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Research Article

Effect of process parameters of mashing on consumer properties and processability of polymalt extracts production process

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Abstract

The development of the technology of viscous polymalt extracts using bare-grained oats will provide the human population with a functional food ingredient and products with specified consumer properties. Existing technologies to obtain of this kind type of extract did not consider the study of the influence of temperature conditions and the duration of the stages of mashing process, using bare-grained oats in its composition. Crops of Belarusian selection were used as raw materials: barley (*Hordeum vulgare*), bare-grained oats (*Avena ativa*), wheat (*Triticum aestivum*) grain. Optimization of parameters in the production of polymalt wort based on barley, oat and wheat malt was carried out by regression analysis and weight coefficients. Dependencies of physico-chemical characteristics of oat-malt and polymalt worts on temperature and duration of mashing are established. These dependencies predict content of dry substances, maltose, amine nitrogen, protein and acidity in the process of production of worts. Optimal technological parameters were selected at the stage of barley-wheat-oat polymalt wort mashing, which made it possible to increase the dry substances by 12.5%, maltose – by 21.3%, protein – by 16.2% and filtration rate – by 25.0%. The maximum solid content 14.4%, maltose 11.4 g·(100·cm³)⁻¹, protein 1.22%, in polymalt wort achieved under the following technological conditions: (37±1)°C for 30 minutes, (44±1)°C for 50 minutes, (53±1)°C for 60 minutes, (63±1)°C for 50 minutes, (72±1)°C for 20 minutes and (78±1)°C for 60 minutes.

Keywords: oat-malt wort, viscous polymalt extract, technological parameters of mashing, consumer properties, process optimization

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Introduction

Special attention is paid by specialists from food science (Lisitsin et al. 2012; Gerasimenko et al. 2016; Kaishev and Seregin 2017; De and Tulipa 2019; Suboch 2019; Derkanosova et al. 2020; Suboch 2020; Bandy et al. 2020; Clark et al. 2020; Salar et al. 2020; Foley et al. 2021) to functional food ingredients and healthy foods, which reduce the risk of developing various diseases and ensure the entry of macro- and micronutrients into the body. In this aspect, viscous polymalt extracts that contain more than 10% to 15% of the daily intake of B vitamins and minerals, as well as essential amino acids and easily digestible carbohydrates, become important. At the same time, polymalt extracts have a very wide field of application as an ingredient in the dairy, alcohol-free and confectionary industries as a sweetener, flavoring and preservative, including for increasing the consumer value of products.

A promising raw material for obtaining viscous polymalt extracts is bare-grained oats (Kriger et al. 2018; Li et al. 2020). On the one hand, it was easier to recycle it into malt due to its low husk content, and on the other hand, unlike other malts, it contained dextrinase. This promotes deeper hydrolysis of starch and other malt substances with mashing and an increase in the yield nutritive and biological value of the finished product. Previously, bare-grained oats were not used in the technology of extracts. At the same time, the use in the composition of barley and wheat malts allows to obtain a product with high quality indicators (Mikulinich et al. 2019; Dorsaf et al. 2020; Rico et al. 2020).

Research into the production of polymalt extract was carried out by scientists of Voronezh State University of Engineering Technologies, Altai State University named after I. I. Polzunov, Kiev Technical Institute of the Food Industry, etc. (Vostrikov et al. 2011; Korotkih et al. 2014; Lokhmatova and Kamenskaya 2018). However, depending on the individual characteristics of the malted raw materials used, their composition and the rheological characteristics of the extracts, the technological parameters of the production process differ.

An important step in the production of extracts is the process of producing polymalt wort. The

temperature and duration of malt mashing significantly affect the integrity of this process. Properly selected temperature conditions ensure a more complete extraction of malt constituents, thereby the duration of saccharification and filtration reduce, increase in the yield and qualitative composition of wort.

The technological aspects of the production of polymalt wort with the combined mashing of barley, wheat and oat (husk) malt have been studied by Domaretsky (2011) and Emelyanova (1989), malt and polymalt worts – Meledina, Lokhmatova, Novikova. (Vostrikov et al. 2011; Chekina et al. 2015), Tsed et al. (2007), Korotkih et al. (2014). Malt mashing variants are based on a classic configuration adopted in the malt industry, including 4 temperature pauses: acid, protein, saccharification and mashout. However, for each malt and its further application, the temperature ranges and the duration of the mashing are different.

To maximize the extraction of all substances from malt to wort, it is necessary to use groups of cytolytic, proteolytic and amylolytic enzymes. It is, therefore, important to consider all stages when choosing technological regimes.

