Technology of lager and dark beers with chicory roots

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Abstract

Introduction. Chicory root (*Cichorium intybus* L.) contains valuable components such as inulin, inulides, bitter substances, pectin, and fibers and is a promising non-traditional raw material for the production of new beer varieties and reduction of their cost.

Materials and methods. Dried and roasted chicory roots, lager and caramel barley malt, enzyme preparation inulinase, granulated hops of "Agnus" variety, yeast *Saccharomyces cerevisiae* (race RH) were used. Inulin content was determined by spectrophotometric method, amine nitrogen was measured by Pope and Stevenson method, content of reducing substances was estimated by Wilstetter-Schudl method. Standard methods accepted in brewing were used to determine other beer characteristics, sensory parameters were evaluated using profile methods.

Results and discussion. The technology for light beer production was proposed, according to which light malt and dried crushed chicory roots taken in the amount of 4% of malt are used as raw materials, and at the stage of mashing the enzyme preparation inulinase with activity of 14 units/g was introduced into the mixture. For the hydrolysis of inulin at the mashing stage, an inulase pause was provided at a temperature of 55–56 °C for 20–30 minutes. The method allows increasing the content of reducing substances in the wort by 1.6%, the apparent and actual fermentation degree by 3.9%, the content of alcohol and carbon dioxide in the beer by 3.2 and 10%, respectively. The finished beer had increased foam resistance and higher foam height, while the introduction of chicory did not impart excessive and extraneous bitterness. The innovative technology of dark beer provides mixing of aqueous extract of roasted chicory with malt wort cooled to the temperature of 85–90 °C. It was found that the optimal mode of the extraction process was the temperature 85–90 °C, hydromodule 1:6, and duration 90 min. Beer with chicory content of 3% was the best in terms of physical, chemical, and sensory properties. The improved method allows to increase the content of reducing substances in wort by 1.5%, apparent and actual fermentation degree by 2.2 and 3%, respectively, to increase the content of alcohol in beer by 2.3%, and carbon dioxide by 3.2%. It was proved that partial replacement of malt by chicory allows to reduce consumption of bitter hops for light beers by 20% (from 14.8 to 12.0 g/dal) and for dark beers by 10% (from 10.3 to 9.3 g/dal).

Conclusions. The addition of dried and fried chicory roots makes it possible to obtain new varieties of high-quality beer with their cost reduction.

Introduction

To obtain new types of beer and reduce the cost of their production, brewing has recently increasingly used non-traditional unmalted raw materials of plant origin, the addition of which to malt will improve the quality characteristics of beer (taste, aroma, foaming) and enrich the drink with biologically active substances (Shoaib et al., 2016).

Chicory root (*Cichorium intubus* L.) is a promising raw material for the production of lager and dark beers. Its most valuable components are inulin and bitter substances (Perović et al., 2021). Inulin is a fructan-type polysaccharide that has health-promoting properties and demonstrates several potential therapeutic benefits. Inulin is considered to be a prebiotic dietary fiber. It could stimulate activities beneficial to human health gut lactic acid bacteria and bifidobacteria (Waqas and Summer, 2017). Being low in calories, inulin can be used as a fat and sugar replacer in manufacturing of dairy products such as ice-cream, yogurt, and cheese (Krishna et al., 2020; Stabnikova and Paredes-Lopez, 2024).

Content of inulin in fresh chicory root crops is in the range from 60.8 to 65.0%, and in dried roots varies from 51.7 to 59.7% in terms of dry matter (DM) (Bais et al., 2001). Inulin, like starch, is not fermented by yeast, but it is hydrolysed when heated with water under the action of the enzyme inulinase (Madrigal et al., 2007). The products of its complete hydrolysis are the monosaccharides: fructose, 97%, and glucose 3%, which are fermented by brewer's yeast (Ricca et al., 2007).

Among bitter substances of chicory roots, glycoside intibin, lactucin, and lactucopicrin have been identified. Chicory also contains bitter cell sap, the bitterness index of which is 1:600. Biologically active substances of chicory include inulides, pectin, fiber, organic acids, amino acids, vitamins, macro- and microelements (Dubova et al., 2022; Massoud et al., 2009).

There are methods of brewing dark beers with chicory, which involve the addition of fried chicory extract in the amount of 5–10% to the wort at the stage of mashing grain products during the protein pause at a mash temperature of 52 °C or during the boiling of wort with hops 30 minutes before the end of the boiling process (Koshova et al., 2018). The disadvantages of described methods are the increase in the cost of finished beer due to the use of expensive concentrated extract, as well as the partial loss of valuable bitter and aromatic substances of chicory under the influence of high temperatures at the wort boiling stage.

Taking into account the fact that coloring substances of roasted chicory roots and caramel malt lie in the same region of the spectrum, and volatile substances of chicory give beer the aroma of rye bread, it is reasonable to use roasted chicory roots as a substitute for valuable coloring malts (caramel, dark, burnt) to produce dark beer (Liscomb et al., 2015; Van Arkel et al., 2012). There is a known method according to which the crushed roasted roots of vegetables were introduced into the filtration apparatus, where, simultaneously with the filtration of mash and washing of crushed root vegetables, extraction of water-soluble substances of chicory took place (Patent SU for invention 1666528. Method of wort preparation for dark beer). This method does not require additional equipment, but has some disadvantages, the main of which are the loss of part of inulin, valuable bitter, and aromatic substances of chicory at the stage of boiling wort with hops (Shoaib et al., 2016).

To exclude the above disadvantages, an innovative method of dark beer brewing has been developed, which involves mixing aqueous extract of roasted chicory roots with partially cooled hoped wort (Patent UA for invention 114994. Method of preparation of wort for dark beer).

