UDC 663.4:64.018

BASIC INGREDIENTS AND THEIR ANALYSIS DURING THE FORMATION OF BEER QUALITY

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Abstract. The analysis and comparative description are carried out of varieties of brewing barley light malt and type 90 hops from domestic and foreign producers, as the main plant raw material that forms the quality of beer. The quality indexes of malt samples and hop pellets have been tested for compliance with applicable standards.

The obtained results indicate that the varieties of barley malt are homogeneous grain mass, do not contain moldy and damaged grains, weed impurities, have a color from light yellow to gray to yellow. Ten samples of malt of various grades for beer production have been studied in terms of mass fraction of moisture (3.2–3.7%), mass fraction of extract in dry matter of fine malt (82.4–87.5%), degree (0 9–1.2%), the mass fraction of protein substances in dry matter of malt (9.1–10.1%), the Kolbach index (39.1–40.2%), the amount of nitrogenous substances (0.70–0, 74%). It has been established that the quantitative content of β-glucans significantly differs in different varieties: the minimum amount is contained in the malt Château Wien, the maximum is Pilsner Weyermann and Munich.

According to the research results, it has been established that barley malt varieties have a pronounced malt aroma and sufficient fermentative activity and can serve as the base in the mash in the production of beer. It is proved that malt samples have an acceptable amount of toxic substances and radionuclides that will not affect the quality of the finished product. In assessing the quality of varieties of hop pellets by organoleptic indicators, the mass fraction of moisture and α-acids, it is established that the samples have the values of the indicators within the permissible limits. The samples have a cylindrical shape of different hues and approximately the same size; pure hop aroma, without an off-aroma; the color on the surface and at the boundary of the pellets meets the requirements of the standard. The mass fraction of α-acids is in the range from 3.0 to 12.7%. It is revealed that bitter and aromatic hops are used for pellet production. The samples Magnym and Hallertau Perle are classified as bitter varieties. Hop pellets of the varieties Premiant and Sladek are bitter and aromatic.

According to the results of the determination of quality indicators, the following ones have been identified as the best: malt – Munich, Pilsner, Carabohemian, hop pellets – Bramling Cross, Mandarina Bavaria and Magnym. The proposed varieties of malt and hops allow obtaining beer with high organoleptic characteristics, colloidal stability and expand the range of the industry by creating new varieties to meet the needs of the consumer.

Keywords: beer, malt barley, hops, brewer's yeast, quality indicators.

ОСНОВНІ ІНГРЕДІЄНТИ ТА ЇХНІЙ АНАЛІЗ ПІД ЧАС ФОРМУВАННЯ ЯКОСТІ ПИВА

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Анотація. Проведено аналіз та порівняльну характеристику сортів солоду пивоварного ячмінного світлого та гранул хмелю тип-90 вітчизняних і закордонних виробників, як основної рослинної сировини, що формує якість пива. Досліджено показники якості зразків солоду та гранул хмелю на відповідність чинним стандартам. Отримані результати свідчать про те, що сорти ячмінного солоду мають виражений солодовий аромат і достатню ферментативну активність та можуть слугувати базовими в затірі при виробництві пива. Доведено, що зразки солоду мають допустиму кількість токсичних речовин та радіонуклідів, що не вплине на якість готової продукції. У ході оцінювання якості сортів гранул хмелю за органолептичними показниками, масовою часткою вологи та α-кислот установлено, що зразки мають значення показників у межах допустимих норм. За результатами визначення показників якості найкращими виявлені такі сорти: солоду – Munich, Pilsner, Carabohemian, гранул хмелю – Bramling Cross, Mandarina Bavaria та Magnym. Запропоновані сорти солоду і хмелю дозволять отримати пиво з високими органолептичними показниками, колоїдною стійкістю та розширити асортимент галузі за рахунок створення нових сортів для задоволення потреб споживача.