The authors (Domaretsky 2011, Emelyanova 1989) proposed a regime involves a mash of wheat, barley/corn and oat malt aging at temperature 44...46°C for 30-45 min, 51...53°C – 15-30 min, 62...64°C – 45-60 min, 71...73°C – not more than 30 min, 76...78°C – 10-15 min. However, it should be removed and marked, that the composition included oat malt obtained husk oats, which significantly affects the technological process.

Novikova et al. (2014) proposed a regime involves a mash of barley, triticale/corn and buckwheat malt aging at temperature of 42...45°C for 40-45 min, 52...55°C – 40-45 min, 63°C – 60 min, 70...72°C – no more than 30 min, 76...78°C – 10-15 min.

Analysis of literature sources showed that for barley and wheat malt optimal temperature ranges for enzyme action are known (Goode et al. 2005; Alyabiev et al. 2016; Panova et al. 2016; Cornaggia et al. 2019; Sun et al. 2020); for oat malt obtained from bare-grained oats, data are not unambiguous (Tsed et al. 2007; Chekina et al. 2015) and depend on its further application.

[Chekina et al. \(2015\)](#) proposed a method of mashing, involving preparation of a mash from oat malt at a temperature of 65...67°C for 60 min, 72...73°C – 30 min and 78°C – 10 min. This makes it possible to obtain wort with high concentration of maltose, which is later used for production of oat syrup.

The authors ([Tsed et al. 2007](#)) proposed a method of treating oat malt obtained from bare-grained oats, involving water-heat treatment at 90°C for 100 minutes, cooling the mass to 56°C and saccharification at this temperature. This made it possible to get a mash with good mobility for its further processing into alcohol wort.

The data show that existing polymalt extracts production technologies, including previous studies of the authors ([Morgunova and Mikulinich 2015](#); [Mikulinich et al. 2019](#)), do not affect the study of technological parameters at the stage of mashing, taking into account the use of bare-grained oats in its composition.

The purpose of the work is to develop the technology of polymalt extracts from malts of grain raw materials, which make it possible to increase the efficiency of using domestic grain raw materials and provide the population with a quality product with the specified consumer properties.

The scientific task is to evaluate the technological properties of polymalt wort using malt from bare-grained oats, wheat and barley, and to establish optimal temperature conditions and the duration of mashing in the production of extract to increase the consumer properties and technological process.

Materials and Methods

The object of the study was technological parameters of wort production using bare-grained oats.

The subject of the research was relationship of qualitative indicators of malt and polymalt worts with technological parameters at the mashing stage.

The object of experimental studies was samples of polymalt wort based on barley, oat, wheat malt and malt wort obtained from oat malt. Wort was prepared from fresh-dried malts obtained in the laboratory of the Department of Commodity

Science and Trade Organization of the Belarusian state university of food and chemical Technologies. The polymalt wort was prepared from the above crushed malts in a weight ratio of 1:1:1. Crops of Belarusian selection were used as raw materials: barley (*Hordeum vulgare*) of "Fest" variety, bare-grained oats (*Avena sativa*) of "Gosha" variety, wheat (*Triticum aestivum*) grain of "Sudarynya" variety. Grinding of malt was carried out with the help of a laboratory mill LM 202. The resulting crushed malted raw materials was divided into fractions by sieving through a steel wire sieves for 5 minutes shaking at 300 vibrations per minute.

Three sieves with different diameters of holes were used to separate the grinding of wheat and oat malt: 1-st – 2.2 mm; 2-nd – 1.0 mm, 3-rd – 0.56 mm; barley malt sieve with hole diameter: 1-st – 1.25 mm; 2-nd – 1.0 mm, 3-rd – 0.56 mm.

The residue on the sieve with a hole diameter of 2.2 mm was attributed to coarse grits, the residue on the sieve with a hole diameter of 1.0 mm – medium grits, the residue on the sieve with a hole diameter of 0.56 mm – fine grits, the residue from the sieve with a hole diameter of 0.56 mm – flour (for wheat and oat malt).

The residue on the sieve with a diameter of holes of 1.25 mm was attributed to husks, the residue on the sieve with a diameter of holes of 1.0 mm – to coarse grits, the residue on the sieve with a diameter of holes of 0.56 mm – fine grits, the residue from the sieve with a diameter of holes of 0.56 mm – flour (for barley malt).