There is no information in the literature about the use of dried chicory root vegetables for brewing lager beers, which requires research. For this purpose an innovative method was developed, which provides mashing of a mixture of malt and dried chicory and differs from the classical one by carrying out inulase pause at temperature 55–56 °C for 20–30 min and introduction of enzyme preparation "Inuloavamorin P10X" for activation of inulin hydrolysis (Patent UA for invention 115398. Method of preparation of low-calorie dietary beer).

Assessing the effectiveness of innovative brewing methods that use partial replacement of malt with dried or roasted chicory, and choosing optimal technological modes is relevant for both craft and large breweries.

The aim of the present study was to improve the technology for light and dark beer by the use of dried or roasted chicory roots to obtain new varieties of beer of enhanced quality at lower costs.

Materials and methods

Materials

The following materials were used for the research: dried chicory roots; fried chicory roots; light barley malt "Best Pilsen Malt" (Germany); caramel malt "Best Caramel Malt Dark" (Germany); enzyme preparation "Inuloavamorin P10X", activity 14 units/g (Ukraine); granulated hops of the Czech variety "Agnus" (α-acid content of 5.2% in terms of air-dry matter, moisture content of 10.3%); bottom fermentation yeast *Saccharomyces cerevisiae*, race RH.

Research methods

Analytical, chemical, physicochemical, organoleptic, profile and calculation methods were used to evaluate the research results obtained using devices and research methods used in brewing.

Determination of reducing substances in wort

The content of reducing substances in wort was determined by the Wilstetter-Schudl method based on the oxidation of aldoses with iodine (Kunze, 2007).

Determination of amine nitrogen content in wort

Amine nitrogen content in wort was determined by an iodometric (copper) method according to Pope and Stevens (Narzib, 2007). The method is based on the ability of amino acids to form soluble complexes with copper. Excess copper is filtered off, acetic acid is added to the filtrate, which detaches copper from the complex compound to form copper acetate, after which potassium iodide is added. When the latter interacts with acetic acid copper, free iodine is released, the amount of which is proportional to the amount of copper and, accordingly, the amount of amine nitrogen. Free iodine is titrated with sodium thiosulfate solution.

Physico-chemical properties of the finished beer

Physico-chemical parameters in the finished beer (acidity, ml of 1 M NaOH per 100 ml of wort; color, ml of 0.1M I_2 per 100 ml of water; carbon dioxide content,%) were determined using an Anton Paar analyzer (Ciocan et al., 2020).

Determination of the dry matter concentration

The method is based on the determination of the content of extractive substances in beer by relative density (Kunze, 2007).

The beer free from carbon dioxide was poured into a cylinder, which was placed on a flat surface, the temperature was measured and an areometer was immersed. The upper meniscus was used to read the areometer and determine the concentration of dry matter (DM), taking into account the correction for temperature.

Determination of the alcohol concentration

The method is based on the distillation of alcohol from a weighed sample of beer, followed by the determination of the mass fraction of alcohol by refractometric method and the solids content by areometric method (Kunze, 2007).

In a dry distillation flask 200 ml of beer freed from carbon dioxide were taken, the flask was connected to a refrigerator through a droplet eliminator and the beer was distilled. After distillation of 1/3 of the sample volume, the rest of the distillation flask was brought to the original volume with water, mixed thoroughly, cooled to the temperature of 20 ºC and the concentration of DM (actual content of the extract) was determined by areometric method. The distillate in the receiving flask was brought with water to the initial volume, mixed thoroughly and the mass fraction of alcohol in the sample was determined at 20 ºC by a dip refractometer using alcohol tables.

Determination of inulin and fructooligosaccharides

High Performance Liquid Chromatography coupled with the Refractive Index Detector (HPLC RID) method for determination of inulin and fructooligosaccharides was used (Petkova et al., 2014, 2015). The essence of the method is the chromatographic separation of chicory extract filtrate on a Shodex® Sugar SP0810 column with a Pb2+ protective column (50 × 9.2 mm i.d.) and an analytical column (300 mm × 8.0 mm i.d.) with a movable phase – ionized water. The movable phase provided long retention time, resolution, and satisfactory chromatogram peak profiles. The column was placed in a thermostat The column was placed in a LCO 102 thermostat (ECOM, Czech Republic). The preparation of the extract involved precipitation of proteins by adding Carrese I (K_4 $Fe(CN)_6$ x $3H_2O$) and Carrese II ($Zn(CH_3COO)_2$ x $2H_2O$) reagents in an amount of 5 ml each. The sample was filtered through a 0.45 µm paper filter, transferred to a 50 mL flask, and made up to the mark with deionized water (Bugner et al., 1992). Prior to injection into the HPLC column, samples were passed through a 0.2 µm cellulose acetate filter (Sartorius AG, Göttingen, Germany). The extract containing inulin was dissolved in hot water to a concentration of 10 mg/ml. From the standard solution prepared in this way, working standard solutions containing 0.05, 0.1, 0.5, 1.0, 2.5, 5.0, and 10 mg/ml of inulin were prepared. The operating temperature of the column was 85 °C and the movable phase velocity was 1 ml/min. The linearity of the method was in the range of 0.1-10 mg/ml, and the correlation coefficient R_2 exceeded 0.997.

Determination of sensory properties

The finished beer was evaluated for clarity, color, taste, aroma, hop bitterness, carbon dioxide saturation, foaming, and foam stability. The maximum tasting score of the prototypes was 25 points and was determined as the sum of the scores for each indicator: clarity, 3; color, 3; taste, 5; hop bitterness, 5; aroma, 4, and foam stability, 5 (Table 1).