Ключові слова: пиво, солод ячмінний, хміль, пивні дріжджі, показники якості

DOI: http://dx.doi.org/10.15673/fst.v12i1.844

Introduction. Formulation of the problem

All over the world, beer is in great demand among the population due to its taste and tonic properties. Today, the situation on the beer market in the domestic market can be compared to an industrial revolution. Craft brewing is developing rapidly, and its share in total production and sales is 0.3–0.5%. According to a

report by the private enterprise "Ukrpivo", an expert estimate of the volume of production of a hop drink in Ukraine for 12 months of 2016 is 179.8 million dal [1].

High level of competition among beer producers determines the need to constantly improve the quality of products. One of the main factors shaping the quality of the beverage is raw materials [2–6]. To date, hop-growing in Ukraine is poorly developed, and the production of malt consists of many technological operations, so its technology needs to be of the highest possible level. Today, breweries want to use raw materials mainly from foreign manufacturers, as it is of a high quality in production [7,8].

The study of the quality of the main raw material for beer production is a topical issue. The demand for malt and hops is quite high due to the opening of breweries, tasting rooms and beer restaurants, brewing the drink according to original recipes with original taste properties. The products have to satisfy the demand of the population to the full and to be of high and stable quality, enterprises must clearly control the quality of the raw materials used.

In the beer production, it is very important to choose high quality vegetable raw materials, which will make it possible to obtain beer with high quality and colloidal resistance. Promising in this direction is the use of different varieties of malt and hops used by minibreweries to create new unique varieties of intoxicating beverages according to the author's recipes [7]. Determining the quality indicators of the main raw material plays an important role, since it forms the quality of the finished beverage. This is due to the fact that raw materials of poor quality can adversely affect the quality indicators and the shelf life of the products, which is of primary importance for the production of the drink. In this regard, when developing new varieties of beer, it is necessary to comprehensively investigate the quality indicators of the main raw materials. The study of its organoleptic, physico-chemical and safety indicators will allow timely control and regulation of technological processes of beer production.

Analysis of recent research and publications

The main ingredients in the beer production are malt and hops. Malt is made from barley of different varieties, so its quality depends on the region and soil-climatic growth conditions. Among the different types of malt, barley malt is widespread due to its high fermentation properties [9,10]. It is a source of sugar that turns into alcohol and carbon dioxide, which are indicators of the quality of the finished beverage. The quality of malt affects the technological process of beer production and is of paramount importance for obtaining the required chemical composition, organoleptic properties and colloidal stability of a beverage [11,12].

After malt, hops are the second most important brewing raw materials. It is used in crushed, pressed (pellets) form or in the form of extracts. The main components of hops are bitter substances, tannins and essential oils. Among the complex of components of bitter substances of hop the most valuable are α-acids (humulon, cohumulon, adhumulon), which in the process of hopping the wort are converted into iso-α-acids, which are the main carriers of bitterness of beer. Depending on the variety, the amount of bitter substances varies from 8 to 36%, α-acids from 1.5% to 17%, and β-acids, 3–7%. Polyphenolic compounds (150–300 mg/dm^3) play an important role in the production of beer, protect bitter substances from oxidation, contribute to the stability, are involved in the process of lighting the beverage, and form its taste. Essential oil determines the specific flavor and taste of the drink, the content of which varies between 0.1 and 3.2%, depending on the variety [13]. The content of toxic elements, radionuclides and pesticides in hops is normalized by DSTU 7067:2009 "Hops. Technical conditions".

Scientists in their works [9,13–14] investigate the quality of raw materials for beer production and its influence on the properties of the finished beverage on the basis of the analysis of scientific works. It is established that the evaluation of the quality of the main plant raw materials from foreign manufacturers that are more and more often used in mini-breweries is a promising direction.

The aim of the research is studying the quality of hops and malt in the formation of beer quality, and conducting a comprehensive analysis of their level of quality, safety and compliance with existing national regulations.