Sieve sizes for classification of ground wheat and oat malts are taken according to ([Domaretsky 2011](#)), for barley malt – ([Ermolaeva 2004](#)).

A malt and polymalt worts was infused at the hydromodule 1:5. The following fractional composition was used at mashing oat malt: a coarse grist – 10%, an medium size grist – 30%, a fine grist – 30%, flour – 30%. Mashing of three malts in combination, the fractional composition of the bare-grained raw material was: a coarse grist – 15%, an medium size grist – 15%, a fine grist – 40% and flour – 30% ([Morgunova and Mikulinich 2015](#)).

The content of dry substances was determined by the refractometric method ([Kosminsky 2001](#)).

The content maltose was determined by the Bertrand method, the essence of which is the reduction of copper (II) from Feling's solution to copper (I) by sugars. The isolated reddish-brown precipitate Cu_2O was dissolved in an acidic solution of $\text{Fe}_2(\text{SO}_4)_3$ and the equivalent amount of FeSO_4 formed was titrated with $0.1 \text{ mol} \cdot (\text{dm}^3)^{-1}$ solution of KMnO_4 (Kosminsky 2001; Ermolaeva 2004).

The protein content was determined by the Kjeldahl method using an automatic Kejeltec 2000 unit. The essence of a method consists in a mineralization of organic matter sulfuric acid with the presence of the catalyst with generating of $(\text{NH}_4)_2\text{SO}_4$, destruction $(\text{NH}_4)_2\text{SO}_4$ alkali with allocation of NH_4OH , steaming off NH_4OH with water vapor in H_2SO_4 solution with the subsequent titration (Ermolaeva 2004).

The determination of amine nitrogen was carried out in a "copper method" based on the ability of most amino acids and peptides to form soluble complex compounds with copper. Excess copper was distilled and its amount equivalent to amine nitrogen was converted to acetic acid salt and quantified by iodometric titration (Kosminsky 2001; Ermolaeva 2004).

The filtration rate of the laboratory wort was determined by the volume of wort passed through a paper filter of average filtration FA-III in 60 minutes (Kosminsky 2001), the duration of saccharification – by an iodine solution, the acidity of the laboratory wort – by titration with $0.1 \text{ mol} \cdot (\text{dm}^3)^{-1}$ sodium hydroxide solution (Ermolaeva 2004).

The experiment was carried out in 2 stages: at the first stage, technological parameters for oat wort were studied, at the second stage- for polymalt wort. The value of the temperature and the duration of the mashing took on the basis of the technological regimes studied during the analysis for oat malt obtained from bare-grained oats. Constant technological modes were for acid pause – 37°C , 30 minutes, saccharification stages at a temperature of 72°C – no more than 30 minutes and mashout pause – 78°C , 60 minutes; values at the following temperatures – $40\ldots 45^\circ\text{C}$, $50\ldots 55^\circ\text{C}$, $62\ldots 65^\circ\text{C}$ for 60 minutes. Samples were taken to determine the physicochemical values of oat and polymalt oats every 20 minutes. The temperature between the pauses was raised at 1°C per minute.

In order to solve the problem of optimizing parameters in obtaining polymalt wort, methods of re-gression analysis and weight coefficients were applied (Morgunova 2000; Grachev 2005; Mikulinich et al. 2016). To determine a generalized indicator, all indicators were brought to a single scale and dimensionless appearance according to the formula:

$$Y_n(\tau) = (Y_{\text{solid matter}}(\tau), Y_{\text{amine nitrogen}}(\tau), Y_{\text{maltose}}(\tau), Y_{\text{acidity}}(\tau)), \quad (1)$$

where:

n is the generalized quality indicator at a certain mashing temperature;

τ is the duration of malts mashing.

Conversion of indicators to a single scale was carried out according to the formula:

$$\tilde{Y}_{\tau n} = \frac{|y_{\tau n} - y_n^*|}{y_n^*} \quad (2)$$

where:

$\tilde{Y}_{\tau n}$ is the converted value of the n -th indicator at τ -minutes;

$y_{\tau n}$ is the value of the n -th indicator at τ -minutes;

y_n^* is the control value of the n -th indicator at τ -minutes.

A single criterion of optimality was calculated by the formula:

$$Y_\tau = \sum_{n=1}^4 a_n \tilde{Y}_{\tau n} \quad (3)$$

where:

Y_τ is the optimality criterion at τ -minutes;

a_n is the weighting factor equal to 0.25 for each indicator.

Analytical determination for each test are executed in 3-fold repeatability. Experimental data processing was carried out by methods of mathematical statistics with use of standard computer programs.

