UDC: 663.533

THE IMPACT OF STILLAGE FILTRATE ON THE SYNTHESIS OF VOLATILE IMPURITIES OF ALCOHOL AND THE OPTIMIZATION OF THE RECTIFICATION PROCESS

https://doi.org/10.15673/fst.v17i4.2783

I. Boiarchuk[1], Ph.D., Deputy Director of Alcohol Production
N. Boiarchuk[2], Ph.D. student
[1]LLC "LVN LIMITED" Ukrainian Street, 14, Nemirov, Vinnytsia region, 22800
[2]Department of Innovation Management and Service Sector
Ivan Puluj Ternopil State Technical University
Building №7, Mykulinetska Street, 46, Ternopil, 46005

Correspondence:

I. Boiarchuk
E-mail: iaroslav.boiarchuk@nemiroff.pro

Cite as Vancouver style citation

Boiarchuk I, Boiarchuk N. The impact of stillage filtrate on the synthesis of volatile impurities of alcohol and the optimization of the rectification process. Food science and technology. 2023;17(4):51-59.
https://doi.org/10.15673/fst.v17i4.2783

Цитування згідно ДСТУ 8302:2015

Boiarchuk I., Boiarchuk N. The impact of stillage filtrate on the synthesis of volatile impurities of alcohol and the optimization of the rectification process // Food science and technology. 2023. Vol. 17, Issue 4. P. 51-59
https://doi.org/10.15673/fst.v17i4.2783

Abstract. The aim of this research is to determine the influence stillage filtrate on the synthesis of volatile impurities in alcohol, with subsequent removal through the rectification process in a rectification unit operating in an energy-saving mode at pressures lower than atmospheric. The study was conducted at the state enterprise (hereinafter – SE) "Kozlivsky Distillery" located at: Ternopil region, Kozlivsky district, urban-type settlement Kozliv, using gas chromatographic method for determining the content of microcomponents (acetaldehyde, methanol, fusel oil components, esters) using capillary columns. The rectification unit includes various components such as the mash column, hydroselection column, rectification column, methanol column, impurity concentration column and "zero" column. During the research, technological parameters of operation of each unit component were studied, and the concentration of organic impurities in alcohol at different stages was determined. The results of this study allow improving the efficiency of the rectification unit, which is of great importance in alcohol production. Research was conducted on the impact stillage filtrate on the synthesis of volatile impurities in alcohol during fermentation. The research was carried out with the full use iltrate of stillage at the stage of preparing the fermenting substrate. The mash had different concentrations of dry substances. The stillage filtrate was obtained by centrifugation of native stillage and its suspended matter concentration did not exceed 1%. The influence of the amount stillage filtrate and the number of cycles of its recirculation on the biosynthesis of volatile organic compounds during fermentation was studied. The research results showed that the use stillage filtrate at the stage of preparing the fermenting substrate contributes to reducing water consumption and slows down the synthesis of acetaldehyde and higher alcohols during fermentation. With repeated use stillage filtrate, the synthesis process changes, which affects the concentration of volatile organic compounds in the fermentation mash. This impact should be taken into account when selecting operating modes of the rectification unit. Therefore, to obtain high-quality rectified alcohol, it is necessary to adjust the appropriate operating mode of the rectification unit and consider the influence stillage filtrate on the fermentation process.

Key words: stillage, stillage filtrate, dry substances, volatile impurities, rectification.

Introduction. Formulation of the problem

One of the main challenges of the processing industry is water resources. This problem is increasing every year. The alcohol industry is no exception to this problem. One relevant solution to this problem is the return of stillage filtrate to the stage of preparing the fermenting substrate.

To obtain high-quality rectified alcohol and minimize losses, it is necessary to optimize the technological parameters of operation of the rectification unit, which operates in an energy-saving mode under pressure lower than atmospheric [1,2]. Studies have shown that the use of stillage filtrate at the stage of preparing the fermenting substrate may affect the synthesis of volatile organic compounds during fermentation [3,4]. However, it is necessary to further study the effect of the amount of stillage filtrate on the fermentation process, as well as to consider changes in the synthesis of volatile organic compound concentrations when stillage filtrate is reused multiple times. Addressing this issue may contribute to increased efficiency of alcohol production and reduced energy resource costs [5-7].

Due to the increasing cost of energy resources, all enterprises need to reduce costs per unit of output, including in the alcohol industry, by applying advanced energy- and resource-saving technologies. To reduce energy costs, which account for over 30% of the cost of rectified ethanol, researchers have studied the distribution of volatile organic impurities in the rectification unit [8-11]. This unit operates under vacuum, and its optimal operating conditions have been determined to obtain high-quality ethanol under the condition of complete use of stillage filtrate at the preparation stage.

Analysis of recent research and publications

In the mash column, various organic components are formed under the support of the necessary temperature, leading to the formation of additional organic impurities. As a result, the concentration of some of these components, such as acetaldehyde, in the distillate from the mash column may be several times higher than in the fermented mash , where, in addition to ethyl alcohol, a significant amount of organic acids, complex esters, higher alcohols, and unsaturated compounds are present [12-15].