To achieve this aim, it is necessary to perform the following tasks:

1) to investigate organoleptic, physicochemical indicators, the content of toxic elements and radionuclides of barley light malt from domestic and foreign producers;

2) to determine the quality indicators of hop pellets, which are sold on the Ukrainian market.

Research materials and methods

Ten varieties of malt and hop pellets of type-90 have been investigated. The samples of high quality barley light malt have been studied: № 1 – Château Pilsen, Belgium; № 2 – Malte-urop, Ukraine; № 3 – Premium Pilsner Weyermann, Germany; № 4 – Pilsen, Ukraine; № 5 – Weyermann Munich type II, Germany; № 6 – Munich, Biowin, Poland; № 7 – Castle Malting Château Wien, Belgium; № 8 – Carabohemian 170-220 Weyermann Germany; № 9 – BernarD, Sladovna Bernard a. s., Czech Republic; № 10 – Munich, Malt, Czech Republic. The research was carried out in scientific laboratories of Kharkov State University of Nutrition and Trade and the production laboratory of OLNA LLC (Kharkov).

Malt and hop pellets have been tested in accordance with the requirements:

– DSTU 4282:2004 "Malt barley malt. General specifications".

– ДR97 "Permissible levels of radionuclides ^{137}Cs and ^{90}Sr in food and drinking water. State Hygienic Norms".

– DSTU 7028:2009 "Crop production. Hop pellets. Technical conditions".

Results of the research and their discussion

The first stage in assessing the conformity of raw material quality is the determination of malt quality indicators. The appearance, smell and taste have been determined organoleptically. According to the research results, it is established that the homogeneous grain mass of all malt samples does not contain mold and damaged grains, weed impurities, has a color from light yellow to gray to yellow, malt aroma and sweetish malt taste. They can be used as basic – up to 100% in the backfill.

Depending on the technology of obtaining barley malt, its physicochemical parameters may differ significantly from each other. The most important indicators of the quality of malt are the duration of saccharification and the mass fraction of extractive substances. The duration of malt saccharification is significantly affected by the moisture of germinated grains. With increasing humidity, the saccharification duration decreases [15]. Analysis of the data of Table 1 shows that malt samples contain a small amount of moisture, which will contribute to a short saccharification process.

Table 1 – Physicochemical parameters of high-quality barley light malt samples

Parameter	Requirements o DSTU 4282:2004	Malt samples									
		№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	№ 7	№ 8	№ 9	№ 10
Sieving through a sieve (2.2 × 20 mm),%, not more than	2.0	1.7	1.4	1.3	1.4	1.1	1.7	1.7	1.2	1.6	1.3
Number of grains,%	90.0	90.3	90.2	92.0	90.5	93.6	91.5	92.1	93.4	92.6	91.7
Powdery, not less than Vitreous, no more than	2.0	1.4	1.6	1.2	1.3	1.0	1.2	1.1	1.3	1.0	1.1
Moisture content,%, no more	4.0	3.3	3.2	3.4	3.5	3.5	3.5	3.3	3.5	3.7	3.2
Mass fraction of extract in dry matter malt fine grinding,%, not less than	80.0	83.0	82.4	83.5	86.8	84.1	82.5	82.6	84.5	87.5	85.3
Difference in weight fractions of extracts in dry matter of malt of fine and coarse grinding,%	1.0–1.5	1.1	1.0	0.9	1.1	1.0	1.2	1.2	0.9	1.0	1.1
Mass fraction of protein substances in dry matter of malt,%, not more than	10.5	9.5	10.1	9.8	9.5	10.0	9.5	9.3	9.1	10.0	9.6
The ratio of the mass fraction of soluble protein to the mass fraction of protein substances in dry matter of malt (Kolbach index),%	39.0–41.0	39.5	40.1	39.3	39.7	39.2	39.6	39.7	39.1	39.3	40.2
Soluble nitrogen in malt (On a dry basis),%	0.75–0.70	0.74	0.72	0.73	0.71	0.70	0.71	0.72	0.72	0.71	0.74
Duration of saccharification, min, not more than	10	10	9	8	8	8	9	10	8	9	10
Laboratory wort: Color, cm^3 of iodine solution with a concentration of 0.1 mol/dm^3 per 100 cm^3 of water	0.18	0.14	0.14	0.16	0.17	0.17	0.13	0.14	0.16	0.17	0.13
Acidity, cm^3 of sodium hydroxide solution with a concentration of 0.1 mol/dm^3 per 100 cm^3 of wort	0.9–1.1	0.94	1.00	1.00	1.00	0.96	1.00	0.93	0.98	0.96	0.95
The final degree of fermentation,%	79–81	79.4	79.6	80.1	72.3	80.3	79.2	79.9	80.0	79.6	80.0
Viscosity MPa•s at 20 °C	1.45–1.54	1.47	1.43	1.43	1.50	1.42	1.49	1.45	1.43	1.49	1.48
The content of β-glucans, mg/l, no more	145	138	139	143	142	139	130	125	147	140	143

