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FEATURES OF OBTAINING MALT WITH USE OF AQUEOUS SOLUTIONS OF ORGANIC ACIDS

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Abstract. Recently, the traditional formulations of essential food products are actively including malt – a valuable dietary product rich in extractives and hydrolytic enzymes, obtained by germination in artificially created conditions. Containing a full set of essential amino acids and a high saccharifying ability of malt, obtained from grain cereals, determines its wide use in the production of beer, alcohol, mono- and poly-malt extracts, bakery products, special types of flour, food additives, cereals, non-alcoholic beverages, lactic acid products and, in particular, in the production of natural coffee substitutes. However, the classical germination technology, which includes 2-3 days of soaking and 5-8 days of germination due to the considerable duration and laboriousness of the process, does not meet the requirements of modern technology and the constantly growing rates of industrial production, so this problem requires finding new and improving existing scientific and technical solutions. The features of malt production using organic acids of different concentrations are presented. The malt production technology has been analyzed and investigated. It includes washing, disinfection, air and water soaking of grains, germination and drying. The feature of the technology under investigation is using of aqueous solutions of butadiene, 3-pyridinecarboxylic acid and pteroylglutamic acid. The results of the inquiry of the effect of these organic acids on energy and the ability of germination of the grain are presented. The optimal values of concentrations of active substances in solutions are revealed. The influence of organic acids on the absorption of grain moisture has been investigated. It has been established that in comparison with the classical technology, the use of these acids as a growth stimulator can reduce the overall length of the reproduction process of the material from 1.5 to 2 times and increase the yield of flour grains in the batch of malt.

Key words: cereal cultures, growth stimulator, succinic acid, 3-pyridinecarboxylic acid, pteroylglutamic acid, germination energy, germination ability, grain flour content.

ОСОБЛИВОСТІ ОДЕРЖАННЯ СОЛОДУ З ВИКОРИСТАННЯМ ВОДНИХ РОЗЧИНІВ ОРГАНІЧНИХ КИСЛОТ

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Анотація. Наведено особливості виробництва солоду з використанням органічних кислот різної концентрації. Проаналізовано та досліджено технологічний процес пророщування зерна, що включає миття, дезінфекцію, почергове повітряно-водяне замочування зерна злакових культур, його пророщування і сушіння. Особливістю досліджуваної технології є застосування в якості дезінфектанту і стимулятора росту на етапі замочування зернового матеріалу водних розчинів бутандіової, 3-піридинкарбонової та птероілглютамінової кислот. Наведені результати дослідження впливу вказаних органічних кислот на енергію та здатність проростання зерна. Наведено оптимальні значення концентрацій діючих речовин у розчинах. Досліджено вплив органічних кислот на процес поглинання зерном злакових культур вологи. Встановлено, що у порівнянні з класичною технологією, застосування органічних кислот у якості стимулятору росту дозволяє скоротити загальну тривалість процесу пророщування матеріалу в 1,5-2 рази і збільшити вихід борошнистих зерен у партії солоду.

Ключові слова: злакові культури, стимулятор росту, бутандіова кислота, 3-піридинкарбонова кислота, птероілглютамінова кислота, енергія проростання, здатність проростання, борошнистість зерна.

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Introduction. Formulation of the problem

A person needs a balanced diet taking into account consumption of the main food components depending on age, physiological needs and physical loads: proteins, fats, carbohydrates, microelements, vitamins and dietary fiber for normal life activity. In the current conditions of production, preservation of the maximum nutrient content, as well as the increase in their digestibility by the body, is difficult to achieve, because the amount of vitamins, phytohormones, enzymes and essential amino acids is reduced during the processing of raw materials, so the need for introducing the products of grain processing into the rations increases.

Recently, the traditional formulations of essential food products are actively including malt - a valuable dietary product rich in extractives and hydrolytic enzymes, obtained by germination in artificially created conditions. Containing a full set of essential amino acids and a high saccharifying ability of malt, obtained from grain cereals, determines its wide use in the production of beer, alcohol, mono- and poly-malt extracts, bakery products, special types of flour, food additives, cereals, non-alcoholic beverages, lactic acid products and, in particular, in the production of natural coffee substitutes.

However, the classical germination technology, which includes 2-3 days of soaking and 5-8 days of germination, although allowing to obtain high quality malt, due to the considerable duration and laboriousness of the process, does not meet the requirements of modern technology and the constantly growing rates of industrial production, so this problem requires finding new and improving existing scientific and technical solutions.

Analysis of recent research and publications

The today's priority areas for the modernization of traditional technology of malt growing are aimed at: creating the most favorable conditions for grain sprouting; reducing the length of the malt production process by optimizing the parameters of soaking, sprouting and drying the grain and reducing the losses of raw materials at each stage of production.

To achieve these objectives, various methods of activating the growth of grain material are used: physical (ultrasonic waves, ionized radiation, electromagnetic fields, incoherent red light), chemical (diammonium phosphate, potassium bromide), physical and chemical (plasmochemical treatment of aqueous solutions) and microbiological (enzyme preparations) [1–6].

The maximum effect in the intensification of the germination process can be achieved by using of special chemicals – biostimulators of grain growth in combination with inhibitors. Their simultaneous use leads to accelerating the dissolution of the cell walls of the endosperm, the accumulation of gibberellic acid and contributes to a shortening of the malt production time. The most common growth stimulators are gibberlinic, lactic, ferulic, indoleacetic acids and coumarin [7–10].