Results and Discussion

Influence of temperature and duration of mashing of oat malt obtained from bare-grained oats on

physico-chemical indices of wort in temperature range 40... 65°C. The results are in Table 1.

Analyzing the results presented in table 1, it was noted that an increase in the temperature and duration of mashing increased the acidity, solid matter content, protein throughout the process and maximum values were observed at a temperature of 65°C and a duration of mashing of 60 minutes. An increase in the process parameters contributed to an increase in the amine nitrogen content until the temperature of 50°C and a maximum value was

observed at a mashing duration of 60 minutes and amounted to $18.6 \text{ mg} \cdot (100 \cdot \text{cm}^3)^{-1}$ of oat wort. However, after 50°C, the amine nitrogen content decreased, possibly due to the action of proteolytic enzymes.

The maximum maltose content was observed at a temperature of 62°C and a mashing time of 60 minutes and was $10.1 \text{ g} \cdot (100 \cdot \text{cm}^3)^{-1}$ of oat wort.

The results obtained in the study are consistent with the authors' (Chekina et al. 2015).

Table 1. Results of influence of technological parameters of mashing on physico-chemical indices of oat-malt wort

Quality indicators	τ , minutes	Temperature, °C					
		40	45	50	55	62	65
Solid matter content, %	20	3,0±0,1	4,0±0,1	6,0±0,1	7,8±0,1	9,9±0,1	11,4±0,1
	40	3,6±0,1	4,0±0,1	6,2±0,1	7,9±0,1	11,0±0,1	12,4±0,1
	60	4,0±0,1	4,6±0,1	6,4±0,1	8,5±0,1	12,0±0,1	13,5±0,1
Amine nitrogen content, $\text{mg} \cdot (100 \cdot \text{cm}^3)^{-1}$ of wort	20	11,9±0,5	12,8±0,5	13,1±0,5	12,3±0,5	12,2±0,5	10,7±0,4
	40	12,5±0,5	13,5±0,5	14,4±0,6	14,4±0,6	14,8±0,6	12,7±0,6
	60	12,9±0,6	14,2±0,6	18,6±0,7	16,9±0,7	16,2±0,7	15,4±0,6
Maltose content, $\text{g} \cdot (100 \cdot \text{cm}^3)^{-1}$ of wort	20	1,2±0,1	3,2±0,1	3,4±0,1	4,2±0,1	6,6±0,1	9,0±0,1
	40	2,1±0,1	4,3±0,1	3,6±0,1	6,6±0,1	8,4±0,1	8,9±0,1
	60	3,1±0,1	4,6±0,1	5,0±0,1	6,6±0,1	10,1±0,1	9,6±0,1
Protein content, %	20	0,14±0,01	0,21±0,01	0,26±0,01	0,76±0,01	0,78±0,01	0,79±0,01
	40	0,16±0,01	0,24±0,01	0,35±0,01	0,94±0,02	0,94±0,03	1,05±0,03
	60	0,16±0,01	0,36±0,01	0,41±0,01	0,96±0,02	1,11±0,03	1,26±0,03
Acidity, ac. unid (cm^3 of 1 $\text{mol} \cdot \text{dm}^3$ of sodium hydroxide solution on 100 cm^3 of wort)	20	1,5±0,1	1,6±0,1	1,9±0,1	2,1±0,1	2,2±0,1	2,2±0,1
	40	1,7±0,1	1,8±0,1	2,2±0,1	2,3±0,1	2,5±0,1	2,5±0,1
	60	1,7±0,1	1,8±0,1	2,1±0,1	2,3±0,1	2,5±0,1	2,6±0,1

The processing of experimental data made it possible to obtain equations establishing the dependence of acidity, solids content, maltose, amine nitrogen, protein on temperature and duration of mashing in the form of:

$$y = k_0 \cdot x_3 + k_1 \cdot x_2 + k_2 \cdot x + b, \quad (4)$$

where:

$y \in \{y_1, y_2, y_3, y_4, y_5\}$; y_1 is the solids content, %;

y_2 is the amine nitrogen content, $\text{mg} \cdot (100 \cdot \text{cm}^3)^{-1}$ of wort; y_3 is the maltose content, $\text{g} \cdot (100 \cdot \text{cm}^3)^{-1}$ of wort; y_4 is the protein content, %; y_5 is the acidity, a. un.; k_0, k_1, k_2 is the coefficients of the equation; x is the duration of mashing, minutes; b is the absolute term.

