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Research Article

Qualimetrical model of polymalt extracts assessment for optimization of technological parameters

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Abstract

In recent years the use of natural ingredients by production of foodstuff becomes evident. Perspective ingredient of multiple purpose for the food industry is polymalt extract which isn't produced by the industry of Republic of Belarus, technological aspects of its receiving from grain crops of local selection aren't researched. Researches of a share malted grain raw materials influence on quality of liquid polymalt extracts from three-component composition of barley, bare-grained oats and wheat are presented in the article. It is noted that the share of grain crops significantly influences on quality indicators of polymalt liquid extracts, in particular on indicators of nutrition and biological value. The possibility of application of qualimetrical model for optimization of technological parameters when receiving polymalt extracts with the set properties is established. Optimization of technological parameters was carried out by computer design by means of a complex indicator. The hierarchical model is developed for assessment of a complex indicator of extracts on levels. The selection of 6 inter- and 27 intra-group indicators of quality for receiving a complex indicator of quality taking into account of consumer properties and technological features of production of extract is grounded. As a result evaluation criteria are defined, single and complex indicators of quality with use of weight coefficients for each composition are calculated. The additive model of multiplicative type of complex assessment allowing to establish optimum shares of malted raw materials for a polymalt wort in composition barley-wheat-bare-grained oats is developed (30:60:10%; 25:50:25%; 30:40:30%; 25:25:50%) and to receive extract with high consumer and technological properties. Practical applications: The conducted complex researches allow to recommend the received scientific results for design of new products as components of healthy food in non-alcoholic and confectionery industry and also can be used in educational process to train highly qualified specialists.

Keywords: modeling, technological parameters, raw materials share, malt extract, hierarchical model, complex indicator.

Abbreviations: CV – coefficient of variation; TR – technical requirements

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Introduction

In recent years it is being substituted by an awareness of the need of consumption of natural foodstuffs by the person that in turn orients a food branch to use natural ingredients at food production. A new natural product and ingredient of multiple purpose for the food industry of Republic of Belarus is polymalt extract which is received from mixture of malts of various grain crops, both husk content, and bare-grained. It is known (Domaretsky 2011) that properties of extract significantly depend on structure and a share of grain raw materials. Use of bare-grained raw materials when receiving polymalt extract is useful as allows to increase an amount of a finished product and to increase its nutrition and biological value due to low husk content. However, increasing of quantitative content of bare-grained malted raw materials (up to 75%) in mixture increases duration of filtering and reduces quality of extract. Analysis of references (Grachev and Plaksin 2005; Telezhko and Kashkano 2014; Machneva et al. 2014; Zhulinskaya et al. 2016; Tokarev 2016) showed that in a situation when increasing of efficiency of process by one criterion causes deterioration in result of process by other criterion, the approaches based on mathematical modeling by means of qualimetric model are used. This model allows to reduce relative and single indicators of quality in one form. However application of qualimetric model demands a certain approach, and each technological process requires specification of criteria depending on a purpose. The aim of this work – to optimize a share of malted raw materials receiving a polymalt extract with use of qualimetric model with high consumer and technological properties.

Materials and Methods

Samples preparation. The experiment has been made on the wort consisting of three ingredients, containing 25% – 30% of barley malt to which oat malt in the amount of 10% – 60% and wheat malt in the amount of 10% – 60% from the total mass of grain raw materials. Used malt received on micromalt-house of "Seeger", BY, OJSC Belsolod.

Grinding of grain raw materials was carried out by means of a laboratory mill of LM 202. A polymalt wort was infused at the hydromodule 1:5 with observance of all main pauses while mashing. 29 indicators were identified in the prepared samples of the wort.