With a decrease in the residence time of the fermented mash in the mash column, the amount of newly formed organic compounds decreases. From this point of view, when choosing contact devices for mash columns, preference should be given to trays with minimal liquid retention time (perforated, valve). At the National University of Food Technologies (hereinafter - NUFT), mash columns with grid-falling trays have been developed, which provide the shortest (compared to trays of other designs) residence time of the mash in the column. Taking into account that the volatility of the main impurities of alcohol in weakly concentrated aqueous-alcohol solutions increases, an effective way to remove them is the rectification of the fermented mash in the rectification unit (hereinafter - RU) of direct action [16,17].

Epuration of the fermented mash can be carried out in a CO_2 separator (epurator) equipped with additional contact devices (Fig. 1).

This method is characterized by the upper part of the mash column being connected via a steam communication with the lower part of the epurator. The hot fermented mash after the preheater 4 enters the upper tray of the epurator 2. The purified fermented mash is then fed into the mash column. In the upper part of the CO_2 separator (epurator) 2, there is a condenser where partial condensation of vapor occurs. Final condensation of vapors enriched with organic impurities (hereinafter - OI) takes place in condenser 3. Organic impurities are extracted in an amount of 0.5–1.5% of the volume of the fermented mash and removed from the installation together with the main fraction or directed to the rectification column (if available). Following this scheme, 25–30% of organic impurities present in the fermented mash are removed in the epurator and do not enter the epuration column, thereby reducing steam consumption for epuration, and the natural excess of the heating steam of the fermentation mash column is effectively utilized for concentrating organic impurities in the epurator [16].

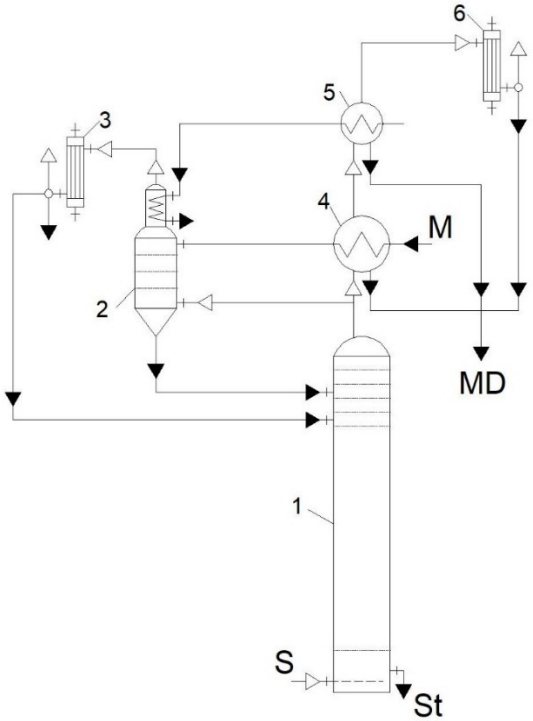

Fig. 1. Mash column with epuration of the fermented mash: 1 - mash column; 2 - CO_2 separator (epurator); 3 - epurator condenser; 4 - mash preheater; 5 - condenser; 6 - alcohol trap.

At the SE "Ovechatsky distillery" in collaboration with the scientific-production association NV LLC "Intermash", a rectification unit with removal of organic impurities at the stage of mash distillation has been developed and implemented. The method of distillation of the fermented mash and its purification from organic impurities is shown in Fig. 2.

Fermented mash passes through the mash preheater 2, where it is heated by aqueous-alcohol vapor coming from the fermentation mash column 1 to a temperature close to the boiling point. The hot fermentation mash enters the upper part of the carbon dioxide separator 4, to the lower part of which aqueous-alcohol vapor from the middle of the fermentation mash column 1 is supplied. Decarboxylation of the mash and removal of a significant portion of organic impurities from it occur in separator 4. Carbon dioxide, together with aqueous-alcohol vapor enriched with organic impurities, is directed to the concentration column 5, where rapid concentration of organic impurities is achieved by returning a portion of the condensate (phlegm) from condenser 6 to the upper tray of column 5. Organic impurities are withdrawn from the process in an amount of 0.1–3.0%.

The cubic residue from the bottom of column 5 returns as phlegm to the mash column above the fermented mash inlet, allowing for additional concentration of the aqueous-alcohol vapor exiting the mash column and the organic impurities present in it.

The condensate freed from a significant amount of organic impurities from the mash heater 2 and condenser 3, in the form of mash distillate, is directed to the epuration column. Extraction and concentration of organic impurities are carried out in two stages - during the decarbonization and epuration stages of the fermented mash [16,18].

Distillation of fermented mash with two-stage extraction and concentration of impurities allows for increasing the concentration of impurities in the alcohol-containing wastes of production, reducing steam consumption for their extraction and concentration in subsequent technological stages. Decarbonization of the fermented mash together with its epuration improves the extraction of organic impurities, reduces their concentration in the mash distillate, and decreases steam consumption for the epuration and rectification of alcohol.

Epuration of the fermented mash allows obtaining mash distillate with reduced impurity concentration, enhancing the quality of the rectified alcohol, and reducing the energy intensity of its production. Pre-epuration of the fermented mash in certain cases may be an alternative to the hydroselection of alcohol impurities in the epuration column [16].

All previous studies were conducted on rectification units operating at excess pressure. Research related to rectification units operating at pressures lower than atmospheric pressure has not been conducted.

