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# A RESOURCE-SAVING AND ENERGY-EFFICIENT TECHNOLOGY OF FERMENTATION OF WORT FROM STARCH-CONTAINING RAW MATERIALS FOR BIOTHETANOL PRODUCTION

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## Introduction. Formulation of the problem

In the context of market economy, an urgent task of the alcohol industry is reducing the cost of commercial products by creating and introducing innovative energy-efficient and resource-saving technologies. Today's energy demand, fluctuations in oil prices, and the consequences of using fossil fuel have increased the need for alternative energy sources. Grain-derived bioethanol is a promising alternative to traditional petrol. Its benefits are the availability of raw materials, reduced production costs, and significantly lower greenhouse gas emissions. The recent studies,

**Abstract.** In the context of market economy, an urgent task of the alcohol industry is reducing the cost of commercial products by creating and introducing innovative energy-efficient and resource-saving technologies. In this aspect, a task of current importance is developing a technology that involves using new high-yielding races of distiller's yeast to ferment highly concentrated wort obtained from grain raw materials. The wort used for fermentation was from different types of grain raw materials: maize, rye, wheat. The studies have shown that an increase in the concentration of dry matter of maize wort (up to 30%) makes it possible to obtain wash with the alcohol concentration 15.65% vol., an increase in the dry mater concentration of wheat wort (up to 27%) – 14.10% vol., in that of rye wort (up to 24%) – 13.00% vol. ethanol. With the standard yield of alcohol from 1 tonne of standard starch, the maximum alcohol content in the maize wash was 14.91% vol., while in the wheat wash, it was 14.1% vol., and in the rye wash, 13.0% vol. It has been studied how the temperature of fermentation of high-concentration wort affects the chemical and technological parameters of fermented maize wash. It has been established that the stage-by-stage fermentation of maize grain wort (at 35 and 30°C) creates conditions for additional saccharification of dextrins in the wort and for its effective end-fermentation. Therefore, this technique is especially effective in the fermentation of high-concentration wort. The introduction of the technology developed will allow efficiently processing agricultural raw materials into alcohol and reducing production waste (post-alcohol stillage). To validate the results of the theoretical and laboratory studies, the technology of highly concentrated alcohol wash from grain raw materials has been tested in the conditions of alcohol production at the company TOV FAZOR in Kozhanka, Fastiv District, Kyiv Region (capacity 6000 dal of alcohol-containing liquids a day). For the manufacturing tests, technological guidelines were developed and approved according to the due procedure.

**Keywords:** highly concentrated wort, bioethanol, fermentation, osmotophilic distiller's yeast, *Saccharomyces cerevisiae*, wash.

which focused on agricultural residues derived from cereals, have illustrated their potential technical benefits for bioethanol production [1,2]. One of the innovative directions is the development of a technology that involves using new high-yielding races of distiller's yeast to fermentat highly concentrated wort obtained from grain raw materials.

When introduced, the technology developed will allow efficiently processing agricultural raw materials into alcohol and reducing production waste (post-alcohol stillage). However, the application of the high-concentration wort fermentation technology poses a number of problems, such as increasing the viscosity of grain mashes or incomplete hydrolysis of raw

materials. This paper considers how to solve these problems. Researchers from the National University of Food Technologies never stop working in this direction, in particular, those at the Department of Biotechnology of Fermentation Products and Winemaking.

#### **Analysis of recent research and publications**

Theoretical and practical studies by the domestic scientists P. Shiyan, S. Oliynichuk, L. Lewandowski, V. Marinchenko and others significantly contributed to the development and improvement of technologies based on high-level processing of grain raw materials in alcohol production.