Methods. Standard (Kosminsky 1998; Yermolaeva 2004) and special methods are used to prepare and carry all the tests. Reducing sugars content was determined by Bertrán's method, amine nitrogen – by «a copper method», a protein – by the Keldal's method at the automatic lab device Kejeltec 2000 (GOST – (State Standard) 10846:2015 Grain and products of his processing. Method of definition of protein; Vinogradova et al. 1991), water-soluble cellulose (humic substances) – on Pris's and Mackenzie's way in Semyonova T.I. and Golenkov V.F. modification (Semyonova 1968), vitamins B1 and B2 – by a fluorometric method on the fluid analyzer «Flyuorat F-02», according to the instruction No 4398 (1987) for definition of Riboflavin in foodstuff and the instruction No 4399 (1987) for definition of thiamine in foodstuff, β -carotene – by a photocolormetric method on a photometer of Federal Energy Regulatory Commission-3 (Yermolaeva 2004), zinc, copper and iron – by an atomic emission method on a spectrometer of MDR-3 Lomo according to TR (technical requirements) BY 1472936.001 (GOST – (State Standard) 30538:1997. Technique of definition of toxic elements by an atomic and issue method), essential amino acids – by using a highly effective liquid chromatography on the Agilent 1200 chromatograph (Methodologies for Measuring Procedures, Measurement Procedure No 1363 (2000) Method by definition of amino acids in food by means of a highly effective liquid chromatography), fractional composition of proteins – by Smirnov-Ikonnikova's method which quantitative contents was determined by the Keldal's method (Yermolaeva 2004; Welikaya and Sukhodol 1983). 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.

Method of calculation of a complex indicator by optimization of technological parameters. The selection of an optimal share of malted raw materials when receiving polymalt extracts with high consumer and technological properties was carried out by computer program Excel using an integrated indicator. The method of calculation of an indicator is constructed on the principles of a qualimetry, product quality control (Fomin 2007; Podolskaya 2011), commodity examination (Evdokhova and Masansky 2013) and, in relation to development of scientific approaches of creation of polymalt extracts is developed for the first time (Morgunova and Mikulinich 2015; Mikulinich et al. 2017). The technique includes the selection of indicators of quality (intra - and intergroup) and determination of criteria of their assessment taking into account consumer properties and technological features of production, calculation of relative indicators of quality with use of a qualimetrical scale weighting factors for intra - and intergroup quality indicators; intra-group relative quality indicators according to weighting factors; intergroup relative quality indicators according to weighting factor and the calculation of an integrated indicator of quality. The hierarchical model of a technique of assessment polymalt extracts quality with significance factors on levels is presented on the Figure 1. For obtaining an integrated indicator of quality of extracts samples the following intergroup indicators of quality have been chosen: technological indicators, indicators of nutrition value, indicators of a vitamin and mineral complex, biological value and extract accessibility. At the same time, the greatest weighting factors (0,20) was appropriated to indicators of vitamin, mineral complex and to a content of essential amino acids as these indicators form the physiological, biological value and accessibility of foodstuff. The following single indicators have been appointed as intra-group technological indicators of quality:

- solids are the indicator of characterizing quality of the prepared wort and correctness of technological process conducting. For the effective course of enzymatic reactions the content of solids in a

polymalt wort shouldn't exceed 16%, however, the higher this indicator the greater solubilization of maximum quantity of substances as starch, proteins, polyphenolic substances, vitamins, mineral substances that increases quality of ready-to-use extract;

- saccharification duration is the indicator characterizing quality of the prepared wort and correctness of observance of temperature pauses while mashing. The fast duration of the saccharification (no more than 30 min.) characterizes high extent of hydrolysis of soluble and non-soluble components of the grain products amounting of a polymalt wort extract;

- rate of filtration is the indicator characterizing filtration process. Rate of filtration of mash and completeness of wort removal depends on extent of grinding of grain products and also on concentration of mash and completeness of saccharification;

- acidity is the indicator characterizing quality of the prepared wort;

- color;

- relative viscosity is the indicator characterizing quality of the prepared wort, in particular, the content of slimy colloidal substances in a polymalt wort. Viscosity increasing of a polymalt wort contribute to production costs increase of his further production;

- fraction A (the high-molecular fraction of nitrogenous substances) and polyphenolic substances. These indicators have influence on accumulation of the haze forming substances in a wort provoking his colloidal turbidity.

At the same time, the greatest weighting factor in group of technological indicators was appropriated to the rate of filtration and acidity – 0.20 as at a low rate of filtration the acidity considerably worsens, in consequence, the quality and storage properties of extract worsen too. For intra-group indicators of nutrition value the greatest weighting factors are appointed for indicators "maltose" and "protein" – 0.40 as these indicators are the main of substance, causing the energy value of extract.