Research Objective. The aim of this study is to determine the influence of the stillage filtrate on the synthesis of volatile alcohol impurities with subsequent removal through the rectification process in a rectification unit operating under energy-saving conditions at pressures lower than atmospheric.

Research Tasks. The objectives of this research include:

1. Analyzing the impact of stillage filtrate on the composition and concentration of volatile organic compounds in fermented mash during fermentation.
2. Experimentally determining the optimal conditions for using stillage filtrate, particularly depending on the concentration of solids in the mash.
3. Evaluating the influence of the quantity and frequency of stillage filtrate recirculation on the biosynthesis of volatile organic compounds.

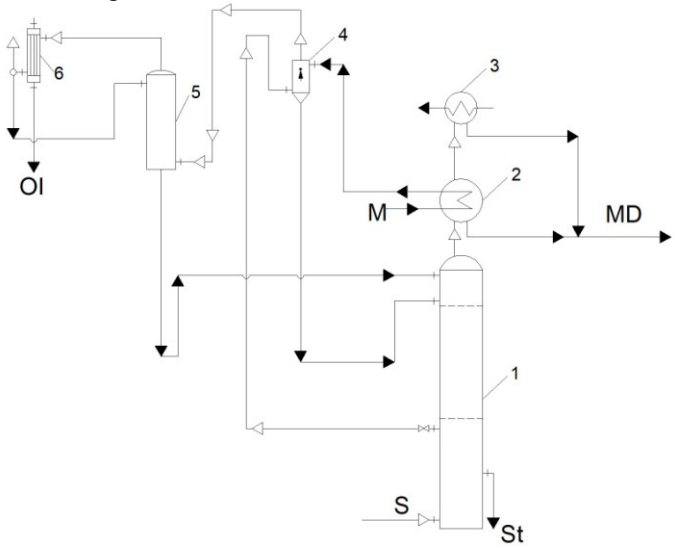

Fig. 2. Method of distillation of fermented mash and its purification from organic impurities: 1 - mash column; 2 - mash heater; 3 - condenser; 4 – separator CO_2; 5 - concentration column; 6 - condenser.

4. Analyzing changes in the characteristics of the final alcohol product based on the using of stillage filtrate.

5. Formulating recommendations for optimizing the rectification process to ensure high quality and production efficiency of alcohol.

Research materials and methods

The research was conducted using the rectification unit of the SE"Kozlivsky Distillery", operating under vacuum with a capacity of 4200 dal/day. Gas chromatography analysis was performed using a gas chromatograph "Crystal 2000M," with a relative error of up to 1.2%.

Prepared samples were injected into the gas chromatograph for further analysis. Components of the samples were separated in the gas chromatographic column based on their chemical properties. After separation, the presence of components was detected using a detector that registers signals of the exiting substances. The obtained data were processed using software, which included spectrum analysis and peak integration to determine the concentrations of components in the sample. This method allows for precise and sensitive determination of the composition and concentration of various components in the sample using gas chromatography.

The rectification unit is of an indirect action type, with a capacity of 4200 dal of rectified alcohol per day, as depicted in Fig. 3 ("Apparatus-technological scheme of the rectification unit operating under vacuum"). It includes the following components: mash column (MC) (1), hydroselection column (HC) (9), rectification column (RC) (15), impurity concentration column (ICC) (33), methanol column (MeC) (23) and "zero" column (ZC) (41).

The fermented mash entering the unit undergoes a two-stage heating in mash heaters (MC) No.1 and No.2 (3), reaching a temperature of 77–78°C. Then, in the CO2 separator (5), the fermented mash is freed from carbon dioxide and other non-condensable gases, after which it is directed to the MC (1). Along with the non-condensable gases, a certain amount of alcohol is removed, which is returned to the distillate tank (43). The fermented mash is fed onto the 17th tray of the MC (feeding tray).

The alcohol-water vapor exiting the MC is condensed in mash heaters No.1 and No.2 and MC deflegmators No.1 and No.2 (4). The remaining vapor is condensed by transferring heat to water in the MC condenser (7) and trap (8). The condensate from mash heater No.1 (3) is directed to the top tray of the MC. The condensate of alcohol-water vapor from MC deflegmators No.1 and No.2 (4) and mash heater No.2 (3) is directed to the distillate collector (6). The mash distillate from the collector is fed onto the 33rd tray (feeding tray) of the HC (9). In the HC, the process of separating alcohol from main and partially final impurities takes place. The alcohol-water vapor is condensed in HC deflegmators No.1 and No.2 (11). The remaining non-condensable vapor is condensed in the HC condenser (12) and trap (13). The condensate from the HC deflegmators is directed as reflux to the HC. The condensate from the HC condenser undergoes alcohol extraction, which is directed to the distillate tank (43).

The cleared of major and partially final impurities epurate is directed to the epurate's tank (14), from where it is fed onto the 15th tray (feeding tray) of the rectification column RC (15). The RC is equipped with deflegmators No.1, No.2, and No.3 (17, 18) and a condenser (19), where the process of vapor condensation exiting the top of the column takes place. From the condenser (19), the selection of unpasteurized alcohol occurs, which is directed to the upper part of the rectification column HC (9). The remaining non-condensed vapor is captured by the trap of the rectification column (20).