Powderiness is the criterion for evaluating the malt dissolution, in particular its endosperm. Uniformity of dissolution of endosperm is the most important indicator of malt quality, it influences the process of obtaining wort and beer, namely, the yield of extract, wort clarification, fermentation and after-fermentation of the drink, its filtration and colloidal stability [11]. Dark grains are not found in malt samples.

For high-quality malt, the amount of vitreous grains should not exceed 2%. An increase in their share leads to an increase in the difference in the mass fractions of the extract of fine and coarse grinding. This has a negative effect on the yield of the extract, filtration and wort lighting, fermentation, after-fermentation and lightening of the finished beer [15].

The degree of malt dissolution is characterized by the difference in yield of the extract when grouting the fine and coarse malt. The researches have shown that this indicator varies in different grades within the permissible norm. The highest percentage is found in the malt Munich Biowin and Chateau Vienna. Pilsner Weyermann and Carabohemian Weyermann have a relatively low percentage.

To assess the malt quality, the mass fraction of protein substances is important. It is determined by the modes of germination and drying of malt. A very high content leads to deterioration in the quality of the finished beverage during production and storage. In all the samples studied, the mass fraction of protein substances in the dry matter of malt does not exceed the permissible standards. This indicator is important in the case of considering it in combination with the Kolbach index.

The Kolbach index shows the ratio of soluble nitrogen to the total nitrogen content in grain products and is an indicator of the degree of protein breakdown [11]. Exceeding the permissible norms of this indicator will lead to a decrease in the flavor of beer. In prototypes, the value of the Kolbach index does not exceed the norm.

It is known that the amount of nitrogenous substances that have dissolved as a result of germination of malt is far less than of those formed during mashing. Reducing their amount in malt will lead to an increase in the fermentation process [15]. In the course of the studies, it has been found that the content of soluble nitrogen in the samples does not differ significantly. The least amount of nitrogen is in the barley malt Weyermann Munich, the highest content is characteristic of the varieties Chateau Pilsen and Munich.

According to the requirements of the current standard, laboratory wort studies have been conducted. It was found that samples of prepared wort from different malt varieties were transparent in appearance. The color and acidity indices of laboratory wort among the studied varieties did not differ significantly and did not exceed the requirements of the standard. To regulate the fermentation process, the final degree of fermentation is determined. It has been revealed that the highest indicator is the malt Weyermann Munich, the smallest, Munich Biowin. The wort viscosity depends on the content of reducing sugars, amine nitrogen and soluble protein. This figure in the malt samples did not exceed the norm.

To assess the quality of brewing malt, the requirements for the content of β-glucans are recommended. Their physiological activity consists in their positive effect on carbohydrate metabolism [11]. It is established that their quantitative content differs significantly in different varieties: the minimum quantity is contained in the malt Chateau Vienna, the maximum is Pilsner Weyermann and Munich.