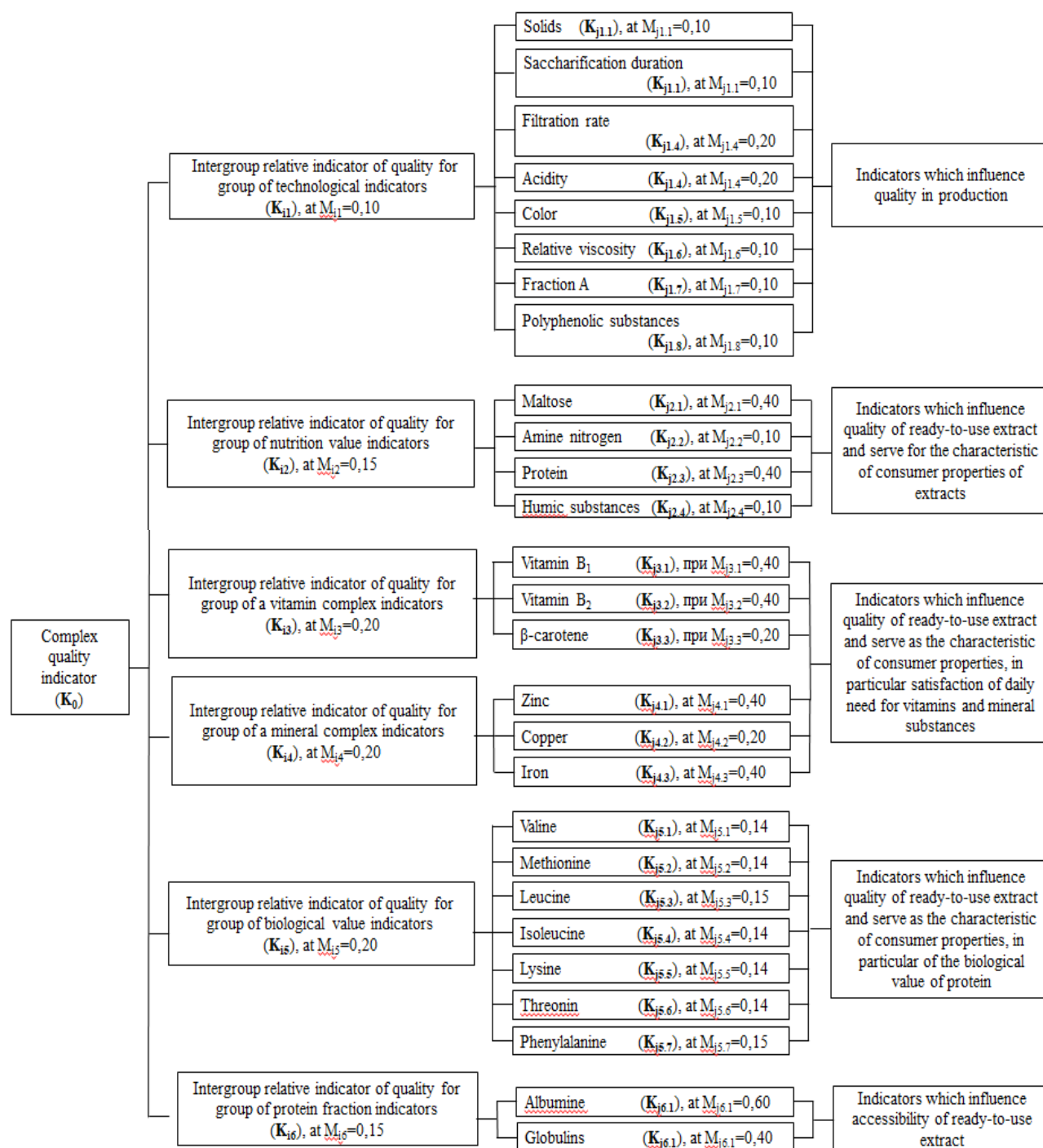


Figure 1. The hierarchical model for the evaluation of quality rating of extracts with significance factors on levels

