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STUDY OF HYDROTHERMAL TREATMENT OF DRIED MALT WITH PLASMOCHEMICALLY ACTIVATED AQUEOUS SOLUTIONS

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Abstract. Studying the specific technological features and functional properties of foodstuffs made with the addition of malt is a particular priority for scientists and experts in the food processing industry. The paper deals with the peculiarities of malt processing, namely, with how it is humidified by means of plasmochemically activated aqueous solutions with different concentrations of hydrogen peroxides. The study presented deals with hydrothermal treatment of dry malt with solutions activated by the action of non-equilibrium contact plasma. In the course of this treatment, microparticles of hydrogen peroxide are formed. When in contact with the raw materials, they can form active oxygen, which is an agent stimulating biochemical transformations that activate the mashing and extraction of malt. The hydrogen peroxide concentration has been determined for the solutions used for further hydrothermal treatment of malt. It has been established which modes of hydrothermal treatment of dry germinated barley grain with plasmochemically activated aqueous solutions ensure the fastest absorption of moisture by malt. The highest water absorption rate was observed in the samples with activated water where the peroxide concentration was 600mg/l. It has been studied how the degree of malt swelling changed with the temperature and mash ratio. When ordinary water was used, the optimum mash ratio was 1:4 (65°C), and with activated water, a similar result was obtained with the mash ratio 1:3, which allows reducing water consumption in the process. The process of malt mashing has been studied, and the malt extracting capacity analysed. When plasmochemically activated aqueous solutions were used, the extracting capacity was observed to be increasing noticeably by 0.06–0.41%, depending on the mashing mode. It has been proved that the antiseptic properties of the activated water allow extra disinfection of raw materials. Using activated aqueous solutions reduces pathogen contamination of grain. It has been found that absolute destruction of mould microflora is possible at high concentrations of peroxides in the solutions. The paper highlights the operational parameters that can be used during industrial processing of malt, and gives recommendations for the use of plasmochemically activated aqueous solutions in barley malt processing.

Keywords: grain, malt, plasmochemically activated aqueous solutions, hydrothermal treatment.

Introduction. Formulation of the problem

Nowadays, the functional properties of foodstuffs have become a particular priority for food industry experts. Food technologies are considered promising if they not only meet people's need for essential nutrients, but are also health-improving and contain bioactive substances. Malt (germinated grain of different crops) is a particularly valuable raw material for various foods. This grain contains enough antioxidants that can reduce the rate of oxidation processes [1-4]. Besides, in the course of germination, enzymatic systems are activated in the grain, and complex components decompose into simpler ones easily absorbed by the human body.

Malt is the main raw material used to produce beer, kvass, alcohol, mono- and poly-malt extracts. It is used in breadbaking, in the production of yeast, special flour types, food additives, fermented milk products, and coffee substitutes. The above is due to the valuable nutritional properties of malt, which have a positive effect on the human body. Many soluble substances and trace elements contained in a grain, which are of vital importance for the human body, can be found in malt extract. They include phosphorus, magnesium, selenium, calcium, manganese, vitamin B complex, and vitamin E [1-5]. However, the use of malt in the food and processing industries is quite limited because of its short shelf life. Malt can only be stored if dried. Storage of dried malt allows a wider range of its application to manufacture various foods. To be further processed, malt should be wetted. So an important task requiring in-depth research is studying how to treat dry germinated grain hydrothermally and selecting the optimum parameters of this process. Besides, owing to the active development of intensive technologies, reducing certain technological processes (like wetting malt grain before processing) looks a very promising task to solve. Advanced technologies of malt production and processing are of much interest to the scientists [6]. Nowadays, the functional properties of foodstuffs have become a particular priority for food industry experts. Food technologies are considered promising if they not only meet people's need for essential nutrients, but are also health-improving and contain bioactive substances. Malt (germinated grain of different crops) is a particularly valuable raw material for various foods. This grain contains enough antioxidants that can reduce the rate of oxidation processes [1-4]. Besides, in the course of germination, enzymatic systems are activated in the grain, and complex components decompose into simpler ones easily absorbed by the human body.

