ANIMAL SCIENCE AND FOOD TECHNOLOGY

Journal homepage: https://animalscience.com.ua/en
Animal Science and Food Technology, 15(1), 55-73
Received 06.11.2023 Revised 26.01.2024 Accepted 28.02.2024

UDC 663.44
DOI: 10.31548/animal.1.2024.55

Use of unmalted cereals with enzyme preparations in brewing

Sergii Loiko
Postgraduate Student
National University of Food Technologies
01033, 68 Volodymyrska Str., Kyiv, Ukraine
https://orcid.org/0009-0003-5853-6836

Zoriana Romanova
PhD in Technical Sciences, Associate Professor
National University of Food Technologies
01033, 68 Volodymyrska Str., Kyiv, Ukraine
https://orcid.org/0000-0003-3974-5758

Marija Zheplinska*
PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-7286-3003

Mykola Romanov
PhD in Technical Sciences, Associate Professor
National University of Food Technologies
01033, 68 Volodymyrska Str., Kyiv, Ukraine
https://orcid.org/0000-0002-0063-819X

Volodymyr Vasyliv
PhD in Technical Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-2109-0522

Suggested Citation:
Loiko, S., Romanova, Z., Zheplinska, M., Romanov, M., & Vasyliv, V. (2024). Use of unmalted cereals with enzyme preparations in brewing. *Animal Science and Food Technology*, 15(1), 55-73. doi: 10.31548/animal.1.2024.55.

**Corresponding author*

Abstract. The use of unmalted grain is one of the methods for improving quality, reducing production costs, and creating new types of beer. However, the enzymatic activity of such raw materials is zero, so the use of enzyme preparations is relevant. The purpose of the study was to compare the quality indicators of 100% malt beer and beer with the replacement of malt with unmalted barley using enzymes. Methods of technical and chemical analysis were used to determine the organoleptic and physico-chemical parameters of beer. Recommendations have been developed for intensifying the preparation of wort using various types of grain raw materials – unmalted barley and rice grits with the addition of enzyme preparations from Novozymes (Denmark) at different stages of brewing were developed. When testing new enzyme preparations (β-glucanase complex, xylanase), the filtration time, wort viscosity, and the content of β-glucans and arabinoxylans decreased by about 20% compared to the control samples. The use of a new enzyme preparation resulted in better breakdown of substances, which affected the quality and duration of filtration. This leads to an improvement of wort quality, reducing the duration of the process and reducing the cost of raw materials. To ensure the required ratio of substances in the wort, it is necessary to introduce complex enzyme preparations – peptidhydrolase, α-amylase, endo-β-glucanase (Ceremis Plus). Preparations containing endo-β-glucanase (Ultraflo Max) should be used at the beginning of mashing to improve the rheological properties of the wort and reduce its viscosity, which improves the filtration process. To obtain beer with the required degree of fermentation during mashing, it is better to use new enzyme preparations (glucoamylase). The practical significance of the study lies in the use of large amounts of unmalted grain together with exoenzymes such as Ultraflo Max and Ceremis Plus, which will allow brewers to produce wort and beer of the same composition and quality as premium wort and beer, using only malt

Keywords: barley; beer; wort; malt; quality

Introduction

Barley is a traditional raw material for beer production. To turn barley grains into fermented wort, enzymes are needed to break down cell walls, release amino acids, and break down starch into fermented sugar. For brewing with a very small amount of malt, barley is a very good choice to replace some of the malt, as it has some special features. Firstly, barley contains β-amylase and peptidase. Secondly, it can be added to the mash, since barley starch has a low gelatinisation temperature. Thirdly, it has a husk that ensures good filtration in the lauter tank when properly crushed (Zamai *et al.,* 2022). The researchers used the replacement of 30% corn and 70% malt with 30% corn grits, 35% barley and 35% malt, and proved that it is possible to produce high-quality beer. However, there is a need to use exoenzymes (Park *et al.*, 2023).

According to G. Birta *et al.* (2021) found that the use of corn grits in brewing allowed to increase the quality indicators and dietary value of beer, and the optimal value of corn grits content ranges from 15 to 20%. A. Fujita *et al.* (2020) proved that single-grain, emmer or spelt grains can be used to make malt of acceptable quality and produce craft beer with a specific taste and aroma. Researchers have investigated the brewing potential of 100% unmalted barley, wheat, oats, and rye compared to 100% malt and proved that in this way, along with the use of enzyme preparations, it is possible to reduce the level of colour, the content of higher alcohols and esters in the finished beer. Results of the study by A. Dabija *et al.* (2021) showed that buckwheat can be used as a raw material for the production of gluten-free beer.

M.E. Ciocan *et al.* (2023) suggested using malted and unmalted sorghum instead of traditional barley malt, which included 60% sorghum malt and 40% unmalted sorghum. N. Cela *et al.* (2022) investigated the combined effect of the composition of sorghum:quinoa and at a ratio of 6 and 34% unmalted sorghum and quinoa, respectively, it was found that the use of unmalted sorghum and quinoa in an optimised combination in brewing allows the development of beer brewed from unconventional grains, without negative impact on consumer perception.

Ukrainian researchers also used unmalted materials to replace some of the malt during brewing. Thus, the analysis of the results obtained by S.P. Orel (2021) indicates the possibility of replacing malt with 20% spring and winter barley, while wort quality indicators decrease, but remain within the normal range. When replacing malt in the amount of 20% spring barley, such qualitative indicators of wort as extractivity, amine nitrogen, reducing substances are slightly higher than when replacing 20% with winter barley. When replacing malt with 25% barley, when using Termamil enzyme preparation in the amount of 0.6 kg/t of barley, a significant increase in the quality indicators of wort was observed. The researcher established that the optimal dose of malt replacement with rye (without the use of enzyme preparations) is 10%. S. Loiko & Z. Romanova (2018) in their research replaced 25% of malt with unmalted barley using the Tetramil enzyme in the amount of 0.15 kg/t of barley and proved by technological indicators the possibility of obtaining high-quality beer using external enzymes and unmalted barley.

According to L.M. Puzik (2019), the main quality indicators of spring barley grain for use in brewing in the first months of its storage under an unregulated temperature regime are intensively improved compared to its storage under a regulated temperature regime. The researcher claims that it is advisable to store spring barley grain with humidity within critical and with good initial quality Indicators in storage facilities for no more than 9 months, with a longer shelf life, such grain should be stored under a controlled temperature regime. Post-harvest grain ripening of brewing spring barley varieties is more intensive under unregulated conditions. Nevertheless, the best preservation of the technological qualities of grain of brewing varieties of spring barley is ensured by its storage in a controlled temperature regime.

The exergy performance of beer produced using the traditional malt and brewing process is compared with that of beer produced using the fermentation process. Therefore, the purpose of the study was to compare the quality indicators of 100% malt beer and beer with the replacement of malt with unmalted barley and rice grits with the additional use of Ondea Pro enzyme preparation from the Danish company Novozymes.