For intra-group indicators of a vitamin complex the greatest weighting factors are appointed for indicators "vitamin B1" and "vitamin B2" – 0.40 as

polymalt extract is a source of vitamins of group B and these vitamins are in the greatest number of in the extract. The choice of vitamins is caused by

thermolability of vitamin B1 and thermostability of vitamins B2 and β -carotene, which contents will indirectly confirm the content of other vitamins of the same group. For intra-group indicators of a mineral complex the greatest weighting factors are appointed for indicators "zinc" and "iron" – 0.40 as in relation to daily need of the person for minerals of zinc and iron is necessary more. The choice of mineral substances (Zn, Cu, Fe) is caused by their deficiency in a human body and also these minerals according to (Domaretsky 2011) are in the smallest quantity in polymalt extract. For indicators of biological value the greatest weighting factors are appointed for indicators "leucine" and "phenylalanine" – 0.15 as in relation to daily need of the person of these amino acids is necessary more; for indicators of fraction of proteins the greatest weighting factors is appointed for an indicator "albumin" – 0.60 as water-soluble proteins have the highest biological value because of all essential amino acids as a part of them are in almost optimum correlation among themselves. Weighting factors of quality indicators was counted according to the experts' data. Experts who have experience in the field of technology of low alcohol and non-alcoholic production, commodity examination, and having degree of Candidate of Technical Sciences in biotechnologies of foodstuff and biologically active agents were a part of expert group; technologies of alcoholic and non-alcoholic food products; technologies of processing, storage and processing of cereal, bean cultures, cereals products, fruit and vegetable products and viticulture and also technology and merchandising of foodstuff, products of functional and specialized purpose and public catering. As the statistics indicator of individual weighting factors characterizing degree of coherence of experts used variation coefficient. The coefficient of variation (CV) of the received expert estimates was less than 0.25, therefore, coherence of the individual weighting factors appointed by experts is considered sufficient.

Calculation of a complex indicator of quality comes down to qualimetrical additive model of multiplicative type on a formula:

$$K_o = \sum_{i=1}^n M_i \sum_{j=1}^m K_j \cdot M_j \quad (1)$$

where: K_o – a complex indicator of quality (generalized); M_i – weighting factor for intergroup i of an indicator of quality; M_j – weighting factor for intra-group j of an indicator of quality; K_j – an intra-group relative indicator of quality; n – number of indicators of quality of production for intergroup indicators; m – number of indicators of quality of production for intra-group indicators.

Results and Discussion

Results on technological indicators and biochemical composition of polymalt extracts are presented in Table 1 at different shares of malted raw materials in mixture. As it will be seen from this table, all samples of a wort had saccharification degree in the normal range which was 10–25 minutes long, at the same time malt extract was marked by a high degree of a saccharification in the ratio 33:33:33% – 10 minutes. Color in compositions varied within 0.65–0.86 col. unit (cm^3 of 0.1 $\text{mol} \cdot \text{dm}^{-3}$ of solution of iodine) from golden to light-golden; acidity – within 1.8–3.1 ac. unit (cm^3 of 1 $\text{mol} \cdot \text{dm}^{-3}$ of sodium hydroxide solution on 100 cm^3 of wort); relative viscosity – 1.13–1.30 $\text{mPa} \cdot \text{s}$. The maximum issue of relative viscosity has been noted in a sample containing 60% of oat malt due to the contents of non-starch polysaccharides at him, namely gummy-substances and mucous compounds.

For control of accumulation of the haze forming substances in wort provoking colloidal turbidity the maintenance of fraction A and polyphenolic substances was defined. The maximum content of polyphenolic substances is noted in a sample of a polymalt wort in the ratio 30:10:60 %, fractions A – in the ratio 25:25:50 %. The maximum maintenance of a maltose has been recorded in samples of a polymalt wort in ratios 30:30:40%; 25:25:50% and 30:10:60% and amounted 9.6 $\text{g} \cdot (100 \cdot \text{cm}^{-3})^{-1}$ of a polymalt wort. The largest protein content is noted in the sample of a polymalt wort containing 60% of oat malt that is explained by high content of protein in initial grain; humic substances – in a sample of the polymalt wort containing 50% of oat malt.