The experience of recent decades shows that ethanol is mostly used in the world for technical purposes [3,4]. The raw materials for fuel and technical-grade bioethanol are renewable plant raw materials, their by-products, and waste from the food industry and agriculture. The available capacity of distilleries can be reoriented to manufacturing technical-grade alcohol to be used both as organic raw material and as bioethanol fuel. That is why organising the manufacture of fuel bioethanol and technical-grade alcohol is an important economic problem. The research of S. P. Jeevan Kumar, N. S. Sampath Kumar, and A. D. Chintagunta and the know-how technologies developed by them prove that cereals are promising substrates for bioethanol production, which will ultimately increase energy security [1].

To make fuel and technical-grade bioethanol competitive on both domestic and foreign markets, it is necessary to introduce advanced technologies that are energy-efficient, resource-saving, and environmentally friendly [5-8].

Many plants do not work at full capacity. A special area in the development of the country's alcohol industry is still the introduction of an innovative technology and highly efficient equipment to manufacture bioethanol. The use of bioethanol as an alternative fuel extremely needed by the state is a promising direction in the work of the alcohol industry. The growing role of biofuels in the energy balance of Ukraine led to developing the Law of Ukraine *On Alternative Liquid and Gaseous Fuels* (14 January 2000, No. 1391-XIV), which defined the legal, social, economic, environmental, and organisational principles of producing and consuming alternative liquid and gaseous fuels: biogas, biodiesel, and bioethanol.

Development of biocatalytic technologies to prepare and ferment concentrated grain wort, with the use of physiologically active yeast races can increase the efficiency of processing agricultural raw materials into alcohol and technologically reduce the generation of production waste, including post-alcohol stillage [9,10].

Increasing production capacity by installing additional tanks is not profitable. It is possible to increase the efficiency of the fermentation department by using high-quality yeast races. Selective breeding of

physiologically active clones of distiller's yeast, which is technologically resistant to adverse factors and has increased productivity, osmophilicity, and thermotolerance, will improve the productivity of alcohol manufacture by intensifying yeast generation and fermentation, reducing losses of alcohol and raw materials [11-13].

Raising the fermentation temperature and osmotic pressure of the medium leads to the creation of extreme conditions for the activity of yeast. This can result in reducing the regenerative and fermentative activity of yeast, which in turn causes unstable fermentation. So, a promising area of research is finding ways to maintain the stability of yeast generation and yeast metabolism processes and increase their fermentation activity [14-18].

The specific yield of alcohol and its quality depends on the choice of optimal technological parameters at all stages of the technological process [8]. Based on previous research, it has been established that the yeast race *Saccharomyces cerevisiae* DO-16 is the most promising for the fermentation of high-concentration wort [19]. For ethanol production in Ukraine, the most common cereals are maize, wheat, and rye [20].

The use of high-yielding distiller's yeast races bred by selection and the development of rational technological parameters for fermentation of highly concentrated wort will ensure higher concentrations of alcohol in the wash and its lower cost by processing agricultural raw materials more efficiently, saving fuel and electricity, and reducing waste.

The novelty of the work lies in researching and developing rational technological parameters of fermentation of high-concentration wort with the distiller's yeast race *Saccharomyces cerevisiae* DO-16 bred by selection.

**Purpose:** selecting the highest possible concentrations of dry matter of wort from different cereal crops, choosing rational technological parameters of fermentation of highly concentrated wort.

#### **Research objectives:**

1. To determine the highest concentrations of dry matter of wort from different grain raw materials during fermentation.
2. Based on theoretical and experimental research, to select rational technological parameters for the fermentation of high-concentration wort.

#### **Research materials and methods**

During the research, wort was prepared from maize, wheat, and rye grain with the starch content  $63.8 \pm 0.1$ ,  $57.3 \pm 0.1$ , and  $56.5 \pm 0.1\%$  respectively. The particle fineness of the milled grain was 100% of the undersize from a screen with the mesh diameter 1 mm.

The enzyme preparations (EP) used for the research were produced by Danisco (Belgium). *Amylex 4T* was used as  $\alpha$ -amylase, *Diazyme TGA* as

glucoamylase, *Alphalase AFP* as protease, *Laminex 750* as cellulose.