Literature Review

While beer was produced using various types of unmalted grain as excipients along with malt, brewing from 100% unmalted grain combined with the addition of mashing enzymes remains largely unknown. Barley, as one of the oldest crops, has great potential to regain its role as a food grain, mainly due to its high nutritional value. W. Kunze (2004) proved that barley's food enzymes, in particular lipase, amylase, and protease, stimulate the breakdown of proteins, fats, and carbohydrates.

As noted by J. Mallett (2014) in the textbook on malt theory, barley is the most suitable cereal for malting in terms of the composition of extractives before fermentation. The main varieties are those that contain a lot of starch and a small amount of protein, which leads to a better yield of extractives. According to F. Guzmán-Ortiz (2019), malt production has provided suitable conditions for the production of various brewing varieties of malt from Doña Josefa barley. Malt had total and reduced sugar values that correspond to brewing. The researcher found that temperature and soaking time are determining factors for the time of enzyme activation. At higher temperatures, enzymatic activation is usually faster, but there are some exceptions. The use of germination can be a promising resource for modifying grain properties and increasing enzymatic activity.

H. Gupta *et al.* (2020) noted that the presence of non-starchy polysaccharides in barley in the form of mixed bonds (1-3), (1-4)-β-d-glucans and arabinoxylans together with enzymes is responsible for its modification. Malt production is a rather complex process that involves important enzymes such as α-amylase, β-amylase, α-glucosidase, and limit-dextrinase. During the malting and brewing process, the by-products left over from wort separation are rich in protein, fibre, arabinoxylanes, and β-glucans. Therefore, the researchers point out the feasibility of using by-products and summarise the properties of barley in relation to the nutritional, functional, and compositional changes that occur during malting and brewing.

F. Nocente *et al.* (2023) showed that fermented beverages made from single-grain, tritordeum, edible sorghum, and teff may be of interest for light and gluten-free beer markets. L. Van Donkelaar *et al.* (2019) found beer produced with added enzymes reduced the use of water, raw materials, and natural gas by 7, 14, and 78%, respectively. In this case, the loss of exergy in the enzyme production process is compensated by preventing the loss of exergy in the overall brewing process. M. Salailenbi *et al.* (2019) used a mixed dough fermentation culture from Khamei dough to produce beer from black rice, which increased the shelf life of the beer and lowered its alcohol content.

The use of enzyme preparations can be carried out with any amount of barley to produce high-quality beer. Therefore, the desired taste is obtained according to the developed brewing recipe or by blending beer, which is confirmed by the results of H. Kábelová-Ficová *et al.* (2018). It was these authors who proved that the highest level of fermentation, which corresponds to 61.7%, is inherent in beer made from spring barley. To confirm the quality of beer, an organoleptic assessment was carried out, which corresponded to the originality of the beer sample.

The use of enzyme preparations can increase the stability of beer and improve its consumer characteristics along with improving the filtration process. Zh. Zamai *et al.* (2022) experimentally investigated and substantiated the possibility of using enzyme preparations available on the market to optimise the filtration process of craft beer. The use of enzyme preparations helps to speed up the technological cycle of production and to obtain finished products with high indicators of colloidal resistance. The effect of the enzyme preparations Laminex® MAX Flow 4G, Amylex 5T, Beerzym® AMYL HT, Beerzym® BG, EnerZyme® P7 on the wort filtration process was studied and evaluated by determining the content of extractives in beer pellets at the premises of the "Bierwelle" brewery.

According to sources (Sustainable brewing starts…, n.d.), beer is produced with standard brewing equipment using a standard mashing profile and time. Ondea Pro enzyme preparation is also particularly suitable for the production of flavoured beer or any type of soft grain beverages, and for the production of extracts from unmalted grains. Standard technological instructions for beer production provide for the use of established modes of brewing beer wort. However, the modern operating conditions of breweries of any capacity require intensification of production processes, which is impossible using old technological methods. One of these techniques, as noted by M. Zheplinska *et al.* (2022a), may be the use of enzyme preparations. There are currently no universal recommendations for the effective operation of the brewery shop. This indicates that there is a need to develop an intensive technology of high-quality beer wort, adapted to the processing of various raw materials using exogenous enzymes, which can replace a certain amount of malt with unmalted material in the form of rice or barley and obtain the wort and finished product – high-quality beer using the method of optimising beer fermentation. This was the issue addressed by A. Rodman & D.I. Gerogiorgis (2021), who found that to accelerate the fermentation process and reduce its duration, it is necessary to optimise it through dynamic modelling.

Materials and Methods

Barley malt, unmalted barley and rice grits were used for the study. Danish enzymes Novozymes Ondea Pro were used to replace some of the barley malt with unmalted barley or rice grits in order to provide effective viscosity, turbidity reduction, and protein degradation. The enzymes work in synergy with endogenous barley enzymes to produce fermented wort. In combination with endogenous barley proteases and β-amylases, Ondea Pro enzymes create a synergistic effect to achieve the best brewing results. The study used enzyme preparations containing the same enzymes as brewing barley malt. The research was conducted in the laboratories of the National University of Food Technologies and the National University of Life and Environmental Sciences of Ukraine.

The physico-chemical parameters of wort and finished beer were determined using a PBA-B generation M beer analyser (Anton Paar, Austria). Physical and chemical parameters (moisture, fat, protein, colour, acidity, amine nitrogen, coagulation nitrogen, pH values, polyphenols and reducing sugars) were determined by standard methods in accordance with DSTU 7103:2009 (2016); DSTU 3888:2015 (2017). Dynamic viscosity was determined using the Hepler device according to the method provided by D. Kumar *et al.* (2017). Determination of organoleptic parameters was carried out in accordance with DSTU 7103:2020 (2023). Barley and rice were crushed on a hammer mill (with adjusted power consumption), which allowed for perfect filtration of the mash. For better roll grinding, barley of uniform size with a particle diameter of more than 2.2 mm was used.

The mashing mode corresponded to a temperature of 53°C for a duration of 15-30 minutes to prevent grain deposition and ensure good enzyme efficiency (Zheplinska *et al.,* 2022b). The saccharification time did not exceed 64°C to maintain the productivity of heat-sensitive barley β-amylase. The pH value of barley grits did not decrease below 5.6 units. The wort was acidified to a pH of 5.2 during boiling to maintain a drop in the pH value during fermentation to the beer pH value of 4.5. The quality of wort and beer obtained from 100% malt with the replacement of 11% malt with rice and 14% malt with barley was investigated. Pre-filling processes were carried out at 50-52°C and at 37-39°C. The main mash was kept at 52 and 63°C for 15 and 40 minutes, respectively, and the total mash was kept for 15 minutes at 72°C until it was completely saccharified, heated to 78°C, and filtered. Pre-mashing processes were carried out at temperatures of 50-52°C, which corresponds to the modes (1.1, 2.1, 3.1) and at 37-39°C (modes 2.2, 2.3, 3.2, 3.3, which are given in the Section "Results and Discussion"). The main mash was kept at 52 and 63°C for 15 and 40 minutes, respectively, and the total mash was kept for 15 minutes at 72°C until completely cooled. The mash was then heated to 78°C and filtered.