Table 1. Influence of a share of malt in mixture on quality indicators polymalt wort in composition barley-wheat-bare-grained oats

Quality indicators	Raw materials ratio in mixture, %						
	30:60:10	25:50:25	30:40:30	33:33:33	30:30:40	25:25:50	30:10:60
	Valid value (P _j) (X ± SD)						
Saccharification duration, min	13±2	15±2	15±2	10*±1	18±1	20±1	25±1
Filtration rate, cm ³ ·h ⁻¹	265*±10	250±12	260±11	240±10	220±12	200±13	180±10
Mass fraction of solids, %	13,5*±0,1	13,2±0,1	13,0±0,1	12,8±0,1	13,0±0,1	13,2±0,1	13,2±0,1
Acidity, a. un.	1,8*±0,1	2,0±0,1	2,0±0,1	2,1±0,1	2,2±0,1	2,7±0,1	3,1±0,1
Colour, c. un.	0,86*±0,05	0,86±0,05	0,84±0,05	0,82±0,05	0,80±0,05	0,70±0,05	0,65±0,05
Fraction A, mg·(100·cm ⁻³) ⁻¹	14,8*±0,3	15,1±0,3	15,0±0,3	14,9±0,2	15,4±0,2	16,0±0,4	15,5±0,3
Relative viscosity, mPa·s	1,26±0,02	1,24±0,02	1,20±0,01	1,13*±0,01	1,16±0,01	1,25±0,02	1,30±0,03
Polyphenolic compounds, mg·(100·cm ⁻³) ⁻¹	9,0±0,3	8,1±0,2	7,1*±0,2	7,1*±0,2	7,2±0,2	8,3±0,3	10,1±0,3
Amine nitrogen, mg·(100·cm ⁻³) ⁻¹	32,5±1,1	38,6*±1,0	38,2±1,1	38,0±1,1	37,5±1,0	29,6±1,1	29,6±1,2
Maltose, g·(100·cm ⁻³) ⁻¹	9,1±0,2	9,2±0,2	9,2±0,2	9,4±0,2	9,6*±0,3	9,6*±0,3	9,6*±0,3
Protein, %	1,12±0,01	1,25±0,03	1,25±0,03	1,25±0,03	1,21±0,02	1,23±0,02	1,26*±0,02
Humic substances, %	0,28±0,01	0,37±0,01	0,33±0,01	0,30±0,01	0,42±0,01	0,47*±0,01	0,43±0,01
Vitamin B ₁ , mg·cm ⁻³	0,63±0,01	0,62±0,01	0,60±0,01	0,58±0,01	0,62±0,01	0,67*±0,01	0,65±0,01
Vitamin B ₂ , mg·cm ⁻³	0,12±0,01	0,13±0,01	0,11±0,01	0,08±0,01	0,15±0,01	0,18*±0,01	0,17±0,01
β-carotene, mg·cm ⁻³	0,026*±0,001	0,022±0,001	0,015±0,001	0,011±0,001	0,012±0,001	0,014±0,001	0,016±0,001
Zinc, mg·cm ⁻³	0,48±0,01	0,55±0,01	0,50±0,01	0,50±0,01	0,72±0,01	0,77*±0,01	0,61±0,01
Copper, mg·cm ⁻³	0,87±0,01	0,99±0,01	0,90±0,01	0,86±0,01	0,99±0,01	1,44*±0,01	0,89±0,01
Iron, mg·cm ⁻³	2,37*±0,01	2,25±0,01	1,95±0,01	1,90±0,01	2,06±0,01	2,27±0,01	2,00±0,01
Content of essential amino acids, mg·(100·cm⁻³)⁻¹:							
Valine	20,1±0,9	21,4±0,8	20,5±0,8	20,1±0,8	21,8±0,9	23,1±0,9	22,5*±0,9
Methionine	5,1±0,1	5,3*±0,1	5,0±0,1	4,2±0,1	4,6±0,1	4,7±0,1	4,6±0,1
Isoleucine	12,6±0,1	13,4±0,1	13,1±0,1	12,9±0,2	13,4±0,1	14,8*±0,1	14,2±0,1
Leucine	14,2±0,2	14,4±0,2	13,8±0,1	13,7±0,1	13,9±0,1	14,9*±0,1	14,7±0,1
Phenylalanine	9,8±0,1	11,4±0,2	11,2±0,1	10,8±0,1	13,1±0,1	13,5*±0,1	12,3±0,2
Lysine	7,7±0,1	7,7±0,1	7,4±0,1	7,2±0,1	7,6±0,1	8,2*±0,1	8,0±0,1
Threonine	7,8±0,1	7,9±0,1	7,5±0,1	7,3±0,1	7,5±0,1	8,1*±0,1	8,0±0,1
Protein fractions, % of the total soluble nitrogen content:							
Albumine	98,6±1,5	98,7±1,8	98,8*±2,0	98,7±1,7	98,6±1,6	98,7±1,9	98,7±2,0
Globulins	1,4*±0,2	1,3±0,1	1,2±0,1	1,3±0,1	1,3±0,1	1,3±0,1	1,3±0,1
Prolamina, glyutelina	Aren't found						