Thus, basing on the results of organoleptic and physico-chemical studies, it is proved that the samples have a pronounced malt aroma and sufficient enzymatic activity to serve as the base malt in the mash, and fully comply with the requirements of the current standard. The best brands of the Bavarian manufacturer Weyermann (Germany) have been found: Munich, Pilsner, Carabohemian.

The safety of grain crops is ensured by identifying the maximum permissible levels of safety indicators, including toxic elements, radionuclides, N-nitrosamines. Among heavy metals, lead, mercury, cadmium, and zinc are especially dangerous. Copper is characterized by high toxicity and the ability to accumulate in the body if constantly consumed. That is why it is practical to investigate their content in samples of brewing barley malt (Table 2).

Table 2 – The content of toxic elements, N-nitrosamines in the high quality brewing barley light malt samples

Parameter	Requirements DSTU 4282:2004, permissible levels mg/kg, no more	Malt samples									
		№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	№ 7	№ 8	№ 9	№ 10
Mercury	0.03	0.0014	0.0011	0.0013	0.0012	0.0011	0.0015	0.0011	0.0013	0.0017	0.0011
Arsenic	0.2	0.013	0.021	0.016	0.011	0.012	0.015	0.013	0.014	0.013	0.011
Copper	10.0	3.81	3.73	3.45	3.32	3.38	3.19	3.62	3.27	3.32	3.10
Lead	0.5	0.054	0.042	0.036	0.021	0.027	0.021	0.020	0.027	0.028	0.023
Cadmium	0.1	0.018	0.011	0.013	0.014	0.011	0.012	0.010	0.018	0.013	0.012
Zinc	50.0	20.0	20.0	19.0	18.0	18.0	18.0	19.0	17.0	18.0	20.0
N-nitrosamines	0.015	0.0011	0.0017	0.0012	0.0010	0.0013	0.0012	0.0011	0.0012	0.0014	0.0017

The research results of the content of toxic elements differ, which can be explained by the place and conditions of growing plants. It has been established that the mercury content in malt test samples does not

exceed the maximum permissible concentration. However, Bernard and Munich Biowin are more capable of accumulating this microelement. Varieties of malt have almost the same ability to accumulate arsenic that does not exceed the maximum allowable level. The most polluted were the varieties Malteurop, Pilsner Weyermann and Munich Biowin. Differences in the content of copper salts are noted: the greatest amount is found in the varieties Chateau Pilsen and Malteurop, the smallest is in Munich.

It should be noted that malt samples contain salts of heavy metals in amounts significantly lower than the maximum permissible concentration. However, the ability of barley to accumulate salts of heavy metals, the number of which depends on climatic conditions and the place of cultivation, is confirmed. These differences should be taken into account when selecting organic varieties of malt.

Grain products are able to accumulate strontium more than cesium, due to the greater mobility of strontium in soils compared to cesium and ion strontium in soil [16]. The specific activity of radionuclides ^{137}Cs and ^{90}Sr in the experimental malt samples is given in Table 3.

The results obtained show that the radiological indices of varieties are almost in the same range. The highest specific activity of radionuclides has been found in the malt samples of Château Pilsen and Chateau. The lowest indicators were Pilsner Weyermann, Weyermann Munich and Carabohemian Weyermann. It has been established that malt samples have a permissible amount of toxic substances and radionuclides, and will not affect the quality of the finished product.

The next step was to study the quality of ten samples of hop pellets of different varieties. In appearance, hop samples are pellets of cylindrical shape of different hues and approximately the same size. The color on the surface and at the boundary of the pellets met the requirements of the standard. This indicates that the cones of hops were collected on time, in compliance with all requirements for drying raw materials. An important indicator of the quality of hop pellets is flavor. All the samples had a hop aroma characteristic of hop cones, without an off-aroma. The most pronounced and pleasant is the aroma of the varieties Mandarina Bavaria and Hersbrucker.

The results of the determination of the quality indicators for hop pellets of various grades are given in Table 4.