Application rates of exogenous enzyme preparations: α-amylase – ≈100 g/t; α-glucanase+xylanase complex – ≈100 g/t. Ultraflo Max was used to accelerate the mash filtration, having previously determined its rational dosage. 100% malt mash was prepared according to mode 1.1 with standard pauses (mash 50, pauses 52, 63, and 72°C). During wort filtration for 10 brews, the filtration time was recorded and the wort viscosity, β-glucan and arabinoxylane content were determined with and without using the Ultraflo Max enzyme according to the classical brewing scheme. Statistical analysis data were obtained using Microsoft Excel and Statistica 15 software suites. All experiments were conducted in 5 replicates, and the results are averages of these replicates with standard deviations. The Student's t-test was used for statistical processing of the results obtained. The data are presented as the mean ± standard deviation from the mean (SDM). The smallest acceptable difference for probes from a single sample is indicated at 5%. The confidence value was chosen as $p<0.05$.

Results and Discussion

A study was conducted on the production of beer with the replacement of part of the barley malt with unmalted barley and rice grits using Novozymes preparations. The research data covers the entire process from raw material processing to the production of finished beer and the obtaining of physicochemical and organoleptic parameters that comply with the DSTU for beer.

Table 1 shows the indicators of grain raw materials, namely, barley malt, barley and rice grits, which were used in the manufacture of beer. Indicators of barley and rice grits as solid raw materials are represented by the mass fraction of moisture, extract, fat, and protein.

Table 1. *Indicators of grain raw materials*

Values	Raw material		
	Barley malt	**Barley grits**	**Rice grits**
Number of grains (%): flouriness	85.0±0.5 3.0±0.1	- -	- -
Mass fraction of moisture (%)	4.5±0.05	14.5±0.05	13.2±0.05
Mass fraction of the extract in the dry matter of finely ground malt (%)	77.8±0.07	63.6±0.06	82.2±0.06
Mass fraction of fat (%)	1.8± 0.01	2.0± 0.02	1.1± 0.01
Difference in the mass fractions of extracts in the dry matter of fine and coarse malt (%)	1.4±0.01	-	-
Mass fraction of protein substances (%)	10.1±0.02	10.9±0.02	7.6±0.03
Duration of saccharification (min.)	15	-	-
Colour (chromaticity units)	0.18±0.005	-	-
Acidity (units)	0.9±0.02	-	-
Amine nitrogen (mg/dm^3)	4.6±0.1	-	-
Viscosity (mm^2/cwt)	1.58±0.02	-	-

Source: compiled by the authors

As can be seen from Table 1, the moisture content of barley and rice grits differs by only 1.3%, but a significant difference in these two solids is observed in the mass fraction of the extract in the dry matter. Thus, for rice grits, this value was 18.6% higher than for barley grits, but barley grits have a higher amount of fat and protein. Therefore, the results obtained for the above indicators allow conducting experiments with such types of unmalted grain, replacing them with barley malt, for which the results obtained for determining the number of grains, flouriness, saccharification time, colour, acidity, amine nitrogen content, and viscosity correspond to DSTU 4282:2018 (2019). Table 1 indicators show a well-ground dispersion of raw materials, which predicts enzymatic hydrolysis to values acceptable for obtaining an optimal extract. The mass fraction of protein substances does not exceed 11%, which predicts the production of wort with an optimal nitrogen composition. Research conducted by Z.M. Romanova *et al*. (2021) confirmed the optimal nitrogen composition by automatic control of the brewing process, which considers the features of the chemical composition of raw materials, the structure and quality of auxiliary materials. The researchers proved that the development and implementation of modern software with its practical use in the preparation of existing and new types of beer will contribute to further intensification of brewing, which is of great importance in the context of compliance with high quality standards for hop beverages.

The optimal effect of drugs and the influence of various factors on their stability have been studied and confirmed, because in general, the quality of beer depends on many factors, such as the chemical composition, physico-chemical characteristics of the wort, the type of beer, the degree of fermentation, etc. The results of the study of the optimal action and activity of enzyme preparations are presented in Table 2.

Table 2. *Characteristics of enzyme preparations*

Enzyme preparation	Manufacturer	Active substance	Optimal conditions actions	
			temperature (°C)	pH value
Ultraflo Max	Humicola insolens	cellulase	70.0±5	5.0±0.5
Ceremix Plus	Bacillus amuliquefacien	α-amylase Endo-®-glucanase endoproteases	70.0±2 50.0±2 45.0±2	5.5±0.1 7.0±0.1 6.0±0.1
Neutraz 0.5 L	Bacillum amynoliquefaciens	neutral protease	40.0±2	6.0±0.1
Attenuzim Pro	Asperglus niger	glucoamylase	60.0±2	4.3±0.1

Source: compiled by the authors

Based on the results obtained in Table 2, it can be seen that the first two enzyme preparations Ultraflo Max and Ceremix Plus are best suited for use in brewing, with the optimum effect on unmalted raw materials at 70°C. In addition, these enzyme preparations are active in an environment with a pH value from 5.0 to 5.6 units, which is exactly what is necessary for the mashing process. I. Zeida (2023) investigated and substantiated the possibility of using enzyme preparations available on the market to optimise the beer preparation process. The use of enzyme preparations helps to speed up the technological cycle of production, to obtain finished products with high indicators of biological and colloidal resistance. The effect of Laminex® MAX Flow 4G, Amylex 5T, Beerzym® AMYL HT, Beerzym® BG, EnerZyme® P7 enzyme preparations on the brewing of beer wort and finished beer was investigated and evaluated.

In the course of the study, it was found out that the use of Hytemphase EP in the mashing process can increase the content of extractives and maltose in the wort, reduce its viscosity, and therefore, improve the quality of beer, reduce the duration of filtration, speed up the fermentation of beer wort, and control its composition. Due to its high thermal stability, the enzyme preparation under study allows carrying out the mashing process at high temperatures, while malt's own enzymes can already be inactivated.

Proteolytic components work in synergy with endogenous barley enzymes. The generation free amino nitrogen compounds (FAN) is directly related to the protein content of the grain. According to an online source (Features of growing..., n.d.), the use of high protein barley can have some negative effects, as barley is naturally high in protein, and high protein levels can affect the enzymatic processes during brewing. This can lead to less efficient breakdown of starch and other components of barley, which affects the quality of beer. A high protein content can also lead to the formation of bilge substances during brewing. This leads to a darkening of the beer and an unpleasant taste. Protein can increase the viscosity of the wort, which can complicate the filtration and separation of wort from the waste. A high protein content can lead to more waste during filtration, which can be inefficient from a production standpoint. In general, brewers choose barley with the appropriate protein content to ensure beer quality and optimal conditions for enzymatic processes. High protein content may be undesirable if its effects on beer production are not controlled.

Figure 1 shows the dependence of FAN content on protein content in barley grain. Using barley with a high protein content can be an advantage when brewing using Ondea Pro enzymes. The amine-nitrogen compounds in barley wort are more easily absorbed by yeast, so barley wort requires only 9-12 mg FAN/L/°P to ensure good fermentation.