* = basic value (P_{bas}) X = mean, Sd = standard deviation; number of pieces ($n=3$)

As a result of an experiment on influence of a share of malted raw materials in mixture on a vitamin complex of a polymalt wort is established that with increase of a share of oat malt in mixture from 33 to

50% the content of vitamins increases by 1.2–2.3 times, and while decreasing of a share of wheat malt from 50 to 33% and increasing a share of oat malt

from 10 to 33% their contents decreases by 1.1–2.0 times.

The maximum content of vitamins B1 and B2 is noted in a sample, containing 25% of wheat malt and 50% of oat malt, β -carotene – in a sample of a polymalt mash in the ratio 30:60:10%. It is noted that with increasing a share of oat malt from 50 to 60% the content of vitamins B1 – decreases of 3.0% and B2 – of 5.6%. As a result of an experiment on influence of a share of malted raw materials in mixture on a mineral complex of a polymalt wort is revealed that with increase of a share of oat malt from 33 to 50% the content of mineral substances increased by 1.2–1.7 times, however at the content of 60% of oat and 10% of wheat malt the content of zinc, copper and iron decreased by 1.1–1.6 times. The largest content of zinc and copper was noted in a sample of a polymalt wort in the raw materials ratio of 25:25:50%; iron – in a sample of a polymalt wort in the raw materials ratio of 30:60:10%. Perhaps, such changing of vitamins and mineral substances due to the different chemical composition of malts, their compositions ratio and also is connected by interaction of vitamins with ions of metals and with enzymatic processes during mashing. At definition of biological value of composite mixtures, it is noted that valine and leucine are prevailing. Total content of essential amino acids varied from 76.2 to 87.1 mg·(100·cm³)⁻¹ of wort. That difference in amino acids composition analyzed by extracts combination is explained by features of the chemical composition and enzymatic activities of the processed grain products. The analysis of fractional structure showed that the water-soluble fraction is prevailing, the salt-soluble fraction contained in smaller amount, alcohol-soluble and alkali-soluble fractions aren't revealed. For the choice of an optimum share of malted raw materials in mixture of a polymalt wort with high consumer rates the complex indicator of quality was used which expressed as the weighted average arithmetic size.

The first stage consists on definition of the relative indicators of quality accepting value from 0 to 1. Definition was carried out on formulas:

$$K = \frac{P_j}{P_{bas}} \quad (2)$$

on a formula (2) – if at increase with an indicator, the quality of extract improves

$$K = \frac{P_{bas}}{P_j} \quad (3)$$

on a formula (3) – if at increase with an indicator, the quality of extract worsens

where: P_j – j value of an indicator (color, acidity, etc.) of extract quality; P_{bas} – basic j value of an indicator of extract quality.

The valid values (P_j) of all indicators of quality are presented in Table 1.

The basic value (P_{bas}) was accepted equal to the maximum value of an indicator of quality (filtration rate, color, content of solids, amine nitrogen, maltose, protein, humic substances, vitamins and minerals, essential amino acids, protein fractions) if with increase of an indicator, the quality of extract improves; if with increase of an indicator, the quality of extract worsens – equal to the minimum value of an indicator (saccharification duration, relative viscosity, acidity, the maintenance of fraction A and polyphenolic substances).

Definition of intra-group relative indicators of quality taking into account of weighting factors (Fig. 1) was carried out on a formula:

$$K_j = K M_j \quad (4)$$

Definition of intergroup indicators of quality was carried out on a formula:

$$K_{jm} = \sum_{j=1}^m K_j \quad (5)$$

Results of calculations of intergroup relative indicators of quality are presented in Table 2. Analyzing the data presented in Table 2 it is noted that variation of the share of malted bare-grained

raw materials has greatest impact on vitamin ($K_{jm}=0.61-0.91$) and mineral ($K_{jm}=0.70-0.98$) complexes, less –on indicators of nutrition value ($K_{jm}=0.88-0.97$).