To prepare grain mash, a 50–70 g portion of milled grain was placed in a 500 cm<sup>3</sup> conical flask, and 150–130 cm<sup>3</sup> of water was added. The mixture was stirred, and the working solution of the diluent enzyme preparation was added by units of activity. The dosage of the enzyme preparations was as follows. Amylolytic:  $\alpha$ -amylase (0.8 units AA/g of starch), glucoamylase (7.5 units GA/g of starch); cellulolytic (0.35 units CA/g of raw materials); proteolytic (0.05 units PrA/g of raw materials).

The concentrations of wort for fermentation were as follows: maize wort – 17, 20, 26, 28, 30% DM, rye wort – 17, 20, 24% CF, wheat wort – 17, 19.8, 23.5, 25.2, 27% DM.

Wort was prepared according to the low-temperature cooking scheme at 85–92°C using concentrated enzyme preparations, with 3 hours of exposure. The diluted mass was cooled to 50–55°C and saccharified with glucoamylase for 0.5 h.

Fermented wash was obtained after 3 days of fermentation of the wort at 30–37°C.

The technology of growing yeast and fermentation was based on the previously developed parameters [21]. Yeast was cultured at 30°C, with the concentration of dry matter in the wort 28.0%. The yeast inoculum was introduced in the proportion 20 million/cm<sup>3</sup> of wort. In the laboratory, the wort was fermented by the method of “fermentation test” in conical flasks with sulphuric acid seals in an incubator where the temperature was stably maintained at 30–38°C. The volume of a test sample was 0.2 cm<sup>3</sup>. Fermentation involved using the osmophilic, acid-resistant, thermotolerant race of the yeast *Saccharomyces cerevisiae* DO-16. The starch content of the original grain was determined by Ewers’ procedure [22]. The dry matter concentration was determined on a refractometer of the RPL-3 type [22].

In the fermented wash, the pH and active acidity were determined by potentiometry using a pH meter MI.

The ethanol content was measured by the pycnometric method and the refractometric method, using an immersion refractometer [22]. The content of total and dissolved carbohydrates was measured photoelectrocolorimetrically (using a photocolimeter KFK-2) with the anthrone reagent [22].

Insoluble starch is determined according the formula:

$$C_{st}=(C_{tot}-C_{c.c.})0.9$$

$C_{st}$  – content of insoluble starch, g/100 cm<sup>3</sup> of wash;

$C_{tot}$  – content of total carbohydrates, g/100 cm<sup>3</sup> of wash;

$C_{c.c.}$  – dissolved carbohydrate content, g/100 cm<sup>3</sup> of wash;

0.9 – coefficient of conversion of sugar into starch.

The total number of yeast cells in 1 cm was determined by direct counting in the counting chamber. The CO<sub>2</sub> content was determined by the weight method [22].

The yield of alcohol from 1 tonne of standard starch, dal/t, was calculated from the formula [23]:

$$Y_a = \frac{C_{s.c.}(Y_{st} + \Delta Ya)}{100}$$

$Y_a$  – yield of alcohol from the tone of conventional starch, dal/t;

$Y_{st}$  – standard yield of alcohol, dal/t;

$C_{s.c.}$  – starch content, %;

$\Delta Ya$  – difference between the theoretical and actual yield of alcohol, dal/t.

The results of the 3 series of experiments were statistically processed by calculating the arithmetic mean of 5 measurements, their standard deviations, and errors. Student’s criterion was used to determine the probable differences between the means. Differences were considered statistically significant at  $p \leq 0.05$ .

### Results of the research and their discussion

Since ethanol production involves using cereal crops with different starch contents and differing significantly in their chemical composition, the maximum possible DM (dry matter) concentrations in the wort were determined depending on the type of grain raw material, with the yield of alcohol meeting the standard.