The rectified (pasteurized) alcohol is collected from trays 5, 7, 9, and 11 counting from the top of the RC and fed onto the feeding tray of the methanol column MeC (23), equipped with deflegmators No.1 and No.2 (26), a condenser (27), and a trap (28).

In the MeC, residual main and partially final impurities are separated from the rectified alcohol (upper fraction) in an amount of 1% of the alcohol introduced into the column, which is directed to the HC (9). The lower fraction, consisting of 3–4%, is directed to the epurate’s receiver.

The rectified alcohol is collected from trays 18–20 of the MeC and, through alcohol coolers (29,30), a dephlegmator (31), and a flow meter (32), enters the alcohol receiving section.

Intermediate impurities are removed from the RC in the form of two products: fusel fraction, collected from trays 6, 7, 8, and 9 counting from the bottom of the column, and fusel alcohol, collected from trays 19, 21, and 25 counting from the bottom.

The fusel fraction, distillates from the MC condenser (7), MC trap (8), MC trap (13), HK condenser (12), RC trap (20), and from the condenser of fusel alcohol (21), are pumped through the distillate tank (43) onto the feeding tray (30th tray) of the impurity concentration column (ICC) (33). The concentration of major and intermediate impurities occurs in its upper part. The vapor exiting the ICC is condensed in deflegmators No.1 and No.2 (35), a condenser (36), and a trap (37), resulting in a heterogeneous mixture consisting of esters, aldehydes, fusel oil and water. The alcohol-water mixture, with a concentration of alcohol of 5–7% and freed from the main mass of impurities, exits the bottom part of the ICC (33) and is directed to the "zero" column (ZC) (41). The condensate from the deflegmator (35) is directed for separation in the decanter of the ICC (38). The upper layer is removed from the unit as a by-product of rectification-concentrate of ester-fusel (CEF) into the CEF tank, while the lower layer, along with the reflux, is directed for refluxing into the ICC.

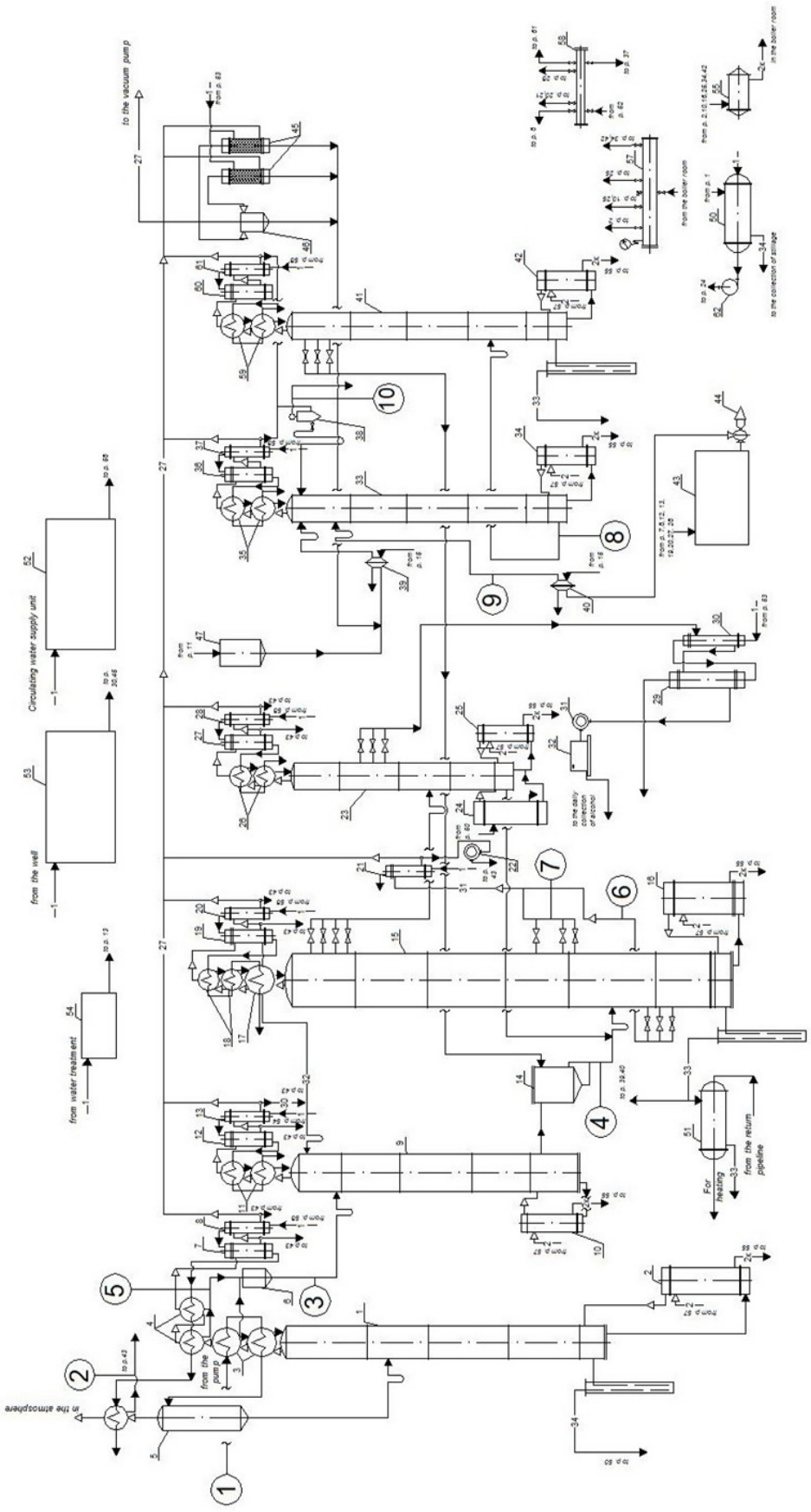

Fig. 3. Apparatus-technological scheme of the rectification unit operating under vacuum