Table 1

Overall beer quality assessment

Evaluation	Total score
Excellent	22-25
Good	19-21
Satisfactory	13-18
Unsatisfactory	12 and less

The tasting committee consisted of five experts from the Department of Biotechnology of Fermentation Products and Winemaking of the National University of Food Technologies. Special cylindrical glasses made of colorless glass with a capacity of 150–200 ml and a diameter of 50-60 mm were used for beer tasting. The beer temperature was 12±2 °C. The order of tasting provided for the evaluation of lager beers first, with initial wort concentration from lower to higher, and then dark beers. The profile method (Bocharova et al., 2017) was used to evaluate the aroma and taste of beer. Comparison of the profiles of the experimental samples allowed to determine their differences and draw conclusions about the quality of beer.

Processing of research results

Determination of physical and chemical parameters of light barley malt, chicory, wort, young and matured beer was carried out in triplicates. The results are shown as mean ± standard deviation.

Setting up the experiment

During the experiment, the quality parameters of wort and beer were investigated and compared with control samples.

Experimental samples of light wort and beer (11% DM)

- sample 1 – 100% barley light malt (control);
- sample 2 – 98% barley malt, 2% dried chicory;
- sample 3 – 96% barley malt, 4% dried chicory;
- sample 4 – 94% barley malt, 6% dried chicory.

Experimental samples of dark wort and beer (13% DM)

- sample 5 – 95% barley malt, 5% caramel malt (control);
- sample 6 – 97% barley malt, 3% fried chicory;
- sample 7 – 95% barley malt, 5% fried chicory;
- sample 8 – 93% barley malt, 7% fried chicory.

At the first step, the effectiveness of the chicory lager beer technology was studied. Chopped dried roots were added to the mash tun along with light barley malt at the rate of 2, 4, and 6% of the malt amount. The extractivity of dried chicory coincided with the extractivity of light malt and amounted to 78–80%. This made it possible to obtain experimental samples of wort with chicory and control wort of the same concentration (11% DM).

To obtain the control sample, barley light malt was mashed without chicory. The infusion method was chosen for mashing (Figure 1).

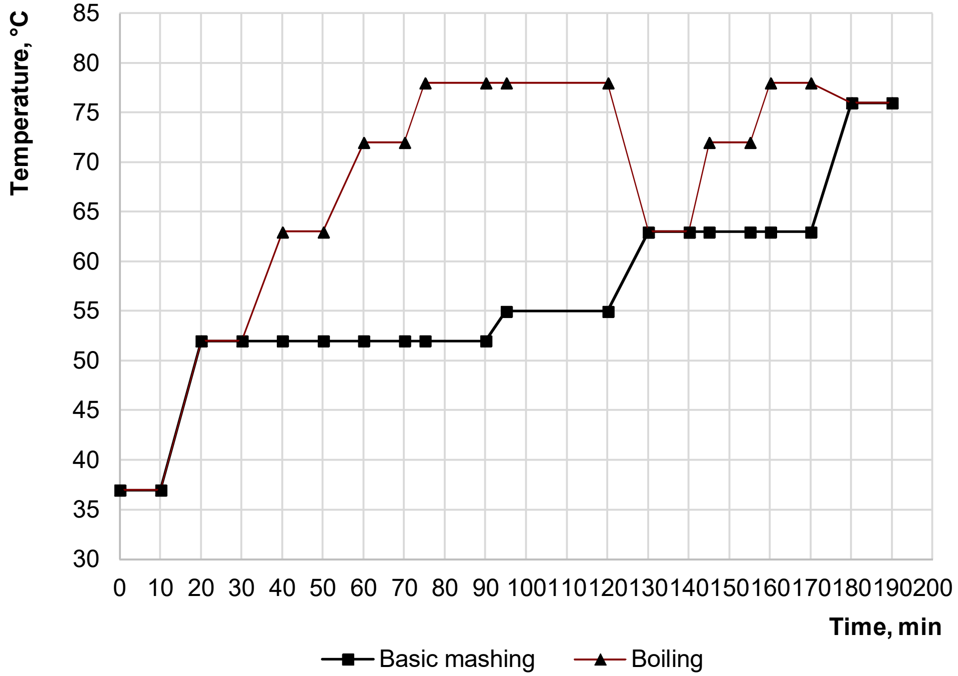

Figure 1. Technological modes of mashing malt with the addition of dried chicory

The mashing process was carried out as follows. The light brewing malt was crushed and mixed with water at a temperature of 37–42 °C in a ratio of 1:4 in a mash tun and kept for 20–30 min (cytolytic pause), then the mash was heated to a temperature of 52 °C and kept for 20–30 min with stirring to hydrolyze proteins (protein pause). After that, the temperature of the mash was gradually raised to 55–56 °C. At this temperature, the enzyme preparation inulinase (Inuloavamorin P10X) was added to the stirrer to perform the inulase pause. At this temperature, inulinase had maximum activity. During the inulase pause, enzymatic hydrolysis of inulin occurred with the formation of fructose and a small amount of glucose.

After 20-30 min, the mash temperature was increased to 63 °C with a heating rate of 1 °C per 1 min to continue the enzymatic hydrolysis of inulin and malt starch, the mash was kept at this temperature for 30 min (maltose pause), after which the temperature was increased to 72 °C, and the mash was kept until the starch was completely saccharified and inulin was hydrolysed. The saccharified mash was then heated to 76 °C and filtered. The resulting wort was boiled with hops for 90 minutes. Due to the addition of chicory bitter substances, the consumption of bitter hops at the wort boiling stage was reduced from 20 to

18-14 g/dal (by 10–30%), depending on the amount of chicory. After clarification of the wort from protein precipitate and its cooling to a temperature of 8 °C, the wort was fermented at this temperature for 7 days. After the end of the main fermentation, the young beer was cooled to a temperature of 1–2 °C, the yeast was removed from the sediment and the young beer was fermented for 14 days.