Table 1 shows the results of studying the fermentation of wort of different concentrations obtained from maize at 35/30±1°C. The data presented make it clear that during the fermentation of wort with the concentration 17, 20, and 26% of dry matter, the main parameters of the fermented washes were at the prescribed levels [24]. With the DM concentration of wort increased to 28 and 30%, the degree of fermentation of starch hydrolysis products decreased. Thus, the content of fermentable carbohydrates increased from 0.449 to 0.590–0.780 g/100 cm<sup>3</sup>, and that of undissolved starch from 0.10 to 0.12 g/100 cm<sup>3</sup> of wash. Increased concentrations of the wort led to an increase in the content of alcohol in the fermented washes, but at the concentration 30% of DM, its yield from 1 tonne of standard starch was lower by 0.2 dal/t.

Hydrolysis of wheat and rye grain components for highly concentrated wort poses a number of technological difficulties due to the peculiarities of their chemical composition. During thermoenzymatic processing, there was a significant increase in the viscosity of the grain mashes obtained, which significantly affected the course of hydrolytic processes when making the wort. Tables 2 and 3 show the parameters of fermented washes obtained during fermentation of the wheat and rye wort at 35/30±1°C.

As can be seen from Tables 1–3, at the same DM concentration of the wort, the amount of alcohol found in the wash during maize fermentation was higher than it was in the wash obtained as a result of fermentation of the wheat and rye wort.

**Table 1 – Technological parameters of fermented wash during fermentation of maize wort**

Concentration of the wort, % of dry matter	$\Sigma\text{CO}_2$ , g/200 cm <sup>3</sup>	pH of the wort, units	Carbohydrate content, g/100 cm <sup>3</sup>		Concentration of ethanol, % vol.	Yeast concentration, million/cm <sup>3</sup>	Alcohol yield from 1 tonne of standard starch, dal
			unfermented carbohydrates	undissolved starch			
17±0.2	13.45±0.63	4.80±0.22	0.120±0.006	0.08±0.004	8.90±0.002	175±8.71	66.60±3.25
20±0.2	16.05±0.78	4.95±0.24	0.229±0.011	0.09±0.004	10.65±0.001	224±10.90	66.61±3.24
26±0.2	20.26±0.96	4.95±0.21	0.449±0.022	0.10±0.005	13.45±0.002	298±14.30	66.60±3.23
27±0.2	21.13±1.05	4.98±0.23	0.497±0.024	0.11±0.005	14.71±0.003	306±15.20	66.60±3.24
28±0.2	22.45±1.02	5.00±0.24	0.590±0.029	0.12±0.005	14.91±0.003	313±15.53	66.60±3.21
30±0.2	23.56±1.05	4.98±0.25	0.780±0.039	0.12±0.006	15.65±0.003	320±15.80	66.40±3.12

**Table 2 – Technological parameters of fermented wash during fermentation of wheat wort**

Concentration of the wort, % of dry matter	$\Sigma\text{CO}_2$ , g/200 cm <sup>3</sup>	pH of the wort, units	Carbohydrate content, g/100 cm <sup>3</sup>		Concentration of ethanol, % vol.	Yeast concentration, million/cm <sup>3</sup>	Alcohol yield from 1 tonne of standard starch, dal
			unfermented carbohydrates	undissolved starch			
17.0±0.2	12.85±0.62	4.30±0.21	0.210±0.010	0.07±0.003	8.60±0.002	185±9.25	66.60±3.21
19.8±0.2	15.18±0.71	4.27±0.20	0.300±0.013	0.07±0.003	10.03±0.003	296±14.80	66.58±3.18
23.5±0.2	18.05±0.86	4.38±0.21	0.313±0.211	0.09±0.004	11.98±0.002	271±13.55	66.50±3.12
25.2±0.2	19.50±0.94	4.46±0.22	0.429±0.213	0.10±0.005	12.95±0.001	258±12.9	66.49±3.08
27.0±0.2	21.23±1.02	4.51±0.22	0.673±0.029	0.28±0.014	14.10±0.003	313±15.65	66.40±3.02

