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The influence of raw materials on the biochemical profile of distillates

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Abstract. This study focuses on exploring novel ingredients for the production of safe, high-quality alcoholic beverages and enhancing the processes involved in fermenting beverages. These efforts aim to support local community development initiatives targeting food security, food sovereignty, and small businesses. The article presents the technology for producing distillates from vegetative raw materials, integrating digital technologies for quality control across all manufacturing stages. Distillates were obtained using the "Minispirtzavod Simpl 2018 set "Authentic" equipment, featuring remote control capabilities and a built-in Wi-Fi module. The quality of distillates derived from various vegetable raw materials, including grapes, apples, wheat, and birch sap, was evaluated through organoleptic analysis, assessing appearance, aroma, and taste. Gas chromatography was employed to determine the content of ethyl alcohol, furfural, methyl alcohol, aldehydes, ethers, and fusel alcohol in the distillates. The resulting distillates contained 40.9% to 43.5% vol.% ethanol and exhibited distinct aromatic profiles and flavors based on the vegetative raw material used. This diversity offers opportunities to expand the range of alcoholic products available.

1 Introduction

Fermented beverages are integral to the global food landscape, utilizing diverse sugary materials like cereals, fruit and vegetable juices, tea, and milk [1].

These beverages encompass both fermented and distilled varieties, with beer and grape wines reigning as global favorites, yet any sugar-supplying raw material can undergo fermentation [2].

Despite exceeding $1.5 trillion in global sales, alcohol-related pathologies, notably chronic liver disease and cirrhosis, have surged in some Central and Eastern European

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countries, potentially linked to low-quality alcoholic beverages containing hepatotoxic aliphatic alcohols [3-4].

Alcohol-related hepatotoxicity stems not only from excessive ethanol consumption but also from other hepatotoxic ingredients, particularly prevalent in poorly produced alcohols [5].

The volatile substance profiles in alcoholic beverages hinge on raw material quality, fermentation yeast, and processing technology [6-7].

Variability in spirit profiles significantly influences taste, emphasizing the importance of feedstock selection for fermentation, subsequently affecting volatile compound concentrations [8-10].

Crude alcohol origin impacts the sensory qualities of rectified alcohols, with resulting products differing based on their sources [11].

Recent studies have explored innovative uses of familiar products, particularly in the distillate industry, fostering interest in novel products from non-traditional raw materials [12-13]. Agricultural residues, including fruit byproducts, have emerged as potential raw materials for distillate production due to their cost-effectiveness and sugar content convertible to ethanol. Birch sap, extracted seasonally in various countries, represents an untapped resource for distillation [14]. Despite its industrial-scale extraction, birch sap remains underutilized in spirits production.

The quest for innovative fermentation technologies is fueled by market demands for new products and alternative uses for food and processing byproducts [15]. Enhancing food safety through digital transformation and optimizing production processes to maximize yield, availability, and quality of raw materials are critical endeavors [16-17]. Internet-based equipment facilitates real-time food quality monitoring, ensuring adherence to safety standards.

This study aims to assess the impact of feedstock on the biochemical profile of distillates, contributing to a comprehensive understanding of spirit production dynamics.

2 Materials and Methods

Raw materials for distillate production included garden apples, grapes, winter wheat from JSC "Kiyatskoe" in Lipetsk, and birch sap harvested in April-May from birch trees in the Leningrad Region.

Apple juice was extracted from washed apples using a juicer and then diluted with water at a ratio of 1:2.5. Similarly, grape juice was obtained by processing grapes through a juicer and diluted with water at a ratio of 1:4. Birch sap was utilized in its pure form without dilution.

The apple, grape, and birch sap juices were placed in fermentation tanks, where alcoholic yeast, sugar, and water were added to initiate fermentation. Additionally, sprouted grains measuring 2-3 cm in length were placed in fermentation tanks, along with yeast and other ingredients, and underwent fermentation. [18].

Consumption of raw materials for mash production is shown in Table 1.

Table 1. Consumption of raw materials for wort production.

Name of raw material	Wort			
	Apple	Grapes	Birch sap	Winter wheat
Apple juice, l	9.1	–	–	–
Grape juice, l	–	7.8	–	–
Birch sap, l	–	–	20	–

Wheat, kg	–	–	–	2.2
Sugar, kg	4	4	5	5
Alcotec Fruit alcoholic yeast (Alcotec Turbo Fruit), g	60	60	–	–
Double Snake Turbo Yeast C48, g	–	–	60	–
Alcotec whiskey yeast, g	–	–	–	73
Water, l	10	22	–	17.8
Total, l	22	30	20	20

Various methods were employed to obtain the wort from different plant raw materials, resulting in distinct distillates as detailed in Table 2.

Table 2. Wort and distillate production method.