The cube liquid from the cube section of the ICC is fed onto the 16th tray (feeding tray) of the ZC (41). Alcohol is extracted from trays 64, 66, and 68 of the ZC and collected in the epurate's tank. The top impurities are extracted from the ZC deflegmator (59) and trap (61) and directed to the CEF tank.

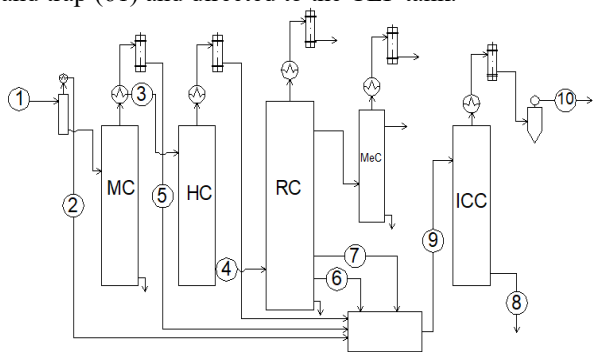

Fig. 4. Sampling zones

Figure 4 shows the sampling zones for determining the concentrations of volatile alcohol impurities. During the experiment, each control point of the unit underwent triple determination of the concentration of organic alcohol impurities. This approach involved conducting three independent measurements for each point to ensure accuracy and reliability of the obtained data. Subsequently, the average concentration value was calculated for each point, forming the basis for further analysis of the results. This measurement approach helped to reduce the influence of random factors and ensure the reliability of the experimental results.

Results of the research and their discussion

The study investigated the influence of stillage filtrate on the synthesis of volatile impurities in the process of fermentation, followed by their removal from the rectification unit.

The results showed that the impact of stillage filtrate on the synthesis of volatile impurities during fermentation significantly alters the characteristics of fermented mash, which is subsequently subjected to rectification. Specifically, the use of stillage filtrate led to an increase in the concentration of certain volatile organic compounds in the fermented mash, as confirmed by gas chromatographic analysis results. This may have a significant impact on the quality and complexity of obtaining rectified ethanol. Thus, the use of stillage filtrate requires additional control and optimization measures in the rectification process to ensure high product quality [19-21].

Corn with a starch content of 68.1% was used as the raw material, with mash concentrations of dry matter at 18%, 20%, and 22%. Stillage filtrate was obtained by centrifuging native stillage on an OS-6M centrifuge. The concentration of suspended solids did not exceed 1%. The experiments were conducted for the complete used of stillage filtrate, the quantity of which depended on the concentration of dry matter in the mash, the alcohol concentration in the fermented mash, and the mash distillate. Considering previous studies, stillage filtrate was introduced based on these factors from colculation of 60%, 70%, and 80% of the total water volume for six recirculation cycles.

Liquefaction was carried out step by step according to previously determined technological parameters, using a complex of enzyme preparations: α-amylase – Amylex A3 – 0.25 U/g of starch, proteolytic enzyme preparation Alphalase AFP at a rate of 0.035 U/g of raw material with an exposure of 30 minutes at a temperature of 55–57°C, followed by an increase in temperature to 65–70°C with an exposure of 120 minutes and final thinning at a temperature of 90°C for 60 minutes in the presence of thermostable α-amylase Tegamyl HS 77 L (0.25 U/g of starch). The mash was cooled to 32 °C, then the enzyme preparation Tegamyl GA 400 L was added at a rate of 6 U/g of starch, and fermentation was carried out for 72 hours with Sacch.cerevisiae yeast DO-11.

Table 1 shows the composition of impurities in ethanol depending on the quantity of stillage filtrate. Figure 5 illustrates the influence of the quantity of stillage filtrate and the cycles of its recirculation on the biosynthesis of volatile organic compounds. Figure 6 shows the effect of stillage filtrate on the concentration of fusel alcohols.

The concentration of acetaldehyde during the use of stillage filtrate at the stage of mash preparation decreases in all cases compared to the control by 4.15; 1.22; and 3.00 times depending on the concentration of dry matter in the mash and the quantity of stillage filtrate.

The synthesis of ethyl acetate decreases in all cases, with the most significant decrease observed at a dry matter concentration of 18% and the use of 80% stillage filtrate. An increase in dry matter in the mash tends to increase the concentration of ethyl acetate.

The total ester concentration ranges: at a dry matter concentration of 18–20% and the use of 80–70% stillage filtrate, it decreases by 2–3.5%, while at a dry matter concentration of 22% and the use of 60% stillage filtrate, it increases by 4.5%.