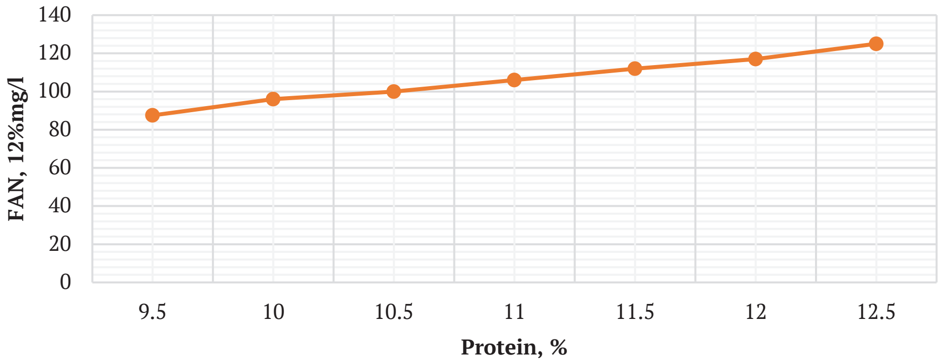

Figure 1. Dependence of FAN on grain protein content

Source: compiled by the authors

T. Pryimachuk *et al.* (2018) note that the quality of beer is largely determined by the characteristics of wort, which depend on the indicators of raw materials, which is why the beer and hop markets are interconnected and respond to economic (prices, purchasing power) and technological (change of equipment, overproduction) indicators. I. Mascia *et al.* (2019) point out the need to use appropriate mashing modes and the ratio of the main components to ensure good physico-chemical and organoleptic characteristics of the finished beer. It is impossible to brew high-quality beer without the appropriate equipment for grinding grain products, mashing them, and filtering them. According to (The brewing equipment..., 2022), due to well-chosen equipment, it is possible to control the degree of grinding, which is used to grind the grains for brewing different types of beer. Therefore, it is important to investigate the effective mashing mode, which was carried out based on composition of raw materials, their ratios and parameters given in Table 3.

Table 3. *Mash composition and ratio*

No. of mode	Dry matter content of initial wort (%)	Ratio			Raw material (%)		
		Decoction	Main part	Total part	Light malt	Barley	Rice grits
1	11.0±0.01	1:4.8	1:3.3	1:3.6	100.0	-	-
2	11.0±0.01	1:5.3	1:3.7	1:4.1	83.0	-	12.0
3	11.0±0.02	1:4.2	1:4.0	1:4.1	81.0	14.0	-

Table 3. Continued

No. of mode	Dry matter content of initial wort (%)	Ratio			Raw material (%)		
		Decoction	Main part	Total part	Light malt	Barley	Rice grits
4	11.6±0.02	1:4.5	1:3.1	1:3.6	83.0	-	-

Source: compiled by the authors

The quality of wort and beer obtained from 100% barley malt (mashing mode 1.1, control) was studied, replacing 12% malt with rice malt (mashing modes 2.1, 2.2, 2.3), 14% malt with barley malt (mode 3.1, 3.2, 3.3). Ceremix Plus enzyme preparation was added to the wort at the rate of 100 g per tonne. This particular drug was chosen because, as can be seen from Table 2, the activity of enzymes has broad actions in the temperature range. Physical and chemical parameters of the obtained wort, which is brewed according to the classical scheme and using unmalted raw materials, are given in Table 4.

Table 4. *Physical and chemical parameters of wort*

No. of mode	Viscosity (mm^2/cwt)	Content in wort					
		Amine nitrogen (mg/dm^3)	Coagulating nitrogen ($mg/100\ cm^3$)	Polyphenols (mg/dm^3)	Reducing sugar (g/dm^3)	Ratio of polyphenols:amine nitrogen
1.1 Control	1.33±0.015	150.0±2.3	1.55±0.05	202.1±2.5	58.5±0.11	1.35
2.1 Rice	1.50±0.020	147.7±1.9	1.58±0.04	190.3±3.1	62.2±0.15	1.29
2.2 Rice	1.46±0.015	137.2±1.5	1.43±0.04	204.4±3.2	63.1±0.10	1.49
2.3 Rice	1.42±0.015	145.2±1.4	1.58±0.04	204.8±1.8	62.9±0.13	1.41
3.1 Barley	1.54±0.02	145.9±2.0	1.54±0.05	213.6± 3.7	59.4±0.10	1.46
3.2 Barley	1.49±0.015	140.7±1.3	1.57±0.05	223.2±3.4	61.6±0.15	1.59
3.3 Barley	1.47±0.015	143.7±1.6	1.45±0.04	221.3±3.3	69.6±0.12	1.54

Source: compiled by the authors
Note: figures are given for 10% wort

Table 4 shows that partial replacement of malt with rice and unmalted barley gives good results regarding the final content of amine nitrogen and coagulating nitrogen, increases the amount of polyphenols and reducing sugars by 9.4 and 18.97%, respectively, especially in samples 3.2 and 3.3. This will contribute to the development of protein-polyphenolic complexes during boiling of the wort, high-quality clarification of the hopped wort, and the richness of taste of the finished beer. Filtration of wort using "classic" technology is the longest technological stage of brewing wort. In modern conditions, it is possible to reduce its duration due to the use of modern equipment and the use of enzyme preparations, the action of which is aimed at hydrolysis of biopolymers, mainly β-glucan. The use of the Ultraflo Max enzyme preparation helped to reduce the viscosity and content of β-glucans in the wort at a dosage of 0.01%, which corresponds to 100 g/t.

V.M. Gulyaev *et al.* (2020) found that the addition of Jerusalem artichoke wort to malt wort causes, as in our case, an increase in the degree of fermentation and the mass fraction of alcohol in young beer. The researchers also observed an increase in the colour of young beer compared to the control sample. But replacing

10% barley malt with Jerusalem artichoke can only be recommended for making dark beers, as opposed to light beers obtained in this study. In brewing technology, classic beer malt wort can be diluted with Jerusalem artichoke wort. The yeast works equally well in the wort specified by the composition. The addition of Jerusalem artichoke wort improves the fermentation process and promotes the accumulation of yeast biomass. The researchers noted that partial replacement of malt wort with Jerusalem artichoke tuber wort will be economically feasible, since it will lead to a reduction in the cost of beer and brewer's yeast production. Jerusalem artichoke raw materials are affordable and cheaper than malt. The product obtained as a result of fermentation – dark beer has satisfactory organoleptic properties, sweet taste, and a light sunflower aftertaste.

Figures 2-4 present the results obtained in determining the viscosity of wort and the content of β-glucan and arabinoxylan, from which the following conclusions can be drawn. The total filtration time using enzyme preparations is reduced due to the lower viscosity of the wort (Fig. 2).

