strong, moderate, weak; character: peculiar to initial raw materials, fruit, flower and honey, including undesirable - fusel, alcohol, musty, sharp; shades: enanthic, grassy, including undesirable - salty, boiled down, medicinal, oxidized.

The following descriptors were used to evaluate the taste: character: soft, refined, oily, including undesirable - sugary, pungent, sharp, rough; harmony: harmonious, inharmonious, disorganized; typicality: typical, atypical, with a foreign tint.

Color and transparency were estimated in the range of 1-2 points. The aroma and taste were estimated in the range of 1-3 points.

According to the results of the organoleptic analysis of distillates from dried Jerusalem artichoke, all samples (control and experimental) were colorless and transparent and received the highest rating for these indicators. The main differences between the samples were identified by the nature and intensity of aroma and taste (Table 4).

Table 4. Organoleptic Analysis of Dried Jerusalem Artichoke Distillates Samples

Sample	Colour (max 2 pts)	Clearness (max 2 pts)	Odor (max 3 pts)	Taste (max 3 pts)	Total (max 10 pts)
C1	2	2	2.6	2.5	9.1
S 1.1	2	2	2.7	2.6	9.3
S 1.2	2	2	2.9	2.8	9.7
S 1.3	2	2	2.9	2.8	9.7
S 1.4	2	2	2.7	2.7	9.4
C 2	2	2	2.7	2.5	9.2
S 2.1	2	2	2.9	2.7	9.6
S 2.2	2	2	3.0	2.8	9.8
S 2.3	2	2	3.0	2.8	9.8
S 2.4	2	2	2.8	2.8	9.6

The results processing of the organoleptic analysis using selected descriptors was carried out graphically, which is widely used in the statistical processing of the organoleptic evaluation of various types of food products. Figures 3 and 4 show the aromatic and taste profiles of distillates from dried Jerusalem artichoke (sample 1 - preparation of the wort in a two-stage process).In the study of the distillate aromatic profiles revealed significant differences between the samples according to the nature and intensity of the aroma.

Unlike the control sample (C 1), which had a weak, unexpressed flavor, the best prototypes (S 1.2 and S 1.3) were characterized by a pronounced aroma of raw materials with bright floral-honey and fruit shades. It was noted that the sample (S 1.4) with the maximum addition of distillate into the wort, was distinguished by a sharp aroma with a strong fuss shade.Analysis of the taste profiles of distillates from dried Jerusalem artichoke made it possible to establish that the control sample (C 1) had an inexpressive taste. The introduction of a certain volume of distillate into the wort (an increase in strength by an average of 2.0% vol.) resulted a product characterized by a pronounced, soft, harmonious, typical taste with oily tints. A further increase in the volume of distillate, introduced into the wort led to the appearance of coarse and sharp tones in the taste of the distillate (S 1.4).