The total higher alcohols concentration remains almost unchanged regardless of the stillage filtrate concentration and dry matter content in the mash, and is within the experimental error.

The concentration of methanol increases by 2.00; 1.67 and 1.14 times at mash dry matter concentrations of 18%, 20%, and 22%, respectively, and with the use of 80%, 70%, and 60% stillage filtrate at the mash preparation stage, respectively.

With an increase in the number of stillage filtrate recirculation cycles up to six, the concentration of acetaldehyde increases by 1.67 times with 30% stillage filtrate and by 3.20 times with 60% stillage filtrate compared to the control.

Table 1 – Concentration of volatile organic impurities in the mash distillate at different quantities of stillage filtrate and dry matter at the stage of mash preparation

№	Organic impurities, mg/dm³	Concentration of dry matter in the mash, %					
		18.0		20.0		22.0	
		Control	80% stillage filtrate	Control	70% stillage filtrate	Control	60% stillage filtrate
1	2	3	4	5	6	7	8
1	Acetaldehyde	10.8±1.08	2.6±0.39	7.4±1.11	2.3±0.34	3.3±0.5	1.1±0.16
2	2-propanol	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
3	1-propanol	20.7±2.07	50.4±5.04	36.9±3.69	50.9±5.09	24.7±2.47	50.0±5.00
4	Isobutanol	62.1±6.21	49.2±4.92	64.4±6.44	63.8±6.38	73.5±7.35	62.1±6.21
5	Butanol	0.6±0.12	0.7±0.14	0.6±0.12	0.7±0.14	0.7±0.14	0.9±0.18
6	isoamyl alcohol	310.5 ±31.05	273.2 ±27.32	313.0 ±31.30	319.8 ±31.98	502.1 ±50.21	497.9 ±49.79
7	total of higher alcohols	494.0 ±49.40	497.8 ±49.78	495.2 ±49.52	505.4 ±50.54	501.2 ±50.12	505.1 ±50.51
8	Ethyl acetate	14.6±1.46	9.7±1.45	12.8±1.28	10.8±1.08	14.8±1.48	14.7±1.47
9	Isoamyl acetate	1.0±0.15	1.0±0.15	0.9±0.18	1.1±0.16	1.7±0.25	1.7±0.25
10	Ethyl lactate	0.6±0.12	2.0±0.30	0.7±0.14	2.0±0.30	0.6±0.12	1.5±0.22
11	Ethyl octanoate	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
12	total of esters	16.2±1.62	12.8±1.28	14.5±1.45	14.0±1.40	17.3±1.73	18.1±1.81
13	methanol, % vol.	0.0004 ±0.0008	0.0008 ±0.0016	0.0006 ±0.0012	0.0007 ±0.0014	0.0007 ±0.0014	0.0008 ±0.0016
14	Acetone	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
15	1-hexanol	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
16	2-phenylethanol	50.5±5.05	58.8±5.88	50.2±5.02	56.6±5.66	50.5±5.05	54.2±5.42

Reliability is – P=0.95.

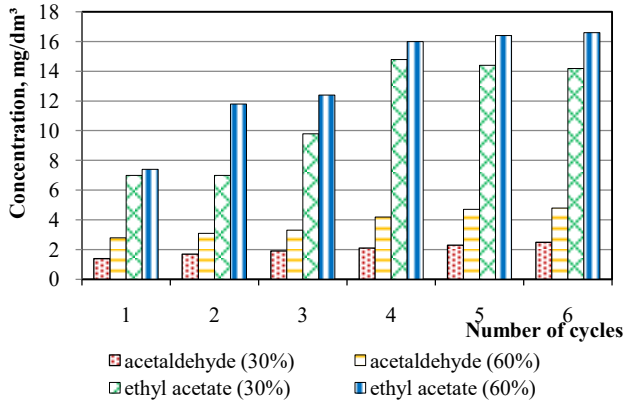

Fig. 5. Concentration of volatile organic impurities (main ones) depending on the quantity of stillage filtrate and the number of its recirculation cycles.

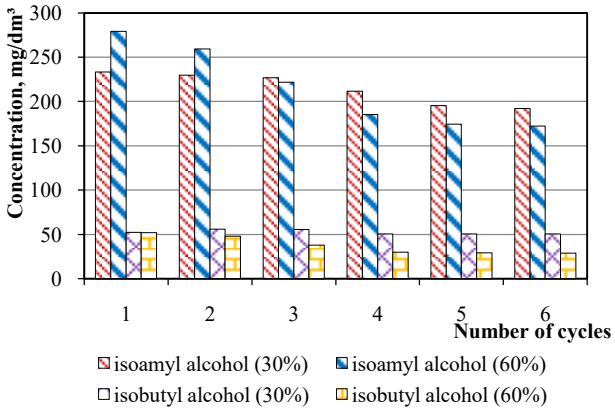

Fig. 6. Concentration of fusel alcohols depending on the quantity of stillage filtrate and the number of its use cycles.

The concentration of ethyl acetate increases in all cases and up to the sixth cycle, it increases by 2.37 and 2.77 times with the use of 30% and 60% stillage filtrate, respectively.