At the second step, the effectiveness of the technology of dark beer with chicory was studied. The proposed method involved the preparation of an aqueous extract of fried chicory and it's mixing with wort cooled to a temperature of 85–90 °C. To prepare the chicory extract, chopped roasted roots in an amount of 3, 5, and 7% of the amount of light malt were poured into an extractor, mixed with water in a ratio of 1:6 at a temperature of 85–90 °C, and soluble substances were extracted for 90 min. Beer wort with a concentration of 13% DM was prepared by the classical method. For its hopping, the consumption of bitter hops was reduced from 20 to 18–14 g/dal (by 10–30%). Fermentation of wort and fermentation of young beer was carried out according to the above modes. As a control, the beer was brewed from light malt with the addition of caramel malt in the amount of 5% at the mashing stage.

At the third step, the optimal consumption of hops for producing lager and dark beers with chicory was determined and the cost of the finished beer was calculated.

To achieve the required bitterness of wort according to the recipe for lager beer (0.82 g/dal in terms of DM), the standard amount of air-dried hops when added to the hot wort was 14.8 g/dal. On this basis, for the preparation of lager beer (control sample 1), granulated hops were added at the wort boiling stage in the amount of 14.8 g/dal. Due to the addition of bitter substances of dried chicory, the consumption of hops was reduced by 10, 20, and 30%. Thus, different amounts of hops were added to the experimental samples of wort: 13.3, 12 and 10.4 g/dal.

To achieve the required bitterness of wort according to the recipe for dark beer (0.57 g/dal in terms of DM), the standard amount of air-dried hops when added to the hot wort was 10.3 g/dal. Based on this, for the preparation of dark beer (control sample 5), granulated hops were added during the wort boiling in the amount of 10.3 g/dal. Due to the addition of bitter substances of fried chicory, the consumption of hops was reduced by 10, 20, and 30% to produce dark beer with chicory. Thus, hops were added to the wort in the amount of 9.3, 8.2 and 7.2 g/dal.

The optimal hop addition was determined by sensory evaluation of lager and dark beer with chicory.

Results and discussion

Physical and chemical properties of wort for lager beer

The physical and chemical properties of wort for lager beer are shown in Table 2.

The content of dried chicory in the samples was: sample 1 (control) – 0%, sample 2 – 2%; sample 3 – 4%, sample 4 – 6% of the malt. All samples almost did not differ from the control in color and acidity. With an increase in the amount of chicory to 4%, the concentration of reducing substances in the wort increased by 1.6%, and the content of amine nitrogen decreased by 0.5% compared to the control. With further increase of chicory, the concentration of reducing substances decreased due to incomplete hydrolysis of inulin at the mashing stage.

Table 2

Physical and chemical properties of wort for lager beer

Indicator	Sample 1 (control)	Samples of wort with dried chicory		
		2	3	4
Content of DM in the initial wort,%	11.0±0.2	11.0±0.2	11.0±0.2	11.0±0.2
Color, ml 0.1 M I_2/100 ml of water	0.6±0.2	0.6±0.2	0.6±0.2	0.7±0.2
Acidity, ml NaOH/100 ml of wort	2.1±0.2	2.1±0.2	2.1±0.2	2.2±0.2
Content of reducing substances, g/100 ml of wort	6.2±0.3	6.2±0.3	6.3±0.3	6.2±0.3
Amine nitrogen content, mg/100 ml of wort	21.8±0.5	21.7±0.5	21.7±0.5	21.6±0.5

Visible extract during the main fermentation of wort for lager beer

During the main fermentation in the experimental samples, the change in the concentration of DM in the wort was analysed (Figure 2).

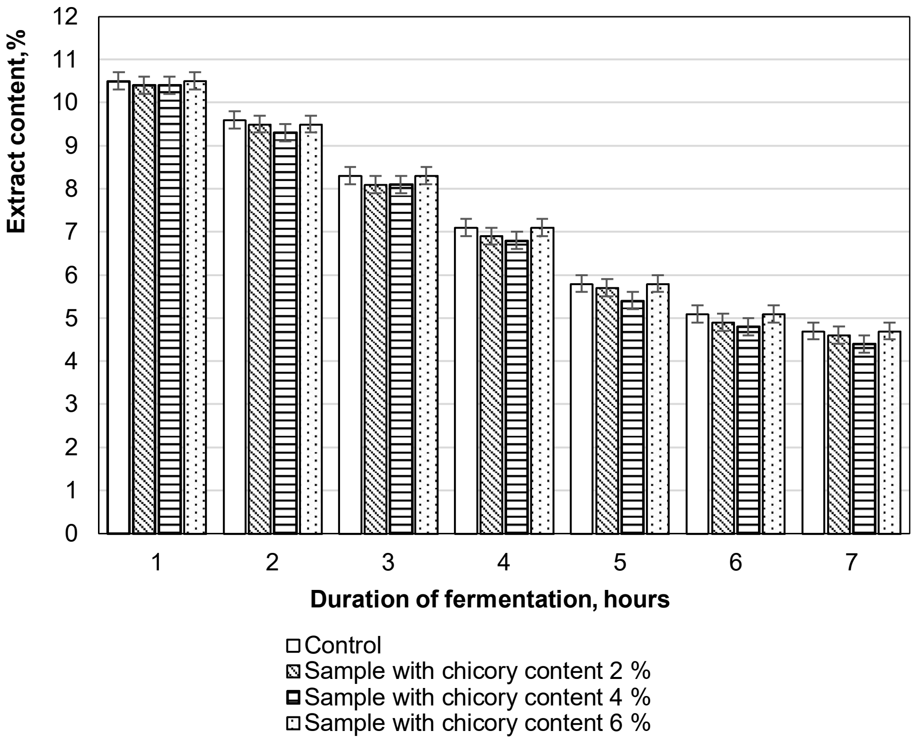

Figure 2. Dynamics of changes in visible extract during the fermentation of wort to produce lager beer

The analysis of the results showed that the sample with a content of dried chicory of 4% fermented faster and more completely than the others. Thus, on the fifth day of the main fermentation, the content of visible extract in the sample with a content of dried chicory of 4% was 5.4% (in the control – 5.7%); on the seventh day, its content in the control was 4.7%, in the experimental samples with a content of dried chicory of 2% – 4.6%, with a content of dried chicory of 4% – 4.4%, with a content of dried chicory of 6% – 4.7%.