**Table 3 – Technological parameters of fermented wash during fermentation of rye wort**

Concentration of the wort, % of dry matter	$\Sigma\text{CO}_2$ , g/200 cm <sup>3</sup>	pH of the wort, units	Carbohydrate content, g/100 cm <sup>3</sup>		Concentration of ethanol, % vol.	Yeast concentration, million/cm <sup>3</sup>	Alcohol yield from 1 tonne of standard starch, dal
			unfermented carbohydrates	undissolved starch			
17.0±0.2	12.58±0.61	4.50±0.21	0.300±0.014	0.10±0.005	8.30±0.001	200±9.00	65.60±3.21
20.0±0.2	14.89±0.72	4.55±0.22	0.567±0.024	0.10±0.004	9.85±0.001	299±14.91	65.50±3.22
21.8±0.2	17.41±0.83	4.65±0.23	0.602±0.030	0.14±0.006	11.56±0.002	233±11.52	65.50±3.19
22.2±0.2	18.82±0.91	4.63±0.24	0.977±0.042	0.24±0.011	12.50±0.002	229±11.42	65.45±3.04
24.0±0.2	19.55±0.93	4.64±0.24	1.270±0.051	0.27±0.012	13.00±0.003	218±10.80	65.10±3.01

Increasing the DM concentration of wort from maize (up to 30%) makes it possible to obtain wash with the alcohol concentration 15.65% vol., of that from wheat (up to 27%) – 14.10% vol., of that from rye (up to 24%) – 13.00% vol. ethanol. With the standard alcohol yield from 1 tonne of standard starch, the maximum alcohol content in the maize wash was 14.91% vol., while in the wheat wash, it was 14.1, and in the rye wash, 13.0% vol.

At the next stage, the rational temperature conditions of fermentation of highly concentrated wort from maize grain were determined. At distilleries, cooking of grain mashes from starch-containing raw materials is carried out with the use of concentrated EP of various selective action. This scheme has a number of advantages over the high-temperature one, but does not always ensure the microbiological purity of the wort: it accelerates the development of contaminating microflora in the saccharifier, which further adversely affects the fermentation process. Saccharifying the

rarefied grain mash directly in the fermenter allows avoiding these negative factors. But hydrolysis of dextrans in the fermenter requires developing rational technological parameters for the fermentation process.

To this end, studies have been conducted to determine the optimal temperature of fermenting highly concentrated wort by the yeast race *Saccharomyces cerevisiae* DO-16. To ferment the wort, milled maize grain with the starch content 69.0±0.1% was used. The wort concentrations were 28 and 32% of DM. The wort was fermented at 30, 32, 35, and 37°C. Industrial yeast was added in the amount 40 million/cm<sup>3</sup> wort.

As can be seen from Table 4 (samples 2, 3, 6, 7), during the fermentation of the wort at 32 and 35°C, the concentration of alcohol in the fermented wash was the highest: 14.65, 14.60% vol. and 15.42, 15.67% vol.

On analysing the experimental data, it was decided to study the process of wort fermentation in two stages.