The total ester concentration increases by 2.33 and 2.92 times when replacing 30% and 60% of artesian water with stillage filtrate on the sixth recirculation cycle, respectively.

The concentration of isoamyl alcohol on the sixth cycle decreases by 1.17 times when the quantity of stillage filtrate (SF) is 30%, and by 1.70 times when it is 60% of SF. The concentration of isobutyl alcohol when using 30% SF remains almost unchanged and is within the experimental error, whereas with 60% SF on the sixth cycle, it decreases by 1.8 times.

With an increase in the use cycles of stillage filtrate, the total sum of higher alcohols gradually decreases and on the sixth cycle decreases:

- when using 30% SF by 1.13 times;
- when using 60% SF by 1.65 times.

The concentration of methyl alcohol decreases on average by 1.5 times, regardless of the cycles of stillage filtrate use.

To obtain high-quality rectified alcohol, it is necessary to establish an appropriate mode of operation for the rectification column.

Conclusion

The use of stillage filtrate at the stage of mash preparation not only reduces the consumption of process water but also slows down the synthesis of

acetaldehyde and higher alcohols during fermentation. With repeated use of stillage filtrate at the stage of mash preparation, the concentration of acetaldehyde and esters increases, while the synthesis of higher alcohols decreases. Therefore, when using stillage filtrate, it is advisable during the production of high-quality alcohol to ensure the selection of accompanying alcohol impurities from zones of their maximum concentration in the following quantities:

- Condenser separator of the fermented mash: 2.5–3.0% from AA (absolut alcohol);
- Condenser MC: 5.0% from AA;
- FGES: 6.0% from AA;
- Fusel fraction: 4.0% from AA;
- Fusel alcohol: 1.0–1.5% from AA.

References:

1. Gunko OM, Shiyan PL. Energy-saving technology of spirit rectification. Kharch. i pererob. prom-st. 2008;(12):7-9. (in Ukrainian).
2. Gunko OM, Shiyan PL. Energy-saving technology of distillation in alcohol production. Kharch. i pererob. prom-st. 2008;(10):4-6. (in Ukrainian).
3. Gromov SI. Return of stillage filtrate to production. Likerovodochnoe Proizvodstvo i Vinodelie. 2010;(7-8):27-29. (in Russian).
4. Chunyan C, Xiaoyu T, Zeyi X. Ethanol fermentation kinetics in a continuous and closed-circulating fermentation system with a pervaporation membrane bioreactor. Bioresource Technology. 2012;114: 707-10. https://doi.org/10.1016/j.biortech.2012.02.089
5. Bonassa G, Schneider L, Cremonez P, de Jesus de Oliveira C, Teleken JG, Frigo EP. Optimization of first generation alcoholic fermentation process with Saccharomyces cerevisiae. Brazil Acta Scientiarum: Technology. 2015;37(3):313-20. https://doi.org/10.4025/actascitechnol.v37i3.25794
6. Ashraf K, Meilana D, Ahmed E, Mohamed H, Saeed M, Mohamed A. Kinetic modeling of the simultaneous production of ethanol and fructose by Saccharomyces cerevisiae. Netherlands, Electronic Journal of Biotechnology. 2018;34:1-8. https://doi.org/10.1016/j.ejbt.2018.04.006
7. Kosiv R, Berezovska T, Kharandiuk L, Polyuzhyn L, Palianytsia N. Optimization of main fermentation of high-gravity wort. Chemistry & Chemical Technology. 2016;3:349-53. https://doi.org/10.23939/chcht10.03.349
8. Tian T-T, Ruan S-L, Zhao Y-P, Li J-M, Yang C, Cao H. Multi-objective evaluation of freshly distilled brandy: Characterisation and distribution patterns of key odour-active compounds. Food Chemistry: X. 2022;14. https://doi.org/10.1016/j.fochx.2022.100276
9. Szambelan K, Nowak J, Szwengiel A, Jeleń H. Comparison of sorghum and maize raw distillates: Factors affecting ethanol efficiency and volatile by-product profile. Journal of Cereal Science. 2020;91. https://doi.org/10.1016/j.jcs.2019.102863
10. Korzenszky P, Barátossy G, Székely L, Géczi G. A case study comparing distillation technologies for plum palinka production. Potravinarstvo Slovak Journal of Food Sciences. 2020;14:1191-1199. https://doi.org/10.5219/1472
11. Xiang X-F, Lan Y-B, Gao X-T, Xie H, An Z-Y, Lv Z-H, et al. Characterization of odor-active compounds in the head, heart, and tail fractions of freshly distilled spirit from Spine grape (Vitis davidii Foex) wine by gas chromatographyolfactometry and gas chromatography-mass spectrometry. Food Research International. 2020;137. https://doi.org/10.1016/j.foodres.2020.109388
12. Douady A, Puentes C, Awad P, Esteban-Decloux M. Batch distillation of spirits: experimental study and simulation of the behaviour of volatile aroma compounds. Journal of the Institute of Brewing. 2019;125(2):268-283. https://doi.org/10.1002/jib.560
13. Darıcı M, Bergama D, Cabaroglu T. Effect of triple pot still distillation on the volatile compositions during the Rakı production. Journal of Food Processing and Preservation. 2019;43(6). https://doi.org/10.1111/jfpp.13864
14. Esteban-Decloux M, Dechatre J-C, Legendre P, Guichard H. Double batch cider distillation: Influence of the recycling of the separated fractions. LWT. 2021;146. https://doi.org/10.1016/j.lwt.2021.111420
15. Heller D, Eimfalt D. Reproducibility of fruit spirit distillation processes. Beverages. 2022;8(2). https://doi.org/10.3390/beverages8020020
16. Shiyan PL, Sosnitsky VV, Oliynichuk ST. Innovative Technologies of the Distillery Industry. Theory and Practice: Monograph. Kyiv: Askania; 2009. 424 p. (in Ukrainian).
17. Heller D, Roj S, Switulla J, Kolling R, Einfalt D. Tackling foam-based process disruptions in spirit distillation by thermal energy input adaptations. Food and Bioprocess Technology. 2022;15(3):821-832. https://doi.org/10.1007/s11947-022-02785-5
18. Buliy Y, Shiyan P., Kuts A, Melnik I. Cyclic rectification technology in alcohol production. Food science and technology. 2019;13(4):104-111. https://doi.org/10.15673/fst.v13i4.1563
19. Krikunova LN, Meleshkina EP, Vitol IS, Dubinina EV, Obodeeva ON. Grain bran hydrolysates in the production of fruit distillates. Foods and Raw Materials. 2023;11(1):35-42. https://doi.org/10.21603/2308-4057-2023-1-550
20. Mirontseva A.A., Tsed E.A., Volkova S.V. Justification of Bioactivated Grain Triticale Use in Alcohol Production. Food Processing: Techniques and Technology, 2018, vol. 48, no. 1, pp. 57-65 (in Russian). https://doi.org/10.21603/2074-9414-2018-1-57-65
21. Udeh HO, Kgatla TE. Role of magnesium ions on yeast performance during very high gravity fermentation. Journal of Brewing and Distilling. 2013;4.:19-45. https://doi.org/10.5897/JBD2013.0041