The coefficient values for equation (4) are in Table 2 and range from 0.97 to 0.99, indicating a high degree of agreement of the regression equation with the actual values.

Table 2. Coefficient values of equation (4) at different modes of mashing

Quality indicators	Coefficient values of equations											
	Mode 1				Mode 2				Mode 3			
	k_0	k_1	k_2	b	k_0	k_1	k_2	b	k_0	k_1	k_2	b
y_1	-0,0602	0,6837	-0,5132	2,8667	-0,1093	1,3008	-2,6328	5,0333	-0,1176	1,4365	-3,0888	5,8333
y_2	0,0130	-0,379	1,8652	10,43	-0,0750	0,475	-0,0500	12,20	0,0491	-1,067	5,8981	7,63
y_3	0,1125	-1,0004	3,7271	-1,550	-0,0600	0,6600	-0,7071	2,520	-0,1121	1,225	-2,4500	4,727
y_4	-0,0258	0,2637	-0,6136	0,5313	-0,0284	0,2879	-0,6320	0,5355	-0,0202	0,1952	-0,3338	0,3350
y_5	-0,0138	0,1161	-0,0887	1,470	-0,0101	0,0839	0,0154	1,550	-0,0129	0,1207	-0,1157	1,695
Note: $Mode\ 1 - \frac{40 \div 45\ ^\circ C}{20'} - \frac{44^\circ C}{50'} - \frac{50 \div 55^\circ C}{20'} - \frac{53^\circ C}{50'} - \frac{62 \div 65^\circ C}{20'} - \frac{63^\circ C}{50'}$ $Mode\ 2 - \frac{40 \div 45\ ^\circ C}{40'} - \frac{44^\circ C}{50'} - \frac{50 \div 55^\circ C}{40'} - \frac{53^\circ C}{50'} - \frac{62 \div 65^\circ C}{40'} - \frac{63^\circ C}{50'}$ $Mode\ 3 - \frac{40 \div 45\ ^\circ C}{60'} - \frac{44^\circ C}{50'} - \frac{50 \div 55^\circ C}{60'} - \frac{53^\circ C}{50'} - \frac{62 \div 65^\circ C}{60'} - \frac{63^\circ C}{50'}$												

The obtained equations can be used for determination of physicochemical indices in the production process of oat-malt wort by calculation method and prediction of physicochemical indices in the process of oat-malt wort production. Taking

into account the results of the first experience, the following process modes at the stage of oat malt mashing can be recommended, (Fig. 1), the temperature conditions of which are based on combined mashing of malts.

Figure 1. Technological modes of mashing of oat-malt wort using bare-grained oats

The results of qualitative indicators of oat-malt wort in accordance with the selected technological regimes showed that the duration of saccharification is in the permissible range of 25–28 minutes. The content of dry substances was 12.2%, maltose – 9.2 g·(100·cm³)⁻¹ of wort, protein – 0.95%, amine nitrogen – 15.2 mg·(100·cm³)⁻¹ of wort; acidity – 2.5 a. un. It is noted that malt wort obtained from bare-grained oats has a low filtration rate (less than 100 cm³·h⁻¹), which is consistent with the data (Chekina et al. 2015) and is associated with the low temperature of gleistening of oat starch, as well as the content of a significant amount of β-glucan in the composition and possibly a low content of a set of enzymes for its cleavage. The filtration rate is estimated as "normal" when, after returning 100 cm³ of the first portion of filtrate, the wort passes through the filter in 60 minutes. Otherwise, the filtration can be estimated as slow or very slow. Therefore, it is recommended to mash oat malt in the composition of malts, and to use enzymatic preparations in the production of oat-malt wort.

At the next stage, the effect of the duration of co-mashing of malts in the production of polymalt wort for protein pause – 44°C for 60 minutes, 53°C for 60 minutes, and at the saccharification stage – 63°C for 60 minutes, on the physicochemical parameters of wort was studied. Results of study of influence of technological modes of malt mashing on physicochemical indicators of barley-wheat-oat of polymalt wort are presented in Figure 2.

Analyzing the results presented in Figure 2 it was noted that with an increase in temperature from 44 to 63°C and a duration of mashing from 10 to 60 minutes, the acidity, content of solid matter, maltose and amine nitrogen increased in 1.9; 2.9; 5.6; 1.1 times, respectively.