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Analysis of recent research and publications

When barley grain is treated hydrothermally, moisture is distributed in accordance with the thermodynamic characteristics of moisture transfer in the main anatomical parts of a grain [7]. Due to its porous structure, the fruit coating of a grain can quickly absorb moisture, though cannot retain it. This function is performed by the seed coat, in particular, by the aleurone layer of the endosperm and the germ itself. So, the grain's water absorption capacity and the rate of moisture absorption are determined by the following factors: vitreosity, protein quality, derived moisture, grain size and fullness, variety and growing area. At first, grain absorbs water intensively, and then, as it becomes saturated with moisture, the rate of moisture penetration gradually decreases. The endosperm of barley is rich in proteins, which makes it harder than endosperm containing more starch. Since high-quality malt should have a mealy structure, grains of malt will absorb moisture better [7-8].

Grain is a capillary-porous colloidal body with the cellular structure and many macro- and micropores. It has sorption properties, i.e. it can absorb water and its vapours, and desorption properties (it can return moisture), so malt grain is hygroscopic [7-8]. Sorption is a complex phenomenon. It includes adsorption (concentration of water molecules on the water surface), absorption (penetration of water into the grain by diffusion), capillary condensation (absorption of moisture to form the condensate in the capillaries of the grain), and chemisorption (absorption of water by the grain, which leads to chemical changes in the grain components). As a result of adsorption and absorption, diffusion-osmotic forces make moisture enter the grain and form solid solutions with colloids: proteins, starch, fibre, pentosans, mucilage, and other macromolecular substances and grain components [5-6]. During swelling, protein substances can absorb up to 250% of moisture or more, starch 30-35%, and mucilage up to 800%. Hydrophobic substances, such as fats and other lipids, fat-soluble pigments, carotenoids, chlorophyll, fat-soluble substances, etc., do not swell in water and do not dissolve in it. Some substances contained in grain are water soluble (sugars, free amino acids, phosphates, and others). Substances capable of swelling in water make up 80-85% of a grain [9].

Heat has a specific effect on the grain. It promotes expansion of the capillaries of the coats and accelerates water penetration, which can catalyse some phenomena causing structural and biochemical changes in the grain and its components.

Steeping grain raw materials in water is the main way to affect its structure. However, this process can only be limited to destruction of water-soluble proteins. To break completely the bonds between starch and other components of raw materials, chemical solutions are used, and their choice depends on the protein content in grain. This causes forced denaturation of proteins and changes the structure of protein substances, which results in releasing starch granules. Besides, chemicals make cellular structures permeable to the diffusion transport of soluble substances into a liquid medium, i.e. into water [10].

Malt wetting has its own specific features, as grains undergo significant biochemical changes, namely, profound decomposition of the caryopsis components [7]. At the very beginning of the process, a malt grain absorbs water regardless of the temperature of the steeping agent. Despite the temperature fluctuations, the amount of moisture retained by the malt grain remains almost unchanged. The moisture held by surface tension forces is absorbed intensively by the coats and internal parts of the malt grain. At this stage, the effect of temperature is more pronounced: the water absorption rate noticeably increases at a temperature as high as 45°C. In a malt grain, moisture is bound physicochemically, which is of great technological importance for malt processing. Thus, with a change in the customary conditions (the temperature), the dynamic equilibrium changes as well. Consequently, moisture is more actively transported into a malt grain. The temperature is very important; with its increase, the bonds of the adsorbed water molecules are partially destroyed, and some of them are desorbed, which results in the formation of free moisture. The specific structural features of malt grains make it very difficult to release moisture into the environment. Weakly bound moisture affects the physicochemical properties of biopolymers, and makes the protein chains of their micromolecules more flexible and mobile. The intermolecular spaces become wider, and the density and hardness of the malt grain decreases, which affects the nature of its deformation [7-8].