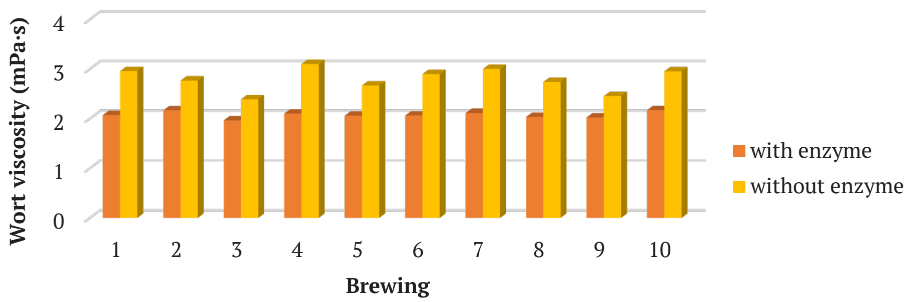

Figure 2. Change in wort viscosity depending on the number of brews
Source: compiled by the authors

As can be seen from Fig. 2, the use of the Ultraflo Max enzyme preparation resulted in a decrease in the wort viscosity by an average of 0.8 mPa·s, which reduces the filtration process by up to 20%. The viscosity of the wort depends on the presence of enzymes, so the amount of β-glucan residues (Fig. 2) and arabinoxylan (Fig. 3) for the variant using an enzyme preparation, it is significantly lower than in the case of traditional wort brewing, in which only barley malt was used without adding an enzyme.

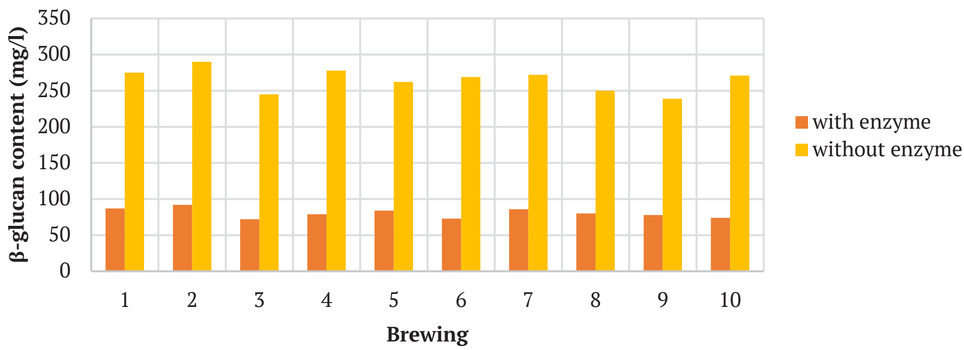

Figure 3. Change in β-glucan depending on the number of brews
Source: compiled by the authors

Arabinoxylane is one of the most important components of the yeast cell walls used for beer production, so its amount should be large. T.V. Bytka *et al.* (2019) found that arabinoxylan itself as a biologically active substance is a promising component for the creation of food and dietary supplements. Therefore, its increased amount in beer will contribute to positive physiological effects for humans. However, as can be seen from Figure 4, the arabinoxylan content in the wort is very low. Accordingly, the effect of enzyme complexes will stimulate its growth for yeast cells during fermentation.

In the brewed beer, physico-chemical parameters were determined, which are shown in Table 5.

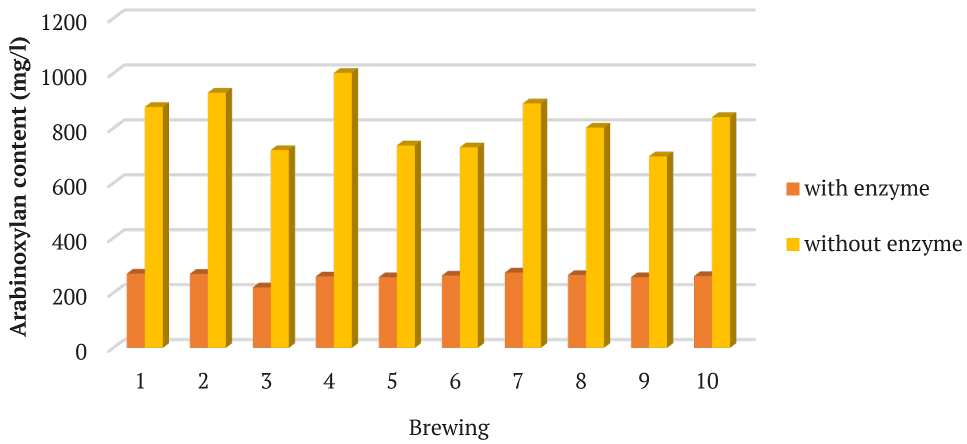

Figure 4. Change in arabinoxylan content depending on the number of brews

Source: compiled by the authors

Table 5. *Physical and chemical parameters of beer obtained according to the classical scheme and using barley and rice grits*

Mashing mode	Final degree of fermentation (%)	Actual degree of fermentation (%)	Dry wort substance (%)	Alcohol content (vol.%)	Total extract (%)
1.1 Control	87.0±0.1	67.5±0.1	11.09±0.02	5.13±0.02	3.61±0.02
2.1 Rice	85.1±0.1	66.2±0.1	11.02±0.015	4.95±0.01	3.72±0.03
2.2 Rice	85.1±0.1	67.6±0.1	11.07±0.01	5.10±0.02	3.60±0.01
2.3 Rice	89.6±0.1	68.0±0.1	11.08±0.02	5.15±0.02	3.53±0.02
3.1 Barley	84.6±0.1	66.8±0.1	11.07±0.01	4.94±0.01	3.79±0.03
3.2 Barley	86.4± 0.1	67.5± 0.1	11.10± 0.01	5.10± 0.01	3.51± 0.01
3.3 Barley	87.6±0.015	66.9±0.01	10.95± 0.01	5.00±0.01	3.63±0.015

Source: compiled by the authors

As can be seen from Table 5, there is a higher final fermentation rate in beer compared to the control sample 1.1 and almost the same result in terms of alcohol content in beer. A higher final fermentation rate in beer can be a consequence of a higher fermentation temperature, which can lead to an increase in the content of esters and higher alcohols in beer. For mode 2.3, the alcohol content is even more important. This follows from Table 4 for this mode, since it has a high content of amine nitrogen. This indicates the presence of protein compounds, which are important components of beer. Amine nitrogen is one of the key indicators of beer quality, as it affects its taste, aroma, and foam stability. Consequently, the complex of enzyme preparations hydrolyses the nutrients of raw materials to values that, in the process of fermentation of the finished wort, give indicators at the level or higher than the indicators of the control sample (Table 5).

K. Habschied *et al*. (2022) evaluated the possibility of using Lutra® Kveik yeast for the production of pseudo-lager. The beer produced showed good physical and chemical quality indicators, comparable to ordinary light beer made using unmalted grain and enzyme preparations. Faster fermentation and no diacetyl residue, no maturation, and no settling time – all in favour of this strong yeast. In terms of sensory characteristics, this yeast can offer a good, balanced, and refreshing light beer, similar to a regular lager. Beer brewed with Ondea Pro enzyme preparations will be successfully produced with 100% barley inclusion on an industrial scale. In the finished product, physico-chemical parameters were determined, which are represented by density, alcohol content, colour, pH value, carbon dioxide content, foam stability, and the actual degree of fermentation in Table 6. The typical composition of Pilsner beer was achieved in terms of its basic physical and chemical parameters.