Name of raw materials for wort production	Fermentation time, day	Fermentation temperature, °C	Ethyl alcohol content in wort, %	Ethyl alcohol content in the distillate after the first distillation, %	Ethyl alcohol content in the distillate after the second distillation, %
Apples	18	26	70	58	62
Grapes	16	26	65	55	58
Birch sap	14	26	74	61	65
Winter wheat	23	26	68	53	55

Following the sedimentation of the pulp, the initial distillation process commenced. Subsequently, the distillate was carefully selected, with the first 8-15% of pure alcohol output being collected separately due to its detrimental impact on taste. This fraction was discarded to ensure optimal quality. Following strength determination, the distillate was diluted with water to 20% and underwent a second distillation. The main fraction selection concluded when the alcohol strength dropped below 40 degrees.

Distillates were procured using equipment designed for alcoholic distillation, featuring a distillation column known as the "Minispirtzavod Simpl 2018 set 'Authentic'," boasting a capacity of 40 liters and a power rating of 4 kW. A notable feature of this unit is its remote control functionality, facilitated by a built-in Wi-Fi module (refer to Figure 1).

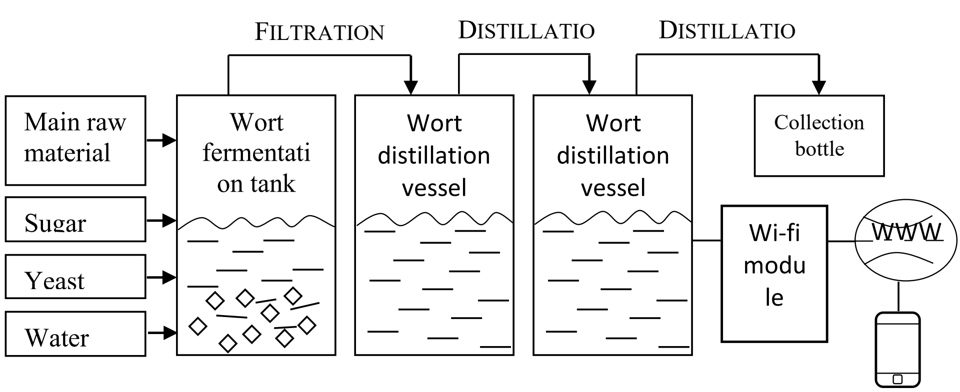

Fig. 1. Scheme of plant-based distillates production.

A sensory evaluation was conducted to assess the quality of the four produced distillates, with each being served at a temperature of 15 degrees Celsius. Organoleptic evaluation was performed according to GOST 33817-2016 on a 25-point scale, considering appearance (clarity, color), flavor (purity, intensity, typicality), and taste (purity, intensity, persistence, typicality).

The ethanol content was determined using the pycnometric method, while the volume fraction of methyl alcohol and the mass concentration of aldehydes, ethers, and fusel alcohols were measured using gas chromatography in accordance with GOST 34675-2020. The gas chromatographic analysis was conducted using a Shimadzu GC-2010 Plus equipped with a flame ionization detector.

Additionally, the mass concentration of furfural was determined following the procedures outlined in GOST 32930. This method involves measuring the color intensity of reaction products formed by the interaction of alcohol ethers with hydroxylamine in an alkaline environment using a Unico 2800 spectrophotometer [18].

3 Results and discussion

The distillates obtained from grape juice (sample 1), birch sap (sample 2), wheat juice (sample 3) and apple juice (sample 4) were studied according to organoleptic and physicochemical quality indicators.

The outcomes of the organoleptic evaluation are depicted in Table 3.

Table 3. Organoleptic evaluation of distillates

Samples	Quality indicators, in points				Total, points
	Transparency	Colour	Fragrance	Taste	
1	3.0	4.0	8.92	8.58	24.50
2	3.0	4.0	7.92	7.25	22.17
3	3.0	4.0	8.17	7.25	22.42
4	3.0	4.0	8.83	9.0	24.83

Following the organoleptic analysis of the distillates, it was determined that all samples derived from different raw materials exhibited excellent quality. Each distillate was characterized by transparency, luster, and a colorless appearance without any additional hues. The distillate produced from apple juice garnered the highest score of 24.83, boasting a distinct aroma and flavor reminiscent of apples. Similarly, the sample derived from grape juice attained a high overall score of 24.50, characterized by a pronounced grape aroma and taste typical of its raw material. The distillates originating from wheat and birch sap achieved respectable overall scores of 22.17 and 22.42 points, respectively. While these samples exhibited slightly subdued alcoholic aromas and tastes, they retained the characteristic flavors associated with wheat and birch sap.

Furthermore, the analysis encompassed the determination of fusel oils, aldehydes, ketones, ethers, and acids content in the distillates. Additionally, the ethanol and methanol content were estimated. For detailed results, refer to Table 4 and Figures 2-3.

Table 4. Physico-chemical parameters of distillates.