There are a number of problems related to the process of hydrothermal processing of malt. One of these is uneven steaming of malt grains, and, as a consequence, irregularities in the course of the physicochemical processes in malt. To avoid this, there are various widely-used methods and techniques of distributing moisture uniformly in the grain material (malt) [7-9,11-12]. To this end, high temperatures of the wetting process are most commonly used. Though effective, this method is rather energy-consuming and significantly increases the cost of the finished product. The methods involving the use of chemical compounds can adversely affect the quality of the beverage produced. So, new intensive and less energy-consuming methods of hydrothermal treatment of malts of varying quality are still searched for.

Activation of water and aqueous solutions by plasmochemical treatment is the first step to using the properties of water without its forced chemisation with foreign chemicals. All processes occurring during this activation taking place solely in water, with no foreign chemical components added. Scientists are highly interested in the reactogenic properties of activated water, because its post-activation properties can be a starting point of a new trend in nanotechnology. Water activated by the action of non-equilibrium contact plasma has antiseptic and antibacterial properties. However, it should be noted that plasma-treated water is cluster-structured and can exhibit new properties, which have been little studied before, but might be of practical importance [6]. For example, it can accelerate the transport of moisture into the grain material, and correct the biochemical transformations in malt grains. in this case, it is especially important to study how activated water effects on the parameters of some processes in food productions, in biochemical and biotechnological industries.

Activated water has a specific composition. Reaction products that determine the reactivity of this water are the most easily detectable ones. This primarily applies to hydrogen peroxide and superoxide compounds, excited particles and radicals, which play an important role in redox processes [13-15].

When it comes to the final components in water and in aqueous solutions treated with non-equilibrium contact plasma, they can be represented as a mixture of hydrogen peroxide, superoxide components, active radicals and particles. However, their quantities (mkg and ppm) can in no way harm the human health. The specific action of these components manifests itself in several directions. First, in the course of hydrothermal treatment of grain raw materials (malt), there are some highly useful processes that intensify malt humidification by changing the very structure of water (water clusters, acted upon by contact plasma, are actively atomised, and these atomised clusters more actively penetrate through the membranes and coats of malt grains during their steeping and further preparation of green malt). These clusters contain hydrogen peroxide microparticles. When in contact with raw materials, they can form active oxygen and water, according to the relevant reaction, and the oxygen formed positively acts as an agent stimulating biochemical transformations to activate the mashing process.

Due to this effect, the hydrothermal treatment of dry malt takes less time and runs at lower temperatures. Using plasmochemically activated aqueous solutions to mash malt allows obtaining wort with increased extraction capacity. This is the result of a lower mashing temperature and of maintaining the malt's enzymatic activity. No chemical compounds, such as complex substances of inorganic or organic origin, have to be added, and no extra energy has to be consumed. This aqueous medium (plasmochemically activated solutions) inspires researchers to create environmentally friendly "green" technologies of malt production and processing. Water treated with non-equilibrium contact plasma has an antibacterial effect against mould fungi at high humidity of the germinated grain material. It is but a small part of the positive effects of the malt processing technology. Hydrothermal treatment of malt with plasmochemically activated solutions has not been used for this purpose before, so this method can be suggested as an innovative technology for processing various malts.

The purpose of the research consists in determining the parameters of plasmochemical activation of aqueous solutions for steeping (humidification) of malt and in establishing the modes of hydrothermal treatment of dry germinated grain for its further use in functional food production.

Research **objectives**:

– determining the optimal concentration of hydrogen peroxides by using solutions of different concentrations to steep (hydrotreat) malt;

– establishing the conditions of hydrothermal treatment of dry germinated barley grain by means of plasmochemically activated aqueous solutions (selecting the optimum mash ratio and temperature of processing malt with plasmochemically activated aqueous solutions);

– studying the extraction capacity of the wort in the course of malt mashing with the use of plasmochemically activated aqueous solutions;

– determining the contents of reducing substances in different modes of malt mashing with the use of plasmochemically activated aqueous solutions;

– analysing the effect of plasmochemically activated aqueous solutions on the pathogen complex of malt during its processing.