**Table 4 – Chemical and technological parameters of the fermented wash depending on the fermentation temperature**

DM concentration of the wort, %	Temperature, °C	$\Sigma\text{CO}_2$ , g/200 cm <sup>3</sup>	Carbohydrate content, g/100 cm <sup>3</sup>		Concentration of ethanol, % vol.
			unfermented carbohydrates	undissolved starch	
28±0.2	30±1	21.76±1.08	0.46±0.021	0.040±0.002	14.52±0.001
28±0.2	32±1	22.05±1.10	0.32±0.140	0.090±0.003	14.65±0.001
28±0.2	35±1	22.01±1.09	0.39±0.018	0.095±0.004	14.60±0.002
28±0.2	37±1	21.69±1.08	0.61±0.029	0.095±0.003	14.42±0.001
32±0.2	30±1	22.81±1.12	0.71±0.31	0.095±0.003	15.15±0.003
32±0.2	32±1	23.23±1.16	0.59±0.023	0.090±0.002	15.42±0.001
32±0.2	35±1	23.60±1.32	0.59±0.025	0.092±0.002	15.67±0.001
32±0.2	37±1	22.55±1.11	0.72±0.032	0.100±0.004	15.00±0.002
28±0.2	35/30±1	22.28±1.09	0.32±0.012	0.089±0.003	14.77±0.002
32±0.2	35/30±1	24.10±1.19	0.48±0.021	0.089±0.003	16.00±0.003

At the first stage (24 hours). fermentation was performed at 35°C, and at the second (48 hours), it was performed at 30°C. Under these fermentation conditions, more ethanol accumulated in the wash, its content was 14.77–16.0% vol. depending on the wort concentration, and the content of fermented carbohydrates decreased by 7–15% relative to the temperature values.

Thus, the stage-by-stage fermentation of wort (at the temperatures 35 and 30°C) creates conditions for additional saccharification of dextrans of the wort and its effective end-fermentation. Therefore, this technique is especially effective in the fermentation of high-concentration wort.

To validate the results of the theoretical and laboratory studies, the technology of highly concentrated alcohol wash from grain raw materials has been tested in the conditions of alcohol production at the company TOV FAZOR (capacity 6000 dal of alcohol-containing liquids a day). For the manufacturing testing, technological guidelines were developed and approved according to the due procedure.

The process flow includes the following main stages (Fig. 1):

- cleaning and preparation of the raw materials;
- thermoenzymatic processing of highly concentrated mashes of the grain raw materials;
- dilution of the cooked mass with thermostable  $\alpha$ -amylase *Amylex 4T* at 85–92°C. The enzyme preparation was added in the amount 0.4 units AA/g of starch for the wort concentration 18%, and 0.8 units AA/g of starch for 25–30%;
- saccharification of the diluted mass with the enzyme preparation glucoamylase *Diazym TGA* (7.5 units GA/g of starch regardless of the concentration of the wort);
- hydrolysis of non-starch polysaccharides and protein with the enzyme preparations: *Laminex 750* (source of the cytolytic enzyme) – 0.35 units CA/g of raw materials, *Alphalase AFP* (source of the proteolytic enzyme) – 0.05 units PrA/g of raw materials;
- wort fermentation with osmophilic thermotolerant

yeast of the race *Saccharomyces cerevisiae* DO-16. The yeast inoculum was introduced in the proportion 20 million/cm<sup>3</sup> of wort, depending on the wort concentration. Urea for the culturing of industrial yeast was added in the proportion 800 g/m<sup>3</sup>. Fermentation was carried out at the appropriate temperatures in two stages: the first (24 hours) at 35°C, the second (48 hours) at 30°C.

Summarising the research results has allowed developing a basic process flow scheme of preparing highly concentrated washes from grain raw materials.