This is explained by the fact that in the sample with a content of dried chicory of 4%, the content of reducing substances was 1.6% higher compared to the control.

Determination of physical, chemical and sensory properties of lager beer

After fermentation, physical, chemical and sensory properties of lager beer were determined (Table 3).

Table 3

Physical and chemical properties of lager beer

Indicator	Sample 1 (control)	Samples of lager beer with dried chicory		
		2	3	4
The actual extract,%	5.1±0.2	5.0±0.2	4.8±0.2	5.1±0.2
Visible extract,%	3.7±0.2	3.6±0.2	3.4±0.2	3.7±0.2
Alcohol content,% vol.	3.4±0.2	3.4±0.2	3.5±0.2	3.4±0.2
The degree of fermentation: - visible,%	66.4±0.2	67.2±0.2	68.9±0.2	66.4±0.2
- actual,%	53.8±0.2	54.4±0.2	55.9±0.2	53.8±0.2
Active acidity (pH)	4.3±0.2	4.4±0.2	4.5±0.2	4.5±0.2
Titrated acidity, ml 1M NaOH/100 ml of beer	2.1±0.2	2.1±0.2	2.2±0.2	2.2±0.2
Color, ml of 0.1 M I_2/100 ml of water	0.4±0.2	0.4±0.2	0.5±0.2	0.5±0.2
Content of carbon dioxide,%, not less than	0.30±0.5	0.30±0.5	0.33±0.5	0.30±0.5

The sample with 4% dried chicory content had a 3.2% higher alcohol content and 10% higher carbon dioxide content than the control sample. The apparent and actual degree of fermentation of this sample was 3.9% higher than that of the control. This is explained by the fact that the content of reducing substances in this sample was the highest.

According to the sensory evaluation, the best sample was the one with a dried chicory content of 4%. This sample had the highest foam stability and foam height. This is explained by the increased concentration of carbon dioxide in it compared to other samples. All samples were characterized by a rich malt flavor, clean hop aroma, and foam height that met the standard requirements. Beer samples with chicory content of 2% and 4% had a pleasant hop bitterness. The sample with 6% dried chicory content had a pronounced excessive bitterness, which is not typical for this type of beer. Thus, the sample with a 4% dried chicory content was the best in terms of physical, chemical and sensory properties of wort and finished beer.

Physical and chemical properties of wort for dark beer

The physical and chemical properties of the wort for dark beer are shown in Table 4.

Table 4

Physical and chemical properties of wort for dark beer

Indicator	Sample 5 (control)	Samples of wort with fried chicory		
		6	7	8
Content of DM in the initial wort,%	13.0±0.2	13.0±0.2	13.0±0.2	13.0±0.2
Color, ml of 0.1 M I_2/100 ml of water	4.5±0.2	4.4±0.2	4.5±0.2	4.7±0.2
Acidity, ml of 1M NaOH/100 ml of wort	2.3±0.2	2.2±0.2	2.3±0.2	2.5±0.,2
Reducing substances content, g/100 ml of wort	6.8±0.3	6.9±0.3	6.8±0.3	6.5±0.3
Amine nitrogen content, mg/100 ml of wort	19.6±0.5	19.4±0.5	19.1±0.5	18.7±0.5

The content of fried chicory in the wort was,% from the amount of light malt: 0, sample 5 (control); 3, sample 6; 5, sample 7; 7, sample 8. The color and acidity of the wort increased with the increase of the amount of fried chicory. The highest content of reducing substances was in the sample with chicory content of 3% (exceeded their content in the control by 1.5%). In samples with chicory content of 5 and 7%, their content decreased, which was explained by an increase in the content of the polysaccharide inulin and melanoidins in the wort, which are not fermented by yeast (Dack et al., 2017). The highest content of amine nitrogen was in control sample 5. As the amount of chicory in the wort increased, the content of amine nitrogen decreased. This is explained by the fact that, compared to barley malt, chicory contained a small amount of protein substances, and part of the sugars was used for the formation of melanoids (Massoud et al., 2009; Narzib, 2007). Due to the increase in the content of melanoidins, which have an acidic character and bitter taste, the acidity of the experimental samples increased (Koshova et al., 2018).

Visible extract during the main fermentation of wort for dark beer

The dynamics of change of visible extract during the main fermentation of wort for dark beer is shown in the diagram (Figure 3).

The diagram shows that compared to the control, the wort with the content of roasted chicory of 3% fermented better and faster: On the sixth day of the main fermentation, the visible extract content in this beer sample was 6.0%, while in the control it was 6.2%; on the seventh day, the extract content in the control was 5.4%, and in the experimental samples with chicory content of 3% – 5.3%, with chicory content of 5% – 5.5%, with chicory content of 7% – 5.5%.