Research materials and methods

As the object of research, we used dry germinated barley grain (malt) produced according to a special technology [16] in compliance with Technical Specifications 30664090-001-2012 (*Ukrsolod*, LLC) "Pale barley malt."

Water was activated using a laboratory plasmochemical unit (Fig. 1).

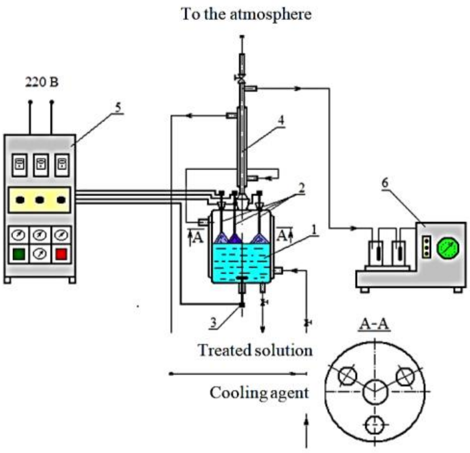

Fig. 1. Layout of the laboratory three-arc plasmochemical unit:
1 – reactor; 2 – anodes; 3 – cathode; 4 – reflux condenser; 5 – power supply; 6 – vacuum pump

Tap water was activated in plasma discharges of reduced pressure, with the voltage 1000–1200V and current intensity 30.0-200.0mA, with the subsequent transition (as the electrical conductance increased) to the mode of non-equilibrium contact plasma with the following parameters: voltage 400-600V, current up to 150mA.

The hydrogen peroxide content (concentration) in the activated water was determined by iodometry [17].

The degree and rate of swelling of dry germinated grain were determined by the method developed in the Belarusian branch of the All-Russian Milk Research Institute (VNIMI) [8]. For this purpose, 1 g of weighed sample of dry germinated grain was placed in a centrifuge test-tube, where distilled water was added in the ratio 1:1-1:5. After setting the temperature parameters, the sample was kept in a steam convection apparatus for up to 48 hours. The following temperature parameters were chosen: 25±1°C; 35±1°C; 45±1°C; 55±1°C; 65±1°C; 75±1°C; 85±1°C. Then, the test-tubes were centrifuged for 5 minutes at 1000 min^{-1}. The centrifugated fluid was carefully discharged. To determine the moisture content in the residue, 10 g of malt was ground in a mill *Pirouette* and then dried in the electric semiautomatic drying cabinet *Brabender* (at 130°C for 40 min) [17]. The degree of swelling was determined by formula:

$$A = (m - ms) \times 100 \div ms, \quad (1)$$

where A – degree of swelling, %;
m – mass of grain after hydration, g;
ms – mass of dry grain, g.

The mass of dry germinated grain after swelling was determined by formula:

$$m = ms \times (100 - B) \div (100 - Bg), \quad (2)$$

where m – mass of grain after swelling, g;
B – mass fraction of moisture in dry grain, %;
Bg – mass fraction of moisture in hydrated grain, %.

Mashing was performed on a laboratory mashing apparatus under the following conditions: 52°C – protease rest (20-30min), 62°C – β-amylase rest (10–30min), 72°C – saccharification rest (max 60 minutes, till complete saccharification).

The extraction capacity of the wort was determined with the use of a hydrometer (saccharometer) AST-1 [17]. The mass fraction of reducing substances (in terms of maltose) was determined by Wiltshtetter and Schudl's iodometric method [17]. The microbiological characteristics of the malt were found by conventional methods [18-20].

Results of the research and their discussion

The characteristics of activated water used to steep the malt are given in Table 1.

The first stage of the work was to determine the optimal concentration of hydrogen peroxides by using solutions of different concentrations (300–700mg) to steep (hydrotreat) the malt. The rate of water absorption of the experimental dry malt samples was determined at the concentration of peroxides within the limits 300–00mg (Fig. 2).