Indicators	Samples			
	1	2	3	4
Alcohols				
Ethanol, vol. %:	43.5	42.7	40.9	42.7
Methanol, mg/dm^3 , not more	0.275	0,085	0,077	0,019
Fusel alcohols, mg/dm^3				
iso-Propanol	199.6	1.0	–	102.2

n-Propanol	–	0.4	2.5	9.7
iso-Butanol	–	0.6	0.2	–
n-Butanol	10.1	23.1	235.0	24.1
2-Methylbutanol	109.2	150.4	89.3	197.5
3-Methylbutanol	486.7	726.2	417.7	969.0
n-Pentanol	–	–	0,6	-
n-Hexanol	13,1	0,2	–	7,1
2-Phenylethanol	–	–	7,0	–
AMOUNT	818,8	902,0	752,3	1309,6
Aldehydes and ketones, mg/dm³				
Acetaldehyde	125,1	3,7	2,9	12,7
Acetone	–	2,1	2,9	–
Furfural	29,8	10,1	18,9	–
AMOUNT	187,2	15,9	24,6	12,7
Organic acids, mg/dm³				
Acetic acid	1,6	1,5	1,2	–
Propionic acid	4,1	0,7	1,1	0,4
Isobutyric acid	56,6	14,8	20,3	–
Butyric acid	35,9	–	–	–
AMOUNT	98,2	16,9	22,6	0,4
Complex ethers, mg/dm³				
Isoamyl acetate	197,9	300,6	149,3	356,1
Ethyl acetate	476,6	201,8	293,1	–
Ethylbutyrate	311,1	169,3	220,2	316,1
Ethylhexanoate	6,6	0,4	1,7	–
Ethylcaprilat	1,1	2,5	141,1	2,1
2-Phenylethyl acetate	1,3	0,5	0,7	-
AMOUNT	994,6	675,0	806,1	674,3
Iron, mg/dm³ , not more	0,46	0,55	0,24	–

Research findings indicate that the distillate derived from grape berries exhibited the highest ethyl alcohol content at 43.5%, while lower concentrations were observed in distillates from birch sap and apple juice. Notably, the distillate from sprouted wheat contained 40.9% ethyl alcohol.

Moreover, analysis of the biochemical composition revealed the presence of methanol in the distillates. The highest methanol content was detected in the distillate obtained from grape juice (0.275 mg/dm^3), whereas the lowest was found in the apple juice distillate (0.019 mg/dm^3). While methanol poses health risks, the levels detected in the distillates were deemed acceptable [18].

Furthermore, the study examined fusel alcohol content, which significantly influences the taste and aroma of alcoholic beverages. Distillates from apple juice exhibited the highest total fusel alcohol content, exceeding 1300 mg/dm^3, substantially more than those from grape fruit, birch sap, and wheat. The minimum fusel alcohol content was observed in distillates derived from wheat (752.3 mg/dm^3). Notably, 3-methylbutanol predominated among the fusel alcohols in apple-derived distillates, albeit at a concentration half that of wheat-derived distillates.

Regarding aldehydes and ketones, their concentrations ranged from 12.7 to 187.2 mg/dm^3 across the distillates, with sample 1 exhibiting the highest concentration. Acetaldehyde was the predominant compound, particularly in sample 1 (125.1 mg/dm^3). Acetaldehyde plays a significant role in ethanol's psychopharmacological effects [18-20].

Grape distillate contained the highest concentration of organic acids, primarily propionic, acetic, isobutyric, and butyric acids. Propionic acid, detected in all distillates, exhibited the highest concentration in sample 1 (4.1 mg/dm^3). Propionic acid is widely utilized in food production due to its antimicrobial properties [18, 21, 22].

Additionally, grape distillate demonstrated the highest ether content (994.6 mg/dm^3), primarily composed of ethyl acetate. Apple and birch sap distillates exhibited lower ether concentrations, with isoamyl acetate being predominant. Ethyl butyrate was present in relatively high concentrations in grape and apple distillates, imparting a fruity flavor akin to pineapple. Wheat distillate, on the other hand, contained a relatively high concentration of ethylcaprylate, contributing to its distinct aroma [18, 23-27].

4 Conclusion

The distillates analyzed in the study exhibit distinct properties attributed to the diverse raw materials used in their production. Here's a summary of the key findings: Grape-Based Distillate: Highest ethanol content. Elevated levels of aldehydes, ketones, acids, and ethers. Low fusel alcohol content. Presence of ethyl acetate contributes to a unique aroma reminiscent of Chinese baijiu vodka. Increased acetaldehyde content may enhance intoxicating effects. Methanol content was observed. Birch Sap-Based Distillate: Exhibits high ethanol and isoamyl acetate content. Original aromatic bouquet with pear notes. Unique characteristics attributed to the raw material. Wheat-Based Distillate: Lowest ethanol content compared to other distillates. Minimal levels of 3-methylbutanol, fusel alcohols, and acetaldehyde. Original aromatic bouquet due to high ethylcaprylate ether content. Distinctive properties arising from wheat as the raw material. Apple-Based Distillate: Contains sufficient ethanol and a rich aroma. High levels of fusel alcohols and ethers, particularly isoamyl acetate and ethyl butyrate. Unique aroma akin to Japanese Ginjo-shu sake notes. In conclusion, the choice of raw material significantly influences the composition and sensory characteristics of the distillates. Each distillate offers a distinct aroma and flavor profile, providing opportunities for innovation and diversification in the alcoholic beverage industry

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