ВПЛИВ ФІЛЬТРАТУ БАРДИ НА СИНТЕЗ ЛЕТКИХ ДОМІШОК СПИРТУ ТА ОПТИМІЗАЦІЯ ПРОЦЕСУ РЕКТИФІКАЦІЇ

Я. Боярчук[1], кандидат технічних наук, заступник директора з питань виробництва спирту[1]
E-mail: iaroslav.boiarchuk@nemiroff.pro
Н. Боярчук[2], аспірант *E-mail:* nazarb1991@gmail.com
[1]ТОВ «ЛВН ЛІМІТЕД», вул. Українська,14, м. Немирів, Вінницька обл., 22800
[2]Кафедра управління інноваційною діяльністю та сферою послуг
Тернопільського державного технічного університету імені Івана Пулюя
корпус № 7, Микулинецька, 46, м.Тернопіль, 46005

Анотація. Мета даного дослідження полягає у визначенні впливу фільтрату барди на синтез летких домішок спирту з подальшим їх виведенням через процес ректифікації на брагоректифікаційній установці, яка працює в енергозберігаючому режимі під тиском нижчим за атмосферний. Дослідження проводилося на державному підприємстві (далі – ДП) "Козлівський спиртзавод", що розташований за адресою: Тернопільська обл., Козівський р-н, селище міського типу Козлів, із використанням газохроматографічного методу визначання вмісту мікрокомпонентів (ацетальдегіду, метанолу, компонентів сивушного масла, естерів) з використанням капілярних колонок. Брагоректифікаційна установка включає в себе різні компоненти, такі як бражна колона, епюраційна колона, спиртова колона, розгінна колона, колона кінцевої очистки та "нульова" колона. У процесі дослідження були вивчені технологічні параметри роботи кожного компонента установки, а також визначена концентрація органічних домішок спирту на різних етапах. Результати цього дослідження дозволяють покращити ефективність роботи брагоректифікаційної установки, що має важливе значення в процесі виробництва спирту. Були проведені дослідження та отриманні результати впливу фільтрату барди на синтез летких домішок спирту в процесі зброджування. Дослідження проводилися при повному використанні фільтрату барди на стадії приготування замісу ферментуючого субстрату. При цьому сусло було з різною концентрацією сухих речовин. Фільтрат барди був отриманий за допомогою центрифугування нативної барди, і його концентрація завислих речовин не перевищувала 1%. У роботі було вивчено вплив кількості фільтрату барди та кількості циклів його рециркуляції на біосинтез летких органічних сполук під час зброджування. Результати досліджень показали, що використання фільтрату барди на стадії приготування замісу ферментуючого субстрату сприяє зменшенню витрат технологічної води і сповільнює синтез ацетальдегіду та вищих спиртів у процесі бродіння. При багаторазовому використанні фільтрату барди змінюється процес синтезу, який впливає на концентрацію летких органічних сполук в зрілій бражці. Цей вплив необхідно враховувати при виборі режимів роботи брагоректифікаційної установки. Отже, для отримання високоякісного ректифікованого спирту необхідно налагодити відповідний режим роботи брагоректифікаційної установки та враховувати вплив фільтрату барди на процес зброджування.

Ключові слова: барда, фільтрат барди, сухі речовини, леткі домішки, ректифікація.