Table 1 – Characteristics of water activated by non-equilibrium contact plasma

Experiment	Water	Activation time, minutes	Hydrogen peroxide concentration, mg/l
1 (control)	Tap water	–	–
2	Activated water	10	300
3	Activated water	20	400
2	Activated water	30	600
4	Activated water	40	650
5	Activated water	60	700

Analysis of the data in Fig.3 has shown that the highest rate of water absorption was observed in the samples with activated water where the peroxide concentration was 600mg/l. As a result, it was decided to use the active water with this very peroxide value in the technological process.

Since we have studied the hydrothermal treatment of malt, i.e. grain that has already undergone certain biochemical changes, our attention should be paid to the peculiarities of water absorption of malts of different biochemical composition. Table 2 shows how changes in the degree of swelling of dry barley malt depend on the mash ratio, temperature, steeping duration, and humidifying agent: in fact, the tap water has been compared with the water activated by non-equilibrium contact plasma.

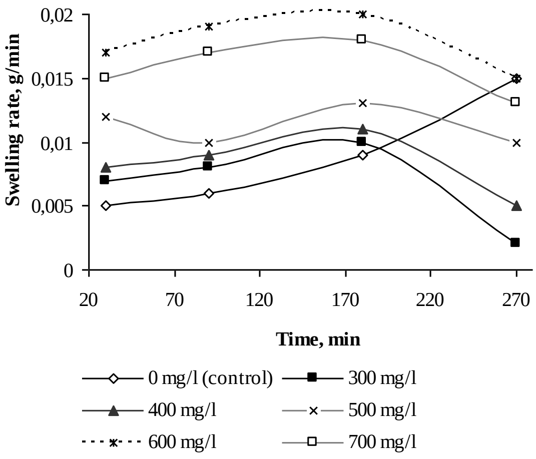

Fig. 2. Rate of water absorption of the activated solutions by the dry barley malt at different concentrations of hydrogen peroxide (n=3)

After analysis of our findings (Table 2), we can conclude that when the water activated under the action of non-equilibrium contact plasma is used as the humidifying agent, the degree of swelling of the germinated grain increases. The processes occurring in malt under the action of activated aqueous solutions are explained as follows:

I. Acceleration of water diffusion into grain. The chaotic motion of ions in the activated water allows accelerating the diffusion of water into the middle of malt grain due to more active influx of charged particles to the grain surface. This aspect confirms that when activated water is used as a humidifying agent, due to its specific composition, moisture is more actively transported into the middle of malt grain.

II. Since the activated water is alkaline by nature (as it has peroxide and superoxide compounds in its composition), an alkaline solution promotes additional washing of malt. Hydrogen peroxide, which is a component of activated water, acts as an oxidant and, as a result, improves the grain purification. Alkaline environment does not have any significant negative impact on the further quality of malt.

So, the degree of swelling in all malt samples steadily increased by 2–4%, which allowed reducing the time needed to wet the grain material and made intensive wetting possible even at lower temperatures.

Analysing the moisture absorption of different samples, we can also conclude that when using ordinary water, the optimum mash ratio is 1:4 at the temperature 65°C. When water activated by the action of non-equilibrium contact plasma is used, we observe that a similar result can be obtained with the mash ratio 1:3, which allows significantly reducing water consumption during wetting the malt processed.

An important aspect in the malt processing technology is the amount of water involved in wetting the grain material. We have investigated the water absorption at mash ratios with ordinary and activated water added. For comparison, the optimum mash ratio 1:4 was taken.

The dynamics of changes in the water absorption activity at the mash ratio 1:4 has the largest values. This proves the right choice of the ratio of the malt amount and the volume of water spent to steep the grain material before its further use in the process. Analysis of the data obtained confirms the stable upward trend in the malt's moisture absorption when using plasmochemically activated aqueous solutions. This positive technological result allows recommending activated water for the further use at grain processing plants.

Mashing of malt is another important process involving water. Mashing is the main process stage in wort preparation. One of the main parameters of malt and wort is their extraction capacity. The standard extraction capacity for hopped wort is 12%, and the efficiency of a brewery is calculated on the basis of the yield of extract 74–79% [1-2].