Table 6. *Physical and chemical parameters of Pilsner beer using Ondea Pro enzyme preparations*

Density (g/cm^3)	Alcohol content (vol.%)	Colour, units	pH value	Content CO_2 (%)	Foam stability	RDF
10.47±0.03	4.9±0.02	5.9±0.05	4.48±0.15	0.5±0.01	258±5	69.8±2.2

Source: compiled by the authors
Note: RDF – real degree of fermentation

When using enzyme preparations, the physical and chemical parameters of Pilsner beer are important for ensuring the quality of the drink. As can be seen in the Table 6 indicators correspond to light beer of Pilsner type: the content of ethyl alcohol in beer usually ranges from 3.4 to 4.5%. In Table 6, the value corresponds to 4.9 vol.%, which is obtained through the use of enzymes (the dissolution processes took place deeper, a larger extract was obtained, more nitrogenous components for yeast nutrition). The beer density is 10.47±0.03 g/cm^3, which corresponds to a light beer such as Pilsner. Mass fraction of CO_2 according to DSTU for beer should be at least 0.3%. According to the data obtained, this value is within 0.5±0.01%. Beer contains dextrins (75-85% of the total amount of carbohydrates), simple sugars (glucose, fructose, sucrose) and complex sugars (polysaccharides, etc.). The actual degree of fermentation for light beer is about 68-75%, that is, it is included in the limits for beer, as well as the values of colour, pH value, and foam stability. The values of the physical and chemical parameters of beer, which are shown in Table 6, is within the normal range.

Thus, Table 6 shows that the physical and chemical parameters of beer obtained using unmalted barley and enzyme preparations correspond to the indicators of the typical composition of Pilsner beer. The conducted organoleptic assessment of beer indicates its excellent quality, which can be seen from Tables 7-8. The developed beer was a transparent straw-yellow drink based on such organoleptic parameters as aroma, taste, smell, and bitterness. The taste of the beer was pronounced, characteristic of raw materials, with a slight aftertaste that did not change the overall flavour. A light original smell was also noted. Despite the added same amount of hops, the bitterness for beer using 100% barley and enzyme preparations was at the highest level, which affected the total score.

Table 7. *Organoleptic parameters according to GAS*				
Values	**100% barley**		**100% malt**	
	fresh	**used**	**fresh**	**used**
Flavour	4.3	3.8	4.2	3.6
Taste	3.9	3.7	4.0	3.8
Smell	4.4	4.3	4.3	4.3
Bitterness	4.6	4.0	4.0	3.9
GAS score	4.3	4.0	4.1	3.9

Note: GAS – German Agricultural Society. Taste score: 5 – very good, 1 – unacceptable
Source: compiled by the authors

As noted by R. Yerolla *et al.* (2022), the temperature of the wort during fermentation affects the content of acids, higher alcohols, and esters of beer. The researchers developed a taste model based on the available literature and built a growth model in MATLAB and compared it with industry data to establish important kinetics of taste development. The beer taste model used by US confirms the obtained data on organoleptic parameters of the developed beer using unmalted raw materials and enzyme preparations according to the methodology of the German Agricultural Society. As can be seen from Table 7 according to such indicators as aroma, smell, and bitterness, beer produced from unmalted barley using enzyme preparations has higher indicators than beer produced using classical technology using only barley malt.

Table 8. *Organoleptic parameters with an emphasis on ageing*				
Values	**100% barley**		**100% malt**	
	fresh	**used**	**fresh**	**used**
Flavour	1.0	1.4	1.0	1.8
Taste	1.0	1.6	1.0	1.8
Bitterness	1.0	1.6	1.0	1.7
Score	1.0	1.5	1.0	1.7
Acceptance (%)	**100**	**77**	**100**	**70**

Note: Ageing conditions: 24 hours of shaking (100 g) at 20°C and 4 days of storage at 40°C: 1 – fresh, 4 – very aged
Source: compiled by the authors

The obtained data on organoleptic parameters of aged beer brewed in two ways also confirmed the high quality of beer in all indicators of aroma, taste, and bitterness, which can be seen in Table 8. Laboratory wort and subsequently prepared beer were examined in terms of transparency and colour (5.13-0.17 units), acidity (0.93-1.0 units), the final degree of fermentation (79.2-80.3%), viscosity (1.32-1.40 mPa·s), and the content of β-glucans (12-140 mg/l) correspond to the indicators of Pilsner beer. The results obtained confirm compliance in all experiments with the current requirements of the standard.

Brewing with Ondea Pro enzyme preparation requires specific ideas and know-how from the brewery to achieve the desired taste of a particular type of beer or brand, similar to making malt-based beer. Therefore, it is recommended to dose Ondea Pro at the beginning of mashing (when approximately 30% of the grain is crushed) at a dose of 1.5-2.5 kg per tonne of raw barley, depending on the mashing mode and recipe. Beer, as a liquid with a dynamic viscosity coefficient of 1.2 mPa·s, is ideal for automatic dosing equipment. Optimisation of saccharification time and dosage is possible to achieve the desired wort profile.

Therefore, the conducted comparative studies of the indicators of barley malt and unmalted grain on the example of barley and rice grits confirmed the possibility of replacing malt with unmalted raw materials. Well-chosen dispersion of unmalted raw materials, which allows obtaining wort with optimal nitrogen content. The optimal effect of enzyme preparations of the Danish company Novozymes was investigated and confirmed. It was found that the use of Ultraflo Max enzyme preparation reduces the duration of the wort filtration process by 20% due to its lower viscosity. The use of enzyme preparations can significantly increase the content of β-glucan and arabinoxylan, which will lead to the growth of yeast cells during fermentation. Studies have shown that the replacement of malt with unmalted grain and the use of enzyme preparations has a higher final fermentation rate and a similar result in relation to the alcohol content in beer. In terms of physico-chemical and organoleptic parameters, the resulting beer corresponds to the indicators of the typical composition of Pilsner beer.

Conclusions

It was found that the selected barley and rice grits as unmalted raw materials for brewing do not exceed 11% in terms of protein content, which allows obtaining wort with an optimal nitrogen composition. The optimal effect of enzyme preparations and the effect of temperature and pH on their stability were investigated and confirmed. Partial replacement of malt with rice and unmalted barley gives good results in terms of the final content of amine nitrogen and coagulating nitrogen, increases the amount of polyphenols and reducing sugars by 9.4% and 18.97%, respectively. The use of the Ultraflo Max enzyme preparation helped to reduce the viscosity by an average of 0.8 mPa·s and the content of β-glucans in the wort at a dosage of 0.01%, which corresponds to 100 g/t. It is recommended to introduce complex enzyme preparations at the beginning of mashing – Peptidhydrolase, α-amylase, endo-β-glucanase (Ceremis Plus) to ensure the necessary ratio of substances in the wort. It was found that to improve the rheological properties of the mash and reduce the viscosity of the wort, which intensifies the filtration process, it is necessary to use preparations containing endo-β-glucanase (Ultraflo Max).