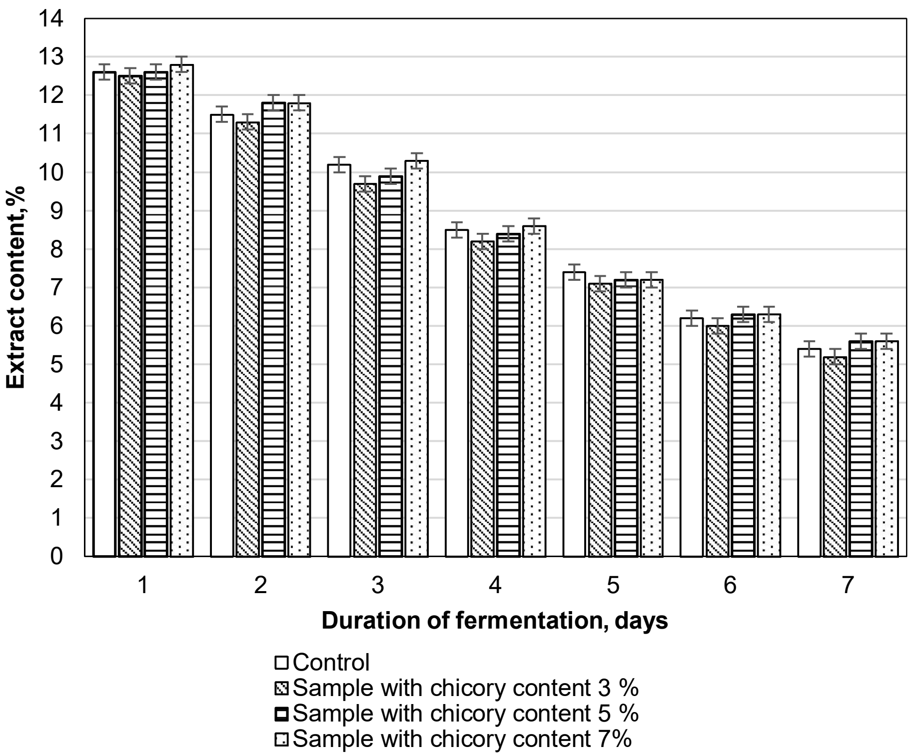

Figure 3. Dynamics of changes in visible extract during the fermentation of wort for dark beer

With the increase of chicory content to 5 and 7%, the rate of fermentation of the experimental wort samples decreased, which was explained by a decrease in the concentration of reducing substances in the wort, which were added with chicory, and an increase in the content of inulin, which was not fermented by yeast (Massoud et al., 2009; Narzib, 2007).

Determination of physical, chemical, and sensory properties of dark beer

The physical, chemical and sensory properties of the dark beer are shown in Table 5.

The beer sample with a chicory content of 3% had by 2.3% higher alcohol content and 3.2% higher carbon dioxide content than control. The visible and actual degree of fermentation of this sample was by 2.2 and 3.0%, respectively, higher than in the control. With the increase in the content of fried chicory due to the addition of coloring substances, the color of the finished beer increased, and the titratable acidity increased. At the same time, the apparent and actual degree of fermentation decreased. This is explained by the fact that an increase in the content of coloring substances led to a decrease in the activity of brewer's yeast (Dack et al., 2017; Kunze, 2007). The acidity of the sample with a roasted chicory content of 7% was higher compared to control. In addition, this beer had the highest color. This is explained by the increased content of melanoids, which have an acidic character (Dack et al., 2017; Langner et al., 2014).

Table 5

Physical, chemical, and sensory properties of dark beer

Indicator	Sample 5 (control)	Samples of dark beer with fried chicory		
		6	7	8
Content: – of the actual extract,%	5.9±0.2	5.8±0.2	5.6±0.2	5.9±0.2
– of the visible extract,%	4.2±0.2	4.1±0.2	3.9±0.2	4.2±0.2
– of alcohol,% vol.	4.3±0.2	4.4±0.2	4.3±0.2	4.2±0.2
The degree of fermentation: – visible,%	57.5±0.2	58.8±0.2	57.5±0.2	56.8±0.2
– actual,%	46.6±0.2	48.0±0.2	46.7±0.2	46.0±0.2
Acidity, ml of 1M NaOH/100 ml of beer	2.8±0.2	2.6±0.2	2.7±0.2	2.9±0.2
Color, ml of 0.1 M I_2/100 ml of water	4.6±0.2	4.5±0.2	4.6±0.2	4.8±0.2
Content of carbon dioxide,%, not less than	0.31±0.5	0.32±0.5	0.31±0.5	0.30±0.5

According to the sensory evaluation, the beer with a fried chicory content of 3% had the best taste and aroma (tasting score of 24 points). The beer prepared with the addition of chicory had a balanced pleasant hop bitterness. Beer with chicory content of 5 and 7% had an excessive and unpleasant bitterness. At the same time, all the beer with chicory were well saturated with carbon dioxide, had a thick, compact, fine-grained and stable foam. The beer with a fried chicory content of 3% was the best in terms of physical, chemical and sensory properties of wort and finished beer.

Effects of hop addition on the sensory properties of lager beer with chicory content of 4%

For the preparation of lager beer and the hopping of pure malt wort (control), bitter hops were added in the amount of 14.8 g/dal. Since the beer sample with a dried chicory content of 4% was chosen as the best in terms of physical, chemical and sensory properties, the amount of bitter hops added at the wort boiling stage was reduced by 10, 20, and 30%. The consumption of hops was 14.8 g/dal for pure malt wort, and 13.3, 12.0, 10.4 g/dal for the experimental samples. After the end of the fermentation process of young beer, the control and chicory beer samples were evaluated by sensory properties (Table 6).

According to the results of the sensory evaluation, beer with bitter hop content of 13.3 and 12 g/dal had better taste and aroma compared to others. The finished beer was characterized by a purely mild, balanced hop bitterness, which was inherent in the control.

It was found that for the preparation of lager beer, the selected mashing method and technological modes can reduce the specific consumption of valuable hops by 20% due to the introduction of bitter substances of dried chicory without deterioration of the quality characteristics of beer.