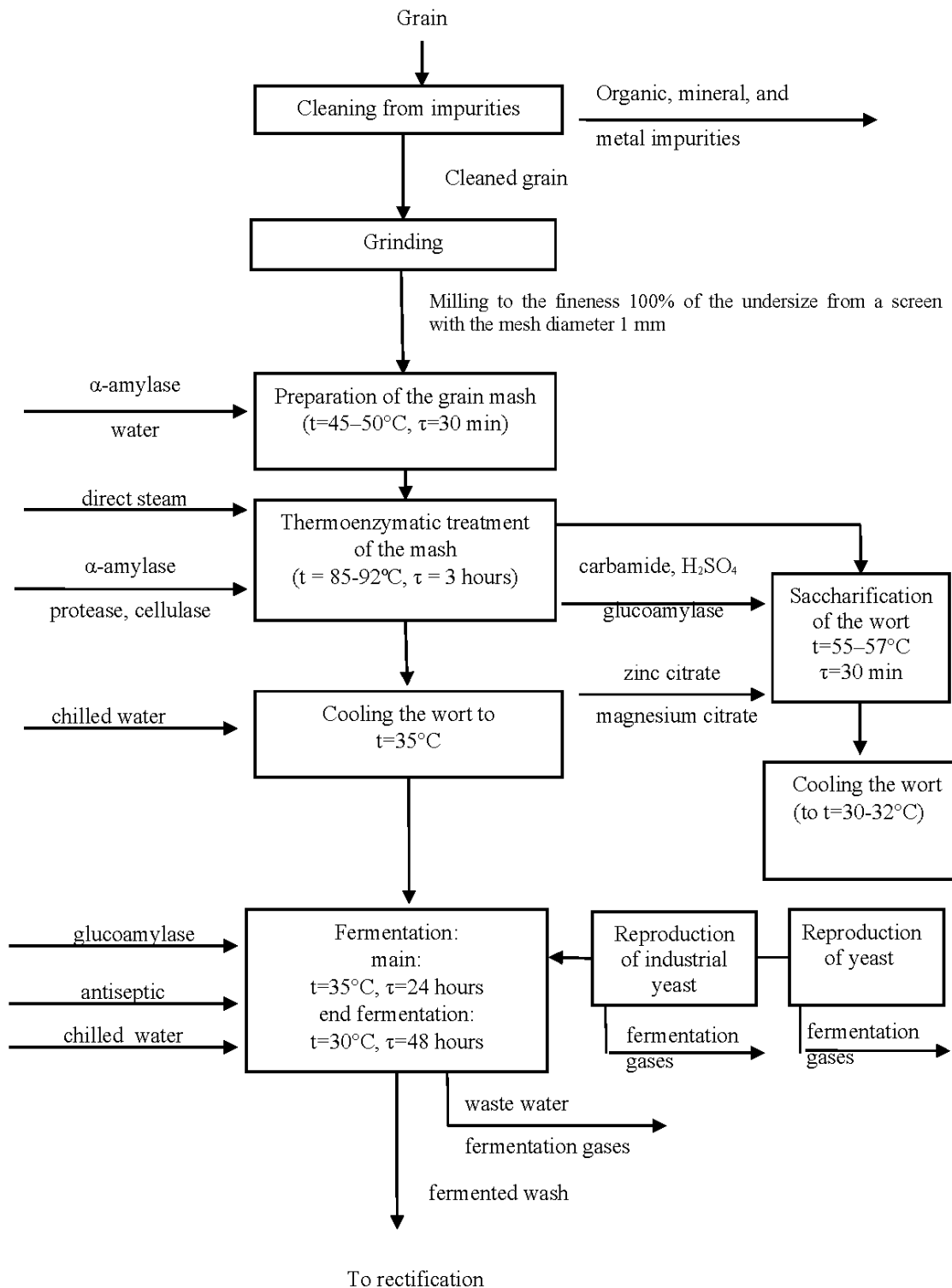
The introduction of intensive energy-saving and waste-free technologies in the country's economy, rational and efficient use of the bioresource potential will require implementing a set of technical and technological measures.

The introduction of the suggested technological methods of fermentation of high-concentration wort will significantly increase the productivity of the fermentation department due to increasing the ethanol concentration in fermented wash, as compared with the classic technology, to 15.65% vol. ethanol (maize wort), 14.10% vol. (wheat wort), and 13.00% vol. (rye wort).

The technology developed, when applied, will reduce the consumption of water spent to maintain the optimal fermentation temperature, and that of steam needed to isolate alcohol from the wash. Besides, it will allow reducing the post-alcohol stillage formed and the production cost of finished products.

The positive factors in the production and use of bioethanol include improving the environment and reducing the harmful effects that exhaust gases produce on the human body. Bioethanol use as an addition agent can increase the octane number of fuel and, accordingly, the efficiency of an engine.