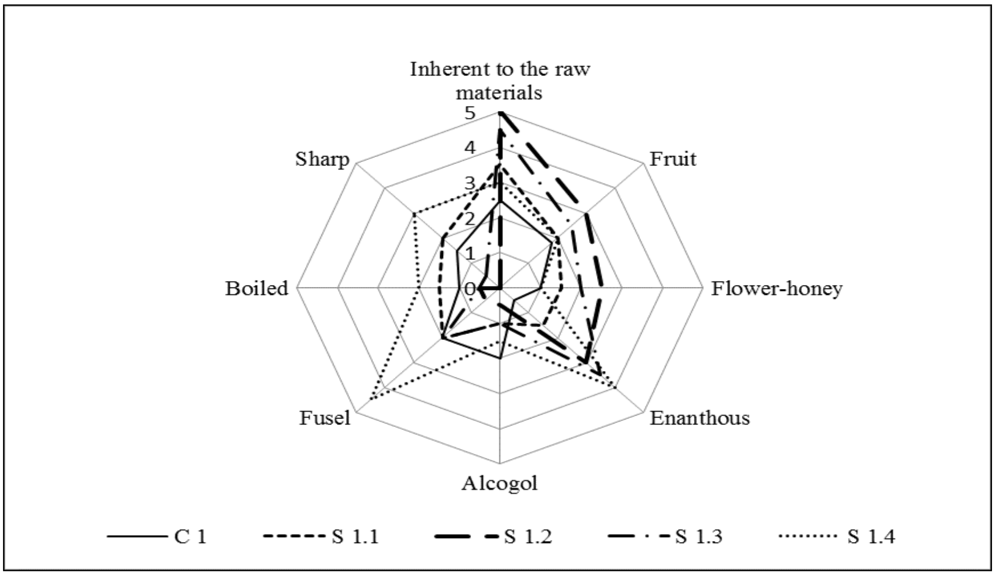

Figure 3. Distillate Aromatic Profiles from Dried Jerusalem Artichoke

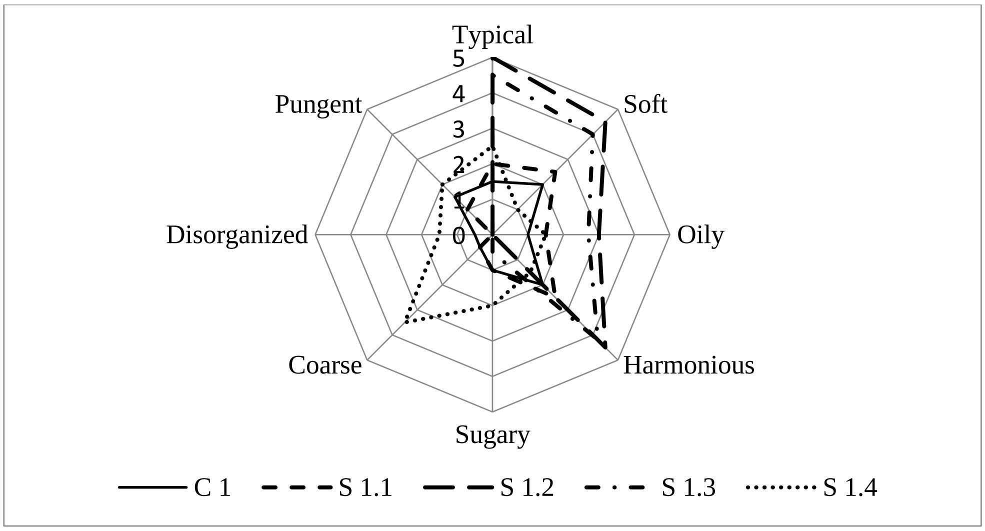

Figure 4. Distillate Taste Profiles from Dried Jerusalem Artichoke

For a deeper understanding of the volatile component influence degree on the taste and aromatic characteristics of distillates, we calculated the pair correlation coefficients between the concentration of individual volatile components, as well as the ratios of individual groups of components, and the tasting assessment (Table 5).

According to the data obtained, the composition of the volatile components of all distillate samples from dried Jerusalem artichoke was dominated by higher alcohols, which accounted for 62-69% of the total amount of volatile components. From aliphatic higher alcohols in the control and experiment samples of distillates 1-propanol, 2-propanol, isobutanol, 1-butanol, isoamylol, hexanol were identified. Despite the high content of this group of volatile components, no significant correlation was found between their total concentration and tasting assessment. Isobutanol and isoamylol, which are the main components of fusel oils, were contained in the studied samples in concentrations from 598 to 1100 mg/dm^3 a.a. and from 1300 to 2459 mg/dm^3 a.a, respectively, which significantly exceeded their threshold concentrations in aroma perception (Arrieta-Garay *et al.*, 2014). However, it was found that the coefficients of pair correlation of these components with the organoleptic evaluation of distillates had low values (0.115 and 0.087), respectively.

The detected concentrations of hexanol turned out to be significantly lower than the threshold ones, while the pair-correlation coefficient for this substance had a numerically significant negative value, well above the critical value. The concentration of 1-propanol with a pleasant, oily-floral aroma ranged from 532 to 821 mg/dm^3 a.a. The threshold perception of 1-propanol is at the level of 100-500 mg/dm^3. The high value of 1-propanol was llowed us to make a conclusion about its positive effect on the formation and character of the aroma of distillates from dried Jerusalem artichoke. Also, the data, presented in Table 5 showed that the ratio of C_3 and C_4 alcohols is significant for evaluation of character of flavor and taste.

Phenylethyl alcohol was found in insignificant amounts. Given that the threshold perception of it is in the range from 10 mg/dm^3 to 80 mg/dm^3, and the value of the r_{xy} for it was 0.011, it can be argued that this component does not affect on the flavor of the distillate from dried Jerusalem artichoke.

Table 5. The Relationship of the Volatile Components Qualitative and Quantitative Composition and the Tasting Evaluation of Jerusalem artichoke Distillates