The greatest changes in the content of amine nitrogen occurred at a temperature of 53°C and the maximum concentration was observed at a mashing duration of 20 minutes and amounted to 39.2 mg·(100·cm³)⁻¹ of wort. After 20 minutes of mashing the content of amine nitrogen decreased and by the end of the process was 29.4 mg·(100·cm³)⁻¹ of wort; the largest changes in the content of maltose – at a temperature of 63°C and by the end of the process, the composition was 11.1 g·(100·cm³)⁻¹ of wort, which is explained by the optimal temperature for the action of amylolytic

enzymes, in particular β-amylase. The solid matter content during the mashing process at temperatures of 44°C and 53°C increased uniformly, however, at a temperature of 63°C, the value varied most intensively. This may be due to intensive hydrolysis of starch.

The values of the coefficients for the equation shown in Figure 2 range from 0.81 to 0.99, indicating a high degree of agreement of the regression equation with the actual values.

The obtained equations can be used to determine the content of solid matter, maltose, amine nitrogen and acidity by calculation and to predict physicochemical parameters in the process of polymalt wort production. Using the regression analysis method, a generalized indicator in the form of a third-degree polynomial was obtained for various technological parameters of mashing.

This allows to determine the minimum of functions (Y) (the mashing process is completed when the generalized indicator reaches the minimum value):

$$Y_1 = 0,0031 \cdot x^3 - 0,0312 \cdot x^2 + 0,0472 \cdot x + 0,1579 \quad (5) \\ (R^2=0,99)$$

$$Y_2 = -0,0015 \cdot x^3 + 0,022 \cdot x^2 - 0,1081 \cdot x + 0,2321 \quad (6) \\ (R^2=0,99)$$

$$Y_3 = 0,0012 \cdot x^3 - 0,0082 \cdot x^2 + 0,0309 \cdot x + 0,2138 \quad (7) \\ (R^2=0,99)$$

where:

Y_1 is the generalized quality indicator at mashing temperature 44°C;

Y_2 is the generalized quality indicator at mashing temperature 53°C;

Y_3 is the generalized quality indicator at mashing temperature 63°C;

x is the duration of malts mashing.

Figure 2. Influence of temperature and duration of mashing on physico-chemical indices of barley-wheat-oat of polymalt wort

Figure 3. Technological modes of mashing of barley-wheat-oat of polymalt wort using bare-grained oats

As a result of the processing of the equations, the optimal mashing mode for the polymalt wort shown in Figure 3 is determined. It is different from the existing duration of the protein and maltose pauses. Results of qualitative indicators of barley-wheat-oat of polymalt wort according to selected technological modes as compared to control are given in Table 4. As a control, a sample of barley-wheat-oat of polymalt wort obtained by the author according to the technological regimes proposed by Domaretsky (2011) was used.

Table 4. Physico-chemical parameters of barley-wheat-oat of polymalt wort in accordance with the selected technological modes

Quality indicators	Control	Polymalt wort
Saccharification duration, min	15–20	10±2
Filtration rate, cm ³ ·h ⁻¹	240	300±10
Solid matter content, %	12,8	14,4±0,1
Amine nitrogen content, mg·(100·cm ³) ⁻¹ of wort	38,0	34,0±1,2
Maltose content, g·(100·cm ³) ⁻¹ of wort	9,4	11,4±0,1
Protein content, %	1,05	1,22±0,02

Analysis of the experimental data presented in Table 4 showed that the process modes of mashing selected during the studies made it possible to

increase the content of solid matter by 12.5% compared to the control, the filtration rate by 25.0%, the content of maltose by 21.3% and protein by 16.2%.

Conclusions

Physico-chemical indices of oat-malt and barley-wheat-oat of polymalt worts depending on temperature and duration of mashing are investigated. Dependencies of solid matter, maltose, amine nitrogen, protein and acidity on temperature and prolonged mashing are determined. Optimal temperatures and duration of mashing during production of oat-malt and polymalt worts are selected. It is recommended for the production of polymalt extract based on barley malt, bare-grained oats and wheat, to carry out mashing at the following modes: 37°C for 30 minutes; (44±1)°C for 50 minutes, (53±1)°C for 60 minutes; (63±1)°C for 50 minutes, (72±1)°C for not more than 30 minutes; (78±1)°C for 60 minutes. Qualitative indices of barley-wheat-oat polymalt wort are characterized by high technological properties (saccharification duration – 10 minutes, solid matter content – 14.4%, maltose – 11.4 g·(100·cm³)⁻¹ of wort, protein – 1.22%, amine nitrogen – 34.0 mg·(100·cm³)⁻¹ of wort).

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