Table 2. Results of calculations of intergroup relative indicators of quality in composition barley-wheat-bare-grained oats

Intergroup indicators of quality	Intergroup relative indicators of quality (K_{jm})						
	30:60:10	25:50:25	30:40:30	33:33:33	30:30:40	25:25:50	30:10:60
Technological indicators	0,94	0,91	0,93	0,94	0,87	0,78	0,72
Indicators of nutrition value	0,88	0,96	0,95	0,95	0,97	0,97	0,97
Vitamin complex	0,84	0,83	0,72	0,61	0,80	0,91	0,89
Mineral complex	0,77	0,80	0,71	0,70	0,86	0,98	0,78
Biological value	0,89	0,94	0,90	0,86	0,92	0,98	0,95
Indicators of protein fraction	1,00	0,97	0,94	0,97	0,97	0,97	0,72

Definition of intergroup relative indicators of quality taking into account of weighting factor (Fig. 1) was carried out on a formula:

quality for each combination was calculated by a formula:

$$K_{in} = K_{jm} M_i \quad (6) \quad K_o = \sum_{i=1}^n K_{in} \quad (7)$$

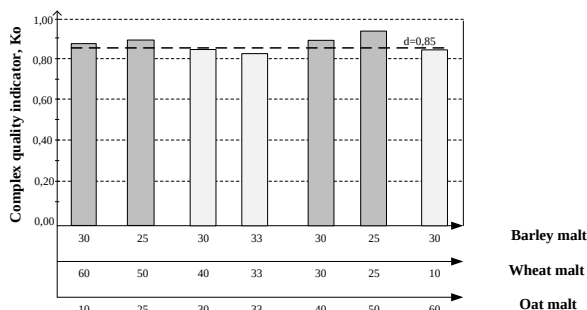
Using values of the intergroup relative indicators of quality presented in Table 3 a complex indicator of

where: K_o – a complex indicator of quality (generalized); K_{jn} – an intergroup relative indicator of quality.

Table 3. Results of calculations of intergroup relative indicators of quality according to weighting factors in composition barley-wheat-bare-grained oats

Intergroup indicators of quality	Intergroup relative indicators of quality (K_{in})						
	30:60:10	25:50:25	30:40:30	33:33:33	30:30:40	25:25:50	30:10:60
Technological indicators	0,09	0,09	0,09	0,09	0,09	0,08	0,07
Indicators of nutrition value	0,13	0,14	0,14	0,14	0,15	0,15	0,15
Vitamin complex	0,17	0,17	0,14	0,12	0,16	0,18	0,18
Mineral complex	0,15	0,16	0,14	0,14	0,17	0,20	0,16
Biological value	0,18	0,19	0,18	0,17	0,18	0,20	0,19
Indicators of protein fraction	0,15	0,15	0,14	0,15	0,15	0,15	0,11

On the basis of the received results and an application programs package of the tabular Excel processor the additive model of multiplicative type depending on a share of malted raw materials in composition barley-wheat- bare-grained oat is simulated (Fig. 2).



A share of malted raw materials in mixture, %

Figure 2. Additive model of multiplicative type depending on an ingredient ratio of malts in composition

Application of qualimetric model (on value of a complex indicator equal 0.85 that corresponds to level of quality of extract as "very good") has allowed to select optimum shares of malted bare-grained raw materials in composition: 30:60:10%; 25:50:25%; 30:30:40% and 25:25:50% providing high consumer and technological properties.

Conclusions

As a result of the conducted researches it is established that the share of grain crops significantly influences on quality indicators of polymalt liquid extracts, in particular on indicators of nutrition and biological value. The selection of 6 inter- and 27 intra- group indicators of quality for receiving a complex indicator of quality taking into account of consumer properties and technological features of production of extract is grounded. The qualimetric model allowing to establish optimum shares of malted raw materials is simulated (30:60:10%; 25:50:25%; 30:40:30%; 25:25:50%) for a polymalt wort in composition barley-wheat-bare-grained oat and to receive the extract with high consumer and technological properties.

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