In experimental samples of wort after the introduction of enzyme preparations, the following results were obtained: a higher final degree of fermentation in beer compared to the control by 0.69 and 2.99% for rice and barley grits, respectively, which may be a consequence of a higher fermentation temperature and lead to an increase in the content of esters and higher alcohols in beer. Using large amounts of unmalted grain together with external enzymes such as Ultraflo Max and Ceremis Plus allows brewers to produce wort and beer of the same composition and quality as high-quality wort and beer using only malt. Studies have established that replacing part of barley malt with such unmalted materials as barley and rice grits using exoenzyme preparations Ultraflo Max and Ceremis Plus leads to high-quality beer, which is confirmed by organoleptic indicators of the aroma, taste, and bitterness of beer.

Promising areas for further research are the use of other unmalted materials, such as buckwheat and oats. Therefore, this work will be continued with studies replacing barley malt with buckwheat and oat malt with the addition of enzyme preparations and comparing the results.

Acknowledgements

None.

Conflict of Interest

None.

References

[1] Birta, G., Burgu, Y., Floka, L., & Oliinyk, Yu. (2021). Prospects of using non-traditional raw materials in brewing technology. In *The 8th International scientific and practical Internet conference* (pp. 55-56). Poltava: Poltava University of Economics and Trade.

[2] Bytka, T.V., Cherno, N.K., & Ozolina, S.O. (2019). Arabinoxylan is a promising component of physiologically functional food ingredients and dietary supplements. In *III International science and practice conference of scientists, graduate students and students* (pp. 111-112). Kyiv: National University of Life and Environmental Sciences of Ukraine.

[3] Cela, N., Condelli, N., Perretti, G., Di Cairano, M., Tolve, R., & Galgano, F. (2022). Gluten reduction in beer: Effect of sorghum:quinoa ratio and protein rest time on brewing parameters and consumer acceptability. *Journal of Cereal Science*, 109, article number 103607. doi: 10.1016/j.jcs.2022.103607.

[4] Ciocan, M.E., Salamon, R.V., Ambrus, Á., Codină, G.G., Chetrariu, A., & Dabija, A. (2023). Brewing with unmalted and malted sorghum: Influence on beer quality. *Fermentation*, 9(5), article number 490. doi: 10.3390/fermentation9050490.

[5] Dabija, A., Ciocan, M., Chetrariu, A., & Mirzan, D. (2021). Comparative evaluation of the physico-chemical characteristics of buckwhweat malt and barley malt. In *21st International multidisciplinary scientific geoconference* (pp. 51-54). Bulgaria. doi: 10.5593/sgem2021/6.1/s25.13.

[6] DSTU 3888:2015. (2017). *Beer. General specifications. Quality management systems – Requirements.* Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=65898.

[7] DSTU 4282:2018. (2019). *Brewing barley malt. General technical conditions. Quality management systems – Requirements*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=79566.

[8] DSTU 7103:2009. (2016). *Beer. Methods for determining organoleptic parameters and volume of production. Change №1. Quality management systems – Requirements*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=95337.

[9] DSTU 7103:2020. (2023). *Beer. Methods of determining organoleptic indicators, product volume and sealing tightness. Quality management systems – Requirements*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=91294.

[10] Features of growing barley for brewing in 2024. (n.d.). Retrieved from https://agroexp.com.ua/uk/osobennosti-vyrashchivaniya-yachmenya-na-pivovarenie.

[11] Fujita, A., Simsek, S., & Schwarz, P.B. (2020). Observations on the malting of ancient wheats: Einkorn, emmer and spelt. *Fermentation*, 6(4), article number 125. doi: 10.3390/fermentation6040125.

[12] Gulyaev, V.M., Maznytska, O.V., Anatskyi, A.S., & Pasenko, A.V. (2020). Study of the possibility of using wort with the addition of Jerusalem artichoke in the production of yeast of the saccharomyces genus. *Collection of Scientific Papers of the Dnipro State Technical University*, 2(37), 124-127. doi: 10.31319/2519-2884.37.2020.22.

[13] Gupta, H., Abu-Ghannam, N., & Gallaghar, E. (2020). Barley for brewing: Characteristic changes during malting, brewing and applications of its by-products. *Comprehensive Reviews in Food Science and Food Safety*, 9(3), 318-328. doi: 10.1111/j.1541- 4337.2010.00112.x/full.

[14] Guzmán-Ortiz, F.A. (2019). Valuation and use of a new variety of barley for brewing craft beer. *Ingeniería Agrícola y Biosistemas*, 11(1), 87-95. doi: 10.5154/r.inagbi.2018.01.001.

[15] Rizhuk, S., Suhoraba, V., Nadtochy , P., Protsenko, L., Tsibulskiy, V., & Ratoshnyuk, T. (2019). The state of the hop industry in Ukraine and the possibility of increasing its effectiveness in modern condition. *Scientific Horizons*, 22(7), 29-40. doi: 10.33249/2663-2144-2019-80-7-29-40.

[16] Kábelová-Ficová, H., Stanislav, K., Gregor, T., Fišera, M., Golian, J., Kubáň, V., & Šopík, T. (2018). Preparation of malts for production of special beers.*Potravinarstvo Slovak Journal of Food Sciences*, 11(1), 441-445. doi: 10.5219/773.

[17] Kumar, D., Kant Lomesh, S., & Nathan, V. (2017). Molecular interaction studies of l-alanine and lphenylalanine in water and in aqueous citric acid at different temperatures using volumetric, viscosity and ultrasonic methods, *Journal of Molecular Liquids*, 247, 75-83. doi: 10.1016/j.molliq.2017.08.057.

[18] Kunze, W. (2004). *Technology brewing and malting*. Berlin: International Edition, VlB.

[19] Loiko, S., & Romanova, Z. (2018). Using unmalted barley for brewing. *Proceedings of the National Aviation University,* 76(3), 93-98. doi: 10.18372/2306-1472.76.13165.

[20] Mallett, J. (2014). *Malt: A practical guide from field to brewhouse (Brewing Elements)*. Boulder: Brewers Publications.

[21] Mascia, I., Fadda, C., Karabín, M., Dostálek, P., & Del Caro, A. (2019). Aging of craft durum wheat beer fermented with sourdough yeasts. *LWT - Food Science and Technology,* 65, article number 487. doi: 10.1016/j.lwt.2015.08.026.10.

[22] Nocente, F., Galassi, E., Taddei, F., Natale, C., & Gazza, L. (2023). Preliminary evaluation of minor cereals as non-traditional brewing raw materials. *Beverages,* 10(1), article number 2. doi: 10.3390/beverages10010002.

[23] Orel, S.P. (2021). *Research of beer wort technology using unmalted raw materials*. Retrieved from https://dspace.nuft.edu.ua/server/api/core/bitstreams/bf80d739-b69d-48fe-acfe-aca91fc88303/content.