We have studied the extraction capacity of the wort during malt mashing using plasmochemically activated aqueous solutions. The mashing conditions were as follows: 52°C – protease rest, 62°C – β-amylase rest, 72°C – saccharification rest (mash ratio 1:4). The data on how the extraction capacity of barley malt depends on the mode of mashing are given in Table 3. With an increase in the duration of some rest periods, the extraction capacity decreases, which can be due to gelatinisation of starch. With 15-minute mashing, starch granules only swell as a result of adding water, but there is no complete liquefaction, and most enzymes are inactivated. Making more enzymatic rests has a positive effect on the extraction capacity and the amount of reducing substances [21-23].

Based on the data from Table 3, we can conclude that high extraction capacity is achieved at short time and high temperature of mashing. With the use of plasmochemically activated aqueous solutions, the pronounced dynamics of extraction capacity increase is observed. At the temperature above 60°C, the enhanced formation of colloidal nitrogen compounds of high molecular weight takes place, which can reduce the extraction capacity of the wort [1,21]. The use of activated water reduces the mashing temperature, allowing increasing the extraction capacity by 0.02–0.1%, which is a positive technological result.

Table 4 shows the content of reducing substances in different mashing modes. Considering these tables, it is necessary to pay attention to the peculiarities of the enzymatic process of splitting during mashing. β-amylase is active at the temperature 60–65°C, but due to its thermal lability, it decomposes at 65°C in 40–60 minutes [23]. During mashing at 65.5°C, α-amylase is suppressed by 50% after 20–30 minutes, and β-amylase after 10 minutes. At extremely high temperatures of 80–90°C, α-amylase and β-amylase remain active for up to 10 minutes [23-27].

Table 2 – Changes in the degree of swelling of dry germinated barley grain depending on the temperature and mash ratio (the humidifying agent is tap water/activated water)

T, °C	Mash ratio	Degree of swelling, %						
		1 hour	**3 hours**	**6 hours**	**12 hours**	**24 hours**	**48 hours**	**60 hours**
25	1:1	11/14	15/18	27/29	37/39	48/51	51/54	49/52
	1:2	14/18	16/19	33/37	38/41	52/55	52/56	50/53
	1:3	17/21	21/25	37/40	43/45	53/55	56/58	51/54
	1:4	21/25	23/27	38/42	45/48	51/55	55/58	55/58
	1:5	18/21	25/28	38/41	43/46	50/24	53/55	53/56
35	1:1	31/33	41/45	56/59	68/71	85/89	91/95	82/86
	1:2	34/37	43/46	65/68	73/76	88/91	98/101	95/98
	1:3	32/35	45/48	67/70	75/78	96/100	101/104	97/101
	1:4	34/38	51/55	73/76	79/83	97/101	110/112	100/103
	1:5	32/36	45/49	68/72	76/80	91/95	103/104	93/96
45	1:1	47/50	73/77	91/95	103/106	123/127	121/125	117/120
	1:2	52/55	77/80	87/91	95/98	125/128	127/130	125/128
	1:3	54/58	75/79	89/83	93/96	129/132	141/144	134/136
	1:4	53/57	76/80	87/90	91/94	125/128	133/136	127/130
	1:5	48/52	74/77	85/88	87/90	120/123	126/128	124/127
55	1:1	52/55	77/80	114/117	127/131	131/134	142/145	135/138
	1:2	57/60	85/88	117/120	133/137	143/147	155/158	155/158
	1:3	58/61	89/92	123/125	137/141	155/158	167/170	167/189
	1:4	62/67	91/95	125/129	139/143	159/163	173/177	173/177
	1:5	54/58	89/94	119/123	133/136	151/154	171/175	165/168
65	1:1	61/65	83/86	127/130	145/147	147/151	159/163	154/158
	1:2	62/65	85/88	145/148	156/160	171/175	179/182	179/181
	1:3	64/**68**	111/**115**	147/**150**	163/**167**	182/**185**	190/**193**	189/**192**
	1:4	**65/68**	**105/108**	**149/152**	**167/170**	**180/183**	**193/196**	**190/193**
	1:5	60/63	95/98	143/146	165/168	179/183	191/193	185/188
75	1:1	58/61	77/80	107/110	115/118	133/136	141/143	135/138
	1:2	55/58	75/79	115/119	124/127	145/148	145/149	144/147
	1:3	57/61	87/91	117/120	129/133	153/156	154/158	155/159
	1:4	62/66	95/98	119/123	133/137	151/154	157/160	151/154
	1:5	59/63	87/91	115/118	125/127	150/152	150/152	141/143
85	1:1	53/56	73/76	79/82	83/85	123/126	123/125	121/124
	1:2	53/55	77/80	80/84	86/90	125/129	126/128	125/127
	1:3	55/59	79/83	85/89	94/98	133/136	141/145	136/139
	1:4	57/60	83/86	95/99	105/108	129/132	133/135	123/126
	1:5	53/55	77/80	87/91	97/101	123/126	123/127	120/124