The threat of depletion of non-renewable energy sources is another factor that makes it necessary to improve the biofuel production technology and develop of resource-saving and energy-efficient technologies.



**Fig. 1. Process flow chart of the preparation of highly concentrated wash from starch-containing raw materials for bioethanol production**

### Conclusion

Based on the theoretical and experimental research, a resource-saving and energy-efficient technology of highly concentrated washes from starch-containing raw materials has been developed and

introduced into production. Rational parameters of fermentation of highly concentrated wort by a yeast race bred by artificial selection have been developed.

It has been found that when fermenting high-concentration wort, with the standard yield of alcohol from 1 tonne of standard starch, the maximum alcohol

concentration, depending on the raw material, was as follows: in the maize wash, 14.91% vol., in the wheat wash, 14.1% vol., and in the rye wash, 13.0% vol.

To intensify alcohol fermentation, highly concentrated wort should be fermented at appropriate temperatures: 35°C at the first stage (24 hours) and 30°C at the second (48 hours) stage. This will also contribute to fuller (by 20–30%) conversion of

carbohydrates, which will result in an increased concentration of ethanol in the wash.

Industrial tests of the newly developed resource-saving and energy-efficient technology at the enterprise *TOV FAZOR* (Kozhanka, Fastiv District, Kyiv Region) have confirmed the results of the laboratory tests.

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## РЕСУРСО- ТА ЕНЕРГОЗБЕРІГАЮЧА ТЕХНОЛОГІЯ ЗБРОДЖУВАННЯ СУСЛА ІЗ КРОХМАЛЕВМІСНОЇ СИРОВИНИ ДЛЯ ВИРОБНИЦТВА БІОЕТАНОЛУ

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**Анотація.** В умовах ринкової економіки нагальним завданням спиртової промисловості є зниження собівартості товарної продукції за рахунок створення та впровадження інноваційних енерго- та ресурсозберігаючих технологій. Актуальним у даному аспекті є розроблення технології збродження сусла високих концентрацій із зернової сировини із використанням нових високопродуктивних рас спиртових дріжджів. Для збродження використовували сусло з різних видів зернової сировини, а саме, кукурудзи, жита, пшениці. Досліджено, що збільшення концентрації сухих речовин сусла з кукурудзи (до 30%) дає можливість отримати бражку з концентрацією спирту 15,65% об., пшениці (до 27%) – 14,10% об., жита (до 24%) – 13,00% об. етанолу. За умови забезпечення нормативного виходу спирту із 1 т умовного крохмалю максимальний вміст спирту в бражці із кукурудзи становив 14,91% об., тоді як із пшениці – 14,1% об., а із жита – 13,0% об. Досліджено вплив температури збродження сусла високих концентрацій на хіміко-технологічні показники зрілої бражки із кукурудзи. Встановлено, що проведення постадійного збродження зернового сусла з кукурудзи (при температурах 35 та 30°C) створює умови для дооцукрювання декстринів сусла та його ефективного добродження. Отже, такий прийом є особливо дієвим при збродженні сусла високих концентрацій. Впровадження розробленої технології сприятиме ефективній переробці сільськогосподарської сировини на спирт, зниженню утворення відходів виробництва – післяспиртової барди. Для підтвердження результатів теоретичних та лабораторних досліджень було здійснено випробування технології висококонцентрованої спиртової бражки із зернової сировини в умовах спиртового виробництва ТОВ «ФАЗОР» смт. Кожанка, Фастівський район, Київська область (потужність 6000 дал/добу спиртовмісних рідин). Для проведення виробничих випробувань була розроблена та затверджена у відповідному порядку технологічна інструкція.

**Ключові слова:** сусло високої концентрації, біоетанол, збродження, осмофільні спиртові дріжджі, *Saccharomyces cerevisiae*, бражка.