Table 6

Sensory properties of lager beer with chicory content of 4%

Amount of hops, g/dal	Taste	Flavor	Appearance	Hop bitterness	Foam
14.8	harmonious, malty, without off-flavors	clean, fresh, pronounced malty	a clear liquid with a shine, without suspensions	purely hop, soft, balanced, consistent with this type of beer	thick, stable, compact, fine-grained
13.3	harmonious, malty, without off-flavors	clean, fresh, pronounced malty	a clear liquid with a shine, without suspensions	purely hop, soft, balanced, consistent with this type of beer	thick, stable, compact, fine-grained
12.0	harmonious, malty, without off-flavors	clean, fresh, pronounced malty	a clear liquid with a shine, without suspensions	purely hop, soft, balanced, consistent with this type of beer	thick, stable, compact, fine-grained
10.4	not very harmonious, malty, without off-flavors	clean, fresh, slightly pronounced malt	a clear liquid with a shine, without suspensions	purely hop, weak, which does not correspond to this type of beer	thick, stable, compact, fine-grained

Effects of hop addition on the sensory properties of dark beer with chicory content of 3%

For the preparation of dark beer and the hopping of the control wort sample containing 95% barley pale malt and 5% caramel malt, bitter hops were added in the amount of 10.3 g/dal. Since the sample with the content of fried chicory of 3% was chosen as the best in terms of physicochemical and organoleptic parameters, the amount of bitter hops added at the wort boiling stage was reduced by 10, 20, and 30%. The hop addition was 10.3 g/dal for control, and 9.3, 8.2, 7.2 g/dal for the wort with chicory.

After the end of the fermentation process of young beer, control and chicory beer samples were sensory evaluated (Table 7).

Table 7

Sensory properties of dark beer with chicory content of 3%

Amount of hops, g/dal	Taste	Flavor	Appearance	Hop bitterness	Foam
10.3	harmonious, clean, with tones of caramel malt without off-flavor	pure hop, malt, with caramel aroma	clear liquid with a shine, without suspensions	purely hop, soft, balanced, consistent with this type of beer	thick, stable, compact, fine-grained
9.3	harmonious, clean, with tones of caramel malt without off-flavor	pure hop, malt with rye bread aroma	clear liquid with a shine, without suspensions	purely hop, moderately mild, balanced, consistent with this type of beer	thick, stable, compact, fine-grained
8.2	harmonious, malty, without off-flavor	clean, slightly hopped, malty with a rye bread aroma	clear liquid with a shine, without suspensions	purely hop, soft, weak, not very balanced, not suitable for this type of beer	thick, stable, compact, fine-grained
7.2	not very harmonious, malty, without off-flavor	clean, very slightly hopped, malty with a rye bread aroma	clear liquid with a shine, without suspensions	purely hop, soft, weak, not balanced, not appropriate for this type of beer	thick, stable, compact, fine-grained

According to the sensory evaluation, the best samples were those with a hop content of 10.3 and 9.3 g/dal. These samples were characterized by a harmonious, clean taste with tones of caramel malt present without off-flavor, clean, balanced hop bitterness that corresponded to this type of beer, and a clean, hop aroma with a rye bread flavor. Other samples did not meet the standard requirements due to insufficient bitterness for finished beer.

It was found that the selected technological methods and modes of brewing dark beer can reduce hop consumption by 10% due to the addition of bitter substances of fried chicory without deteriorating the quality of beer.

Beer sensory properties

After determining the physical and chemical properties of the finished beer and the optimal consumption of hops, the best experimental samples of light and dark beer were evaluated by their sensory properties and compared with control (Table 8).

Table 8

Sensory properties of the lager and dark beer

Indicator	Lager beer		Dark beer	
	Experimental sample*	Control*	Experimental sample**	Control**
Appearance	9	8	11	9
Flavor	3	3	4	3
Taste	8	7	10	8

*Experimental sample of lager beer: content of dried chicory 4%, hops – 12 g/dal. Control sample of lager beer: light malt content 100%, hops – 14.8 g/dal.
**Experimental sample of dark beer: content of fried chicory 3%, hops – 9.3 g/dal. Control sample of lager beer: pale malt content 95%, caramel malt content 5%, hops content 10.3 g/dal.

It was found that in terms of quality indicators, the samples of lager beer with chicory almost did not differ from the control, and the indicators of dark beer received higher tasting scores compared to the control. Based on the results of the sensory evaluation of the samples, profilograms of beer aroma and taste were constructed, which are presented in Figures 4, 5, 6, 7.

When comparing the profilograms of light beer with chicory and the control sample (Figures 4, 5), it was found that the experimental samples with an initial wort concentration of 11% by weight were characterized by a rich malt flavor and a clean hop aroma.

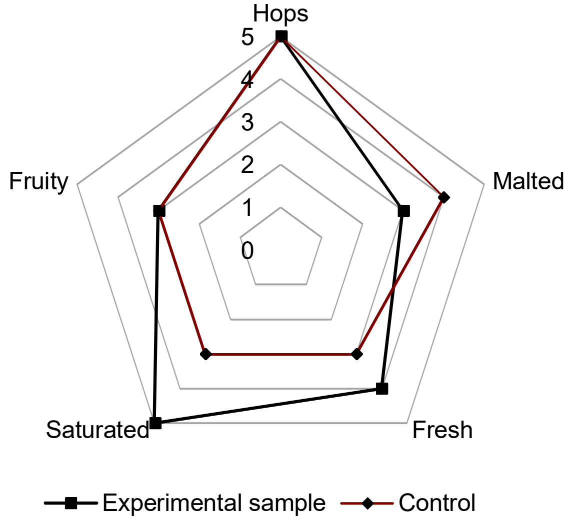

Figure 4. Aroma profile of lager beer

The control sample had a better malt flavor. Beer with chicory had a more pronounced fresh and rich flavor. The addition of chicory bittering substances did not impart excessive and extraneous bitterness to the finished beer. In the experimental sample, there was more acidity due to the addition of dried chicory, the active acidity of which was 4.3, which affected the aftertaste and sweetness of the beer. The resulting lager beer was characterized by better balance, fullness of flavor and less aftertaste.