Table 3 – The content of radionuclides in the high quality brewing barley light malt samples

Parameter	The requirements of DR-97 allowable levels of Bq/kg, no more	Malt samples									
		№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	№ 7	№ 8	№ 9	№ 10
^{137}Cs	50.0	3.60	1.22	1.53	2.04	1.15	1.31	2.57	1.33	2.22	1.03
^{90}Sr	20.0	5.80	4.50	4.10	5.30	4.32	4.70	5.80	4.60	5.51	4.96

Table 4 – Parameters of quality of type-90 hop pellets of different varieties

Sample	Parameter		
	Color	Moisture content,%	Mass fraction of α-acids,% in air-dry matter, not less than
Requirements of DSTU 7028:2009	From light green to the green on the surface of the pellets and at their joint	7.0–10.0	Aromatic – 2.5; Bitter – 4.0
Clone-18, Belarus	Light green on the surface and on the fracture of pellets	8.1	Aromatic – 3.0
Mandarina Bavaria, Germany		7.5	Aromatic – 7,4
Premiant, Czech Republic	Green on the surface and on the border of pellets	8.0	Aromatic, bitter – 9,0
Saaz, Czech Republic		8.1	Aromatic – 3,1
Bramling Cross		7.5	Aromatic – 5,7
Sladek, Czech Republic		8.3	Aromatic, bitter – 5,2
Magnym, Germany	Light green on the surface and on the fracture of pellet	7.4	Bitter – 12,7
Hallertau Perle		7.9	Bitter – 8,4
Hallertau Hersbrucker	Green on the surface and on the border of pellets	7.9	Aromatic – 5,0
Williamette, United States		8.8	Aromatic – 5,0

To assess the quality of hop pellets, the mass fraction of moisture that influences the processes occurring during its storage and the quality of the finished beverage is important [17]. In all prototypes, the humidity is within the requirements and does not exceed the permissible standards. The greatest indicator was for the

pellets of hops Williamette, the smallest value – for Magnym.

The source of hop bitterness in beer is soft resins that contribute to foam retention, form the flavor of beer, suppress the growth of microorganisms, and ensure the stability of beer during storage [18]. The main indicator of the hop quality is the mass fraction of α-acids. It has been revealed that bitter and aromatic hops are used for pellet production. Samples Magnym and Hallertau Perle are classified as bitter varieties. Hop pellets of the varieties Premiant and Sladek are bitter and aromatic.

So, in the course of assessing the quality of hop pellets, it has been revealed that all samples meet the requirements of the current standard and have the value of indicators within the limits of acceptable standards. Based on the results of the determination of quality indicators, the leaders are varieties of Bramling Cross and Mandarina Bavaria aromatic hops, Magnum bitter.

Conclusion

The quality indicators of brewing barley light malt and pellets of type-90 hops as the main plant raw material are studied. They form the quality of the finished beverage. According to the studies, malt samples have a pronounced malt aroma and sufficient enzymatic activity to serve as the base in the mash. It is established that malt varieties do not exceed the permissible level of toxic substances and radionuclides. According to the results of the determination of quality indicators, the best varieties were: malt – Munich, Pilsner, Carabohemian, hop pellets – Bramling Cross, Mandarina Bavaria and Magnym.

The suggested varieties of malt and hop guarantee obtaining beer with high organoleptic characteristics and colloidal stability.

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Отримано в редакцію 15.01.2018 Received 15.01.2018
Прийнято до друку 06.03.2018 Approved 06.03.2018

Цитування згідно ДСТУ 8302:2015
Benderska O., Bessarab A., Shutyuk V. Study of the use of edible powders in tomato sauce technologies // Food science and technology. 2018. Vol. 12, Issue 2. P. 80-86. DOI: http://dx.doi.org/10.15673/fst.v12i1.837

Cite as Vancuver ctyle citation
Benderska O, Bessarab A, Shutyuk V. Study of the use of edible powders in tomato sauce technologies. Food science and technology. 2018; 12(1): 80-86. DOI: http://dx.doi.org/10.15673/fst.v12i1.837