[24] Park, J., Park, H.Y., Chung, H.J., & Oh, S.R. (2023). Starch structure of raw materials with different amylose contents and the brewing quality characteristics of Korean rice beer. *Foods*, 12(13), article number 2544. doi: 10.3390/foods12132544.

[25] Pryimachuk, T., Protsenko, A., Rudyk, R., & Shtanko, T. (2018). Beer and hops industry of Ukraine: Conjuncture and integration. *Bulletin of Agrarian Science* 4, 61-67. doi: 10.31073/agrovisnyk201804-10.

[26] Puzik, L.M. (2019). *Brewing properties of spring barley grain under different storage conditions*. Retrieved from https://repo.btu.kharkov.ua/bitstream/123456789/4972/1/22.pdf.

[27] Rodman, A., & Gerogiorgis, D.I. (2021). Multiobjective process optimisation of beer fermentation via dynamic simulation. *Food and Bioproducts Processing,* 100, 255-274. doi: 10.1016/j.fbp.2016.04.002.

[28] Romanova, Z.M., Loiko, S.M., Romanov, M.S., Kosogolova, L.O., & Khlynovskiy, M.D. (2021). Intensification of high-quality brewing processes processes. *The International Journal of agricultural equation*, 43-53. doi: 10.33687/ijae.009.00.3720.

[29] Strapchuk, S., & Mykolenko, O. (2022). Algorithm for selecting alternative strategies for sustainable intensification of agricultural enterprises. *Scientific Bulletin of Mukachevo State University. Series "Economics"*, 9(2), 9-17. doi: 10.52566/msu-econ.9(2).2022.9-17.

[30] Sustainable brewing starts with enzymes. (n.d.). Retrieved from https://www.novozymes.com/en/solutions/brewing.

[31] The brewing equipment you need to open a brewery. (2022). Retrieved from https://www.vdobrew.com/brewing-equipment-you-need-to-open-a-brewery/.

[32] Van Donkelaar, L., Mostert, J., Zisopoulos, F.K., Boom, R., & van der Goot, A.J. (2019). The use of enzymes for beer brewing: Thermodynamic Comparison on resource use. *Energy,* 115(1), 519-527. doi: 10.1016/j.energy.2016.09.011.
[33] Yerolla, R., Mohammed Mehshan, K.M, Nevin, R., Nekkanti, S.H., Myreddy Prudhvi P.G., & Chandra, S.B. (2022). Beer fermentation modeling for optimum flavor and performance. *IFAC-PapersOnLine*, 5(1), 381-386. doi:10.1016/j.ifacol.2022.04.063.
[34] Zamai, Zh., Humenyuk, O., Khrebtan, O., Ponomarenko, S., & Ivanenko, K. (2022). Analysis of the effectiveness of enzyme preparations and requirements for their safety in craft beer production. *Technical Sciences and Technologies*, 3(29), 126-135. doi: 10.25140/2411-5363-2022-3(29)-126-135.
[35] Zeida, I. (2023). *The project of the brewing department of the brewery with a capacity of 10.5 million dal for a year using enzyme preparations*. Retrieved from https://dspace.nuft.edu.ua/server/api/core/bitstreams/1032715c-383f-452b-a2e3-f0bafd9b95f4/content.
[36] Zheplinska, M., Vasyliv, V., Deviatko, O., Ulianko, S., & Kanivets, N. (2022b). *Research of wheat fiber with pumpkin pectin plant additive*. Retrieved from https://www.springerprofessional.de/en/research-of-wheat-fiber-with-pumpkin-pectin-plant-additive/22838396.
[37] Zheplinska, M., Vasyliv, V., Shynkaruk, V., Khvesyk, J., Yemtcev, V., Mushtruk, N., Rudyk, Y., Gruntovskyi, M., & Tarasenko, S. (2022a). The use of vapor condensation cavitation to increase the activity of milk of lime in sugar beet production. *Potravinarstvo Slovak Journal of Food Sciences,* 16, 463-472. doi: 10.5219/1781.

Використання несоложеної сировини з ферментними препаратами в пивоварінні

Сергій Михайлович Лойко
Аспірант
Національний університет харчових технологій
01033, вул. Володимирська, 68, м. Київ, Україна
https://orcid.org/0009-0003-5853-6836

Зоряна Миколаївна Романова
Кандидат технічних наук, доцент
Національний університет харчових технологій
01033, вул. Володимирська, 68, м. Київ, Україна
https://orcid.org/0000-0003-3974-5758

Марія Михайлівна Жеплінська
Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-7286-3003

Микола Сергійович Романов
Кандидат технічних наук, доцент
Національний університет харчових технологій
01033, вул. Володимирська, 68, м. Київ, Україна
https://orcid.org/0000-0002-0063-819X

Володимир Павлович Василів
Кандидат технічних наук, доцент
Національний університет біоресурсів і природокористування
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-2109-0522

Анотація. Застосування несоложеної сировини є одним із методів для підвищення якості, зниження собівартості і створення нових сортів пива. Але при цьому ферментативна активність такої сировини дорівнює нулю, тому актуальним є використання ферментних препаратів. Метою дослідження було порівняння показників якості 100 % солодового пива та пива з заміною солоду несоложеним ячменем із застосуванням ферментів. В роботі використовувалися методи техніко-хімічного аналізу для визначення органолептичних та фізико-хімічних показників пива. Розроблено рекомендації щодо інтенсифікації приготування сусла з використанням різних видів зернової сировини – несоложеної ячмінної та рисової крупки з додаванням на різних етапах пивоваріння ферментних препаратів фірми Novozymes (Данія). При випробуванні нових ферментних препаратів (бета-глюканазний комплекс, ксиланаза) після контрольних зразків зменшилася тривалість фільтрації приблизно на 20 %, в'язкість сусла, вміст бета-глюканів, арабіноксиланів. Завдяки застосуванню нового ферментного препарату відбулося краще розщеплення речовин, що вплинуло на якість і тривалість фільтрації. Це призводить до поліпшення якості сусла, скорочення тривалості процесу і зменшення у витратах сировини. Для забезпечення необхідного співвідношення речовин у суслі на початку затирання необхідно вводити ферментні препарати комплексної дії – пептидгідролазу, α-амілазу, ендо-бета-глюканазу (Ceremis Plus). Препарати, що містять ендо-бета-глюканазу (Ultraflo Max), необхідно використовувати на початку затирання для поліпшення реологічних властивостей сусла і зниження в›язкості сусла, що покращує здійснення процесу фільтрації. Для отримання пива з необхідним ступенем бродіння при затиранні краще застосовувати нові ферментні препарати (глюкоамілазу). Практична цінність роботи полягає у використанні великої кількості несоложеного зерна разом із зовнішніми ферментами, такими як Ultraflo Max і Ceremis Plus, що дозволить пивоварам виробляти сусло та пиво такого ж складу та якості, що й сусло та пиво преміум-класу, використовуючи лише солод

Ключові слова: ячмінь; пиво; сусло; солод; якість