Table 3 – Extraction capacity of wort depending on the mashing mode, %

Mashing mode, °C	Time, min		
	15	30	60
Tap water			
52/62/72	12.38	12.91	13.22
62/72	13.51	12.97	12.95
72	13.53	12.54	12.79
Plasmochemically activated water			
52/62/72	12.45	12.99	13.28
62/72	13.65	13.01	13.05
72	13.67	12.95	12.86

Table 4 – Dependence of reducing substances on the mashing mode, %

Mashing mode, °C	Time, min		
	15	30	60
Tap water			
52/62/72	81.42	81.32	79.51
62/72	76.71	76.32	77.31
72	71.85	67.81	68.95
Plasmochemically activated water			
52/62/72	83.45	82.77	81.55
62/72	77.82	76.95	79.37
72	75.89	68.91	68.83

Analysing the data in Table 4, we should emphasise the increase in the amount of reducing substances when using plasmochemically activated aqueous solutions. It is explained by more active splitting of starch by enzymes. Since the use of active water reduces the mashing temperature, it will allow enzymes to retain their ability to decompose complex substances remaining in the malt. As a consequence, we can speak of the expected increase in the extraction capacity – the increased content of reducing substances in the wort. Comparing the results with the findings in similar studies [7-9,12], it should be noted that the technology suggested increases the amount of reducing substances by 0.5-4%, and this, undeniably, positively characterises the technological solution presented.

Besides, it should be noted that plasmochemically activated aqueous solutions have antiseptic properties, which further reduces the microbial contamination of malt and has a positive effect on the microbiological parameters of the finished product. So, the quantity of contaminated malt grains is significantly reduced, when using activated aqueous solutions (Table 5). Using plasmochemically activated aqueous solutions led to a decrease in the pathogen contamination of malt grain (Table 5). It has been found that absolute destruction of mould microflora is possible at high concentrations of peroxides in the solutions. After disinfection, the malt contains no peroxides. This proves the chemical purity and safety of the disinfectant and the possibility of obtaining competitive raw materials meeting the European standards and food requirements.

Table 5 – Effect of plasmochemically activated aqueous solutions on the pathogen complex of malt, % of contaminated grains

Pathogens	Control	Peroxide concentration in plasmochemically activated aqueous solutions, mg/l						
		100	200	300	400	500	600	700
Aspergillus	90	63	31	11	0	0	0	0
Alternaria	32	23	12	7	0	0	0	0
Penicillium	21	9	5	1	0	0	0	0
Fusarium	7	3	2	1	0	0	0	0
Mucor	35	20	11	5	0	0	0	0

Conclusion

It has been proved how practical it is to use plasmochemically activated aqueous solutions in hydrothermal treatment of dry barley malt:

1. The optimal concentration of hydrogen peroxides has been determined by using the solutions of different concentrations to steep malt (subject it to hydrotreatment). It has been found that the optimal activation time is 30 minutes, at the concentration of peroxides 600mg/l.