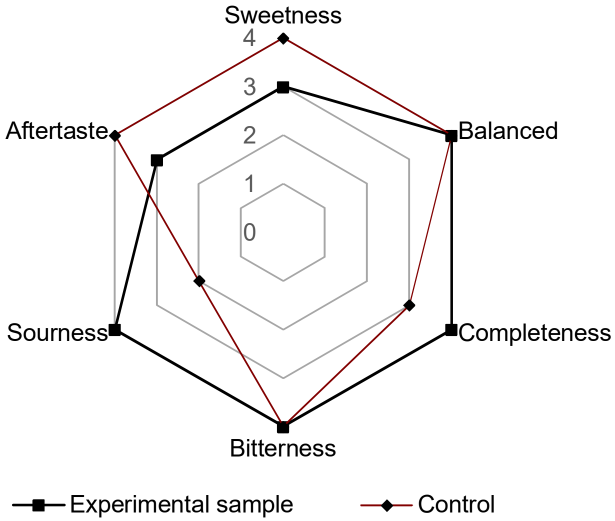

Figure 5. Taste profile of lager beer

When comparing the profilograms of dark beer with fried chicory and the control sample with caramel malt (Figures 6, 7), it was found that the hop aroma in the experimental sample was less than in the control, which is explained by the reduced content of hop aromatics in beer. At the same time, dark beer with chicory was characterized by a richer and fresher aroma due to the addition of chicoryol essential oil and aromatic substances of fried roots, which have the aroma of rye bread.

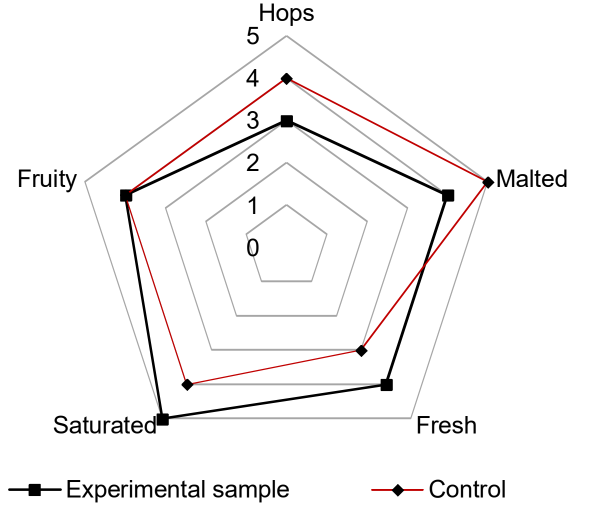

Figure 6. Aroma profile of dark beer

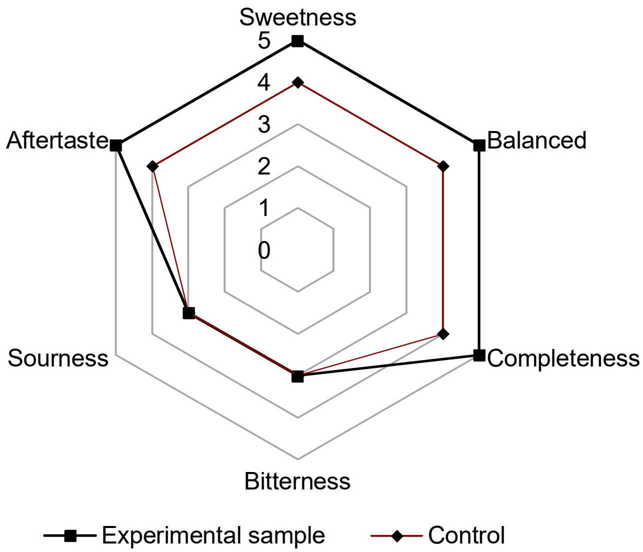

Figure 7. Taste profile of dark beer

The chicory beer sample was characterized by higher sweetness, better aftertaste, and fullness. This is due to the fact that the test sample contained more fructose and inulin. Melanoids from fried chicory give the finished beer a more pronounced aftertaste and fullness (Langner et al., 2014).

Conclusions

The use of dried and fried roots makes it possible to produce new varieties of lager and dark beer of improved quality.

1. An innovative method of preparing wort for light beer involves adding crushed dried chicory, an enzyme preparation of inulinase with an activity of 14 units/g to the mash and an inulinase pause at a temperature of 55–56 °C for 20–30 minutes.
2. The selected technological modes allow to increase the content of reducing substances in wort by 1.6%, to increase the visible and actual degree of beer fermentation by 3.9%, and the content of alcohol and carbon dioxide in the finished beer by 3.2% and 10%, respectively.
3. According to physical, chemical and sensory properties, light beer with a content of dried chicory of 4% of the malt was found to be the best. The resulting lager beer was characterized by increased foam resistance and higher foam height, and the addition of chicory bitter substances did not impart excessive and extraneous bitterness to it.
4. An improved method of brewing dark beer involves the production of an aqueous extract of fried chicory and it's mixing with the cooled hopped wort. The optimal conditions for the extraction of water-soluble substances of fried chicory are a temperature of 85–90 ºC, a hydraulic module of 1:6, and a time of 90 minutes.
5. According to physical, chemical and sensory properties, dark beer with a content of fried chicory of 3% of the malt was found to be the best. The resulting dark beer was

characterized by a more intense and fresh aroma of rye bread, greater sweetness, and better fullness of flavor and aftertaste.

6. Partial replacement of malt with chicory can reduce the use of bitter hops for light beer by 20% (from 14.8 to 12 g/dal) and for dark beer by 10% (from 10.3 to 9.3 g/dal), thus reducing the cost of lager beer.

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