Indicator	Volatile Components, mg/dm^3 of a.a.										r_{xy}
	C 1	S 1.1	S 1.2	S 1.3	S 1.4	C 2	S 2.1	S 2.2	S 2.3	S 2.4	
Ethanol , % v/v	84.2	84.5	84.7	84.5	84.2	83.9	84.0	84.1	83.7	84.0	
Methanol	1407	1496	1536	1587	1970	1050	1241	1302	1421	1802	-0.074
Acetaldehyde	214	202	186	187	204	143	130	120	118	115	-0.584
Isobutyraldehyde	2	2	1	1	2	1	0	0	1	1	-0.670
Acetone	7	8	5	5	6	6	5	4	4	6	-0.872
2-propanol	5	4	2	3	4	4	4	2	2	3	-0.941
1-propanol	544	659	796	821	705	532	609	725	751	740	0.728
Isobutanol	706	826	853	904	1100	598	710	765	832	904	0.115
1-butanol	24	19	13	15	25	23	18	10	13	19	-0.935
Isoamilol	1552	1800	1939	2058	2459	1300	1461	1611	1800	1987	0.087
Hexanol	16	14	8	10	13	14	10	5	7	10	-0.967
Phenylethyl alcohol	8	8	7	7	7	9	8	9	8	8	0.011
Isoamylacetate	5	6	8	10	9	7	9	11	12	7	0.862
Ethyl acetate	68	64	64	75	98	70	70	70	89	109	0.059
Ethylcaproate	13	14	15	15	12	14	14	15	15	14	0.807
Ethyl lactate	4	3	1	1	2	3	3	2	1	2	-0.801
Ethyl caprylate	11	12	16	15	14	13	14	17	17	15	0.952
Ethylcaprate	24	29	41	48	61	28	41	49	70	81	0.492
Aldehydes and ketones	223	212	192	193	212	150	135	124	123	122	-0.603
Higher alcohols	2847	3322	3611	3811	4306	2471	2812	3118	3405	3663	0.199
Ethers	125	128	145	164	196	135	151	164	204	228	0.401
Enanthic ethers sum	48	55	72	78	87	55	69	81	102	110	0.588
The ratio of alcohols C_5 to the sum of C_3, C_4	1.24	1.21	1.18	1.19	1.36	1.15	1.10	1.08	1.13	1.21	-0.604
The ratio of alcohols C_3 / C_4	0.77	0.80	0.93	0.91	0.64	0.89	0.86	0.95	0,90	0.82	0.717
Σ of enanthic ethers / ethyl acetate	0.71	0.86	1.12	1.04	0.89	0.79	0.99	1.16	1.14	1.00	0.966
Tasting evaluation, score	7.4	7.5	7.7	7.7	7.5	7.5	7.6	7.8	7.8	7.6	

The ethers in the studied samples were represented by ethyl acetate, isoamyl acetate, ethyl caproate, ethyl lactate, ethyl caprylate, ethyl caprate. Ethyl acetate, whose threshold concentration ranged from 50 to 100 mg/dm^3 was found in the largest quantities in studied distillates. It has been established that there is practically no correlation between the concentration of ethyl acetate and the tasting assessment (r=0.059). The mass concentration of enant ethers (ethylcaproate, ethylcaprylate, ethylcaprate) significantly exceeded their threshold concentrations. The values of r_{xy} for ethylcaproate and ethylcaprylate were close to 1.0, which indicates their significant role in formation the distillates aroma. A high positive correlation was noted between the tasting evaluation and the ratio of the sum enanthic ethers and ethyl acetate (r = 0.966).

The concentration of isoamylacetate, which in its pure form has a sharp, fruity smell like pears, in the studied samples ranged from 5 to 12 mg/dm^3 a.a. The correlation coefficient for isoamyl acetate was 0.862, which, taking into account the threshold concentration of this component (0.5-5.0 mg/dm^3), indicates its importance in the perception of the distillates aroma from Jerusalem artichoke.

Of the carbonyl compounds (aldehydes and ketones) in the studied samples, acetaldehyde was the main (in concentrations exceeding the threshold by 1.5–2 times). Isobutyraldehyde was presented in trace concentrations. All carbonyl compounds had high negative correlation coefficients with a tasting score.

The concentration of methanol in distillates from dried Jerusalem artichoke varied from 1050 to 1970 mg/dm^3 a.a. The dependence of the increase in methanol concentration on the level of increase in the strength of fermented wort was revealed. The absolute values of this indicator in samples of distillates from dried Jerusalem artichoke did not exceed the permissible maximum content of methanol in distillates (2 g/dm^3) established in the Russian Federation. According to the results of the correlation analysis, it was concluded that methanol in the indicated concentrations had no effect on the organoleptic characteristics of the distillates obtained (r=-0.074).

In general, the obtained results allowed us to single out a number of individual components and groups of compounds that, to one degree or another, influence the character of the aroma and the taste perception of distillates from dried Jerusalem artichoke. On the basis of the obtained results, we recommended the following criteria for assessing the quality of distillates from dried Jerusalem artichoke: the total concentration of methanol should not exceed 1.6 g/dm^3 a.a., enanthic ethers should be at least 70 mg/dm^3 a.a., the total content of carbonyl compounds should not exceed 200 mg/dm^3 a.a., the ratio of the sum of enanthic ethers to the concentration of ethyl acetate should be at least 1.1.

4. Conclusions

Revealed regularities of changes in the concentrations of the main volatile components of the distillate from dried Jerusalem artichoke depending on the strength of the fermented wort and its composition. It is shown that an increase in the strength of fermented wort is on average 2% vol. leads to an increase in the yield of distillate and its enrichment with valuable volatile components (higher alcohols and enanthic ethers).

A high degree of correlation was established between the tasting evaluation of distillates from dried Jerusalem artichoke and the concentration of individual volatile components, groups of compounds and their ratios: positive for 1-propanol, ethyl caproate, ethyl caprylate, amounts of enanthic ethers, ratios of C_3 and C_4 alcohols, ratio of the amount of enanthic ethers to ethyl acetate; negative for acetaldehyde, isobutyraldehyde, the sum of aldehydes and ketones, ethyl lactate, the ratio of alcohols C_5 to the sum of alcohols C_3, C_4.

A new distillate technology from dried Jerusalem artichoke has been developed, based on the regulation of strength and composition of fermented wort, which allows to increase the efficiency of the process.

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