2. The modes of hydrothermal treatment of dry germinated barley grain have been determined. When using the ordinary water, the optimum mash ratio is 1:4, and when the water is activated by non-equilibrium contact plasma, a similar result can be obtained with the mash ratio of 1:3. This allows significantly reducing the water consumption while wetting the malt processed. The optimum temperature of hydrothermal treatment of malt is 65°C.

3. It has been studied what extraction capacity the wort has when the malt is mashed with the use of plasmochemically activated aqueous solutions. When plasmochemically activated aqueous solutions are used, the extracting capacity increases noticeably by 0.06–0.41%, depending on the mashing mode. Using plasmochemically activated aqueous solutions to mash malt allows obtaining wort with increased extraction capacity. This is the result of a lower mashing temperature and of maintaining the malt's enzymatic activity.

4. The contents of reducing substances have been studied for different modes of mashing the malt with the use of plasmochemically activated aqueous solutions. It should be noted that using the plasmochemically activated aqueous solutions led to a 0.63–4.04% increase in the amount of reducing substances.

5. It has been analysed how plasmochemically activated aqueous solutions effect on the pathogen complex of malt during its processing. Using plasmochemically activated aqueous solutions allowed reducing the contamination of the malt grain with pathogens (*Aspergillus*, *Alternaria*, *Penicillium*, *Fusarium*, *Mucor*). It has been found that absolute destruction of mould microflora is possible at high concentrations of peroxides in the solutions (400-700mg/l).

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ДОСЛІДЖЕННЯ ГІДРОТЕРМІЧНОЇ ОБРОБКИ СУХОГО СОЛОДУ ПЛАЗМОХІМІЧНО АКТИВОВАНИМИ ВОДНИМИ РОЗЧИНАМИ

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Анотація. Дослідження особливостей технології та функціональних властивостей продуктів харчування з додаванням солоду є об'єктом підвищеної уваги вчених та фахівців харчопереробної промисловості. У роботі наведено особливості переробки солоду, а саме процесу його зволоження, при використанні плазмохімічно активованих водних розчинів з різною концентрацією пероксидів водню. Представлено дослідження, що стосуються гідротермічної обробки сухого солоду розчинами, активованими під дією контактної нерівноважної плазми. У процесі такої обробки утворюються мікрочастки пероксиду водню, які при контакті з сировиною здатні утворити активний кисень, який є стимулювальним агентом біохімічних перетворень для активації процесу затирання та екстрагування солоду. Визначено концентрацію пероксиду водню в розчинах, які в подальшому використовувались для гідротермічної обробки солоду. Підібрано режими гідротермічної обробки сухого пророщеного зерна ячменю плазмохімічно активованими водними розчинами, при яких солод найшвидше поглинає вологу. Найбільша швидкість водопоглинання спостерігалась у зразках із активованою водою, що мала концентрацію пероксидів 600 мг/л. Досліджено зміну ступеня набухання солоду залежно від температури та гідромодуля. При використання звичайної води оптимальним гідромодулем є 1:4 (65°С), при використанні активованої води, аналогічний результат отримано при гідромодулі 1:3, що дозволяє скоротити витрати води на технологічний процес. Досліджено процес затирання солоду, проаналізовано екстрактивність. Так, при використанні плазмохімічно активованих водних розчинів спостерігається виражена динаміка збільшення екстрактивності, в залежності від режиму затирання на 0.06–0.41%. Доведено, що антисептичні властивості активованої води дозволяють додатково дезінфікувати сировину. При використанні активованих водних розчинів знижується патогенна зараженість зернового матеріалу. Відмічена можливість абсолютного знищення пліснявої мікрофлори при високій концентрації пероксидів в розчинах. У роботі висвітлено технологічні параметри процесу, які можуть бути використані при промисловій переробці солоду. Наведено технологічні рекомендації щодо використання плазмохімічно активованих водних розчинів в процесі переробки ячмінного солоду.

Ключові слова: зерно, солод, плазмохімічно активовані водні розчини, гідротермічна обробка.

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