In addition to organic acids, in technology also used: alkyl esters of arachidonic, eicosapentaenoic or jasmine acids in the presence of antioxidants; a suspension of ultra-disperse silver and copper powder, which promotes the acceleration of respiration and oxidative phosphorylation in the mitochondria of root cells, which leads to stimulation of their bioenergetic activity and growth [11–16].

Despite the efficacy, the mentioned substances have drawbacks: there is a high cost or insufficiently high efficiency, which forces the scientists to continue searching for a universal growth stimulator which would be able to provide proper quality of malt with minimum waste of time, raw and auxiliary materials.

To eliminate all listed shortcomings, it is proposed to use as growth activators the 3-pyridinecarboxylic acid aqueous solutions, which acts as an acceptor and intermediate carrier of hydrogen atoms in the initial stages of oxidation of carbohydrates and fatty acids; pteroylglutamic acid, because it is able to recover to coenzyme, which promotes the synthesis of nucleic acids; succinic acid, which is involved in the processes of cellular respiration, oxidation of carbohydrates, lipids, which is why it can stimulate growth and increase the productivity of agricultural plants.

The purpose of the study is to determine the possibility of using aqueous solutions of succinic, 3-pyridine car-boxylic and pteroylglutamic acids to reduce the malt germination process length, increase its energy and germination ability, as well as to improve its quality characteristics.

Research tasks:

1. to select the optimal concentrations of organic acids selected for the study for their further application;
2. to analyze the influence of various concentrations of acids on energy and the ability of cereal grain to germinate;
3. to identify the specifics of the technological process of growing malt with the participation of selected growth activators;
4. to substantiate the efficiency of the use of selected acids for the intensification of seed germination.

Research Materials and Methods

Materials of research: wheat, barley, rye, triticale; sprouted grains of the mentioned crops at different stages of research of the malting process; organic acids been selected as growth promoters.

To assess the initial quality of grain raw materials, standard methods of determination were used, they meet the requirements of the current normative and technical documentation: organoleptic characteristics, full mass, contamination of cereal stocks with microorganisms and pests, content of impurities, humidity – under DSTU 4138-2002; the germination process was carried out in accordance with the methodology of the standard specified; chalky malt grains were determined under DSTU 4282:2004.

In order to establish the effectiveness of influence the investigated organic acids on energy and the ability of cereal crop grain to germinate, only 36 sample weights were formed with 500 grains in each.

Aqueous solutions of succinic, 3- pyridine carboxylic and pteroylglutamic acids in the range of concentrations from 0.025 to 2.5 g/m^3 were used as a liquid for soaking the grain.

Germination was carried out in a laboratory malt house, which is a set of plastic containers covered with a layer of filter paper and wetted with aqueous solutions of acids with appropriate concentration.

Treatment of grain material with solutions of organic acids was carried out as follows: the grain material prepared for sprouting was saturated with acid solution of a given concentration in 2 stages. Pre-soaking was carried out for 4 hours at a temperature of 18–20°C. At the end of the stage, the nutrient solution was drained, and the grain was allowed to stand for 16 hours without access to water. When re-soaking, solutions of acids of similar concentration were used. To prevent their acidification during the second stage of soaking the grain, alkali solutions were added. Air-water soaking was carried out for 24 hours until the cereal grain was fully saturated with preparations. Germination was carried out for 6 days at a constant temperature of 17–21°C, periodically moisturizing and turning the layer of grain with a height of no more than 45–55 mm in order to distribute the fluid evenly and prevent the formation of caking. The final stage of the technological process was to dry the resulting malt for 8 hours at a temperature of the drying agent of 65–68°C to a constant moisture content of 5–6% [17].

72 hours after the completion of soaking the energy of the material germination is determined, which is calculated by the number of grains in which the root has come out, including those that sprouted. To determine the germination capacity, the kernels that are not germinated for 3 days are left moistened for another 48 hours, after which the number of sprouted grains is counted. Both indicators are expressed in % of the total number of grains in the sample. The conclusions on the effectiveness of the preparations were based on the change in the performance of the samples compared with the control, which grain was not processed chemically.

The water absorption capacity of cereal crops was determined by their four-hour soaking in acid solutions. With an interval of 30 minutes, the working solutions were drained, and the test samples were weighed on laboratory scales with a division value of 0.1 g. The indicator was expressed in % to the weight of dry grain.

After drying, the consistency of the endosperm was studied in order to determine the influence of aqueous solutions of succinic, 3-pyridinecarboxylic and pteroylglutamic acids on the quality of malt.

Results of the research and their discussion

Indicators for establishing the feasibility of using selected organic acids in malt production technology are: water absorption capacity of the material characterized by the rate of absorption of vegetative moisture by grain colloids (Table 1), its energy and germination ability (Tables 2–5), as well as the output of mealy grains in the batch of finished product (Fig. 1.).

Table 1 – Dependence of water absorption capacity of cereal crop grain on the duration of contact with solutions of organic acids

Duration of soaking, min	Water absorption capacity, %			
	Control (water)	succinic acid	3-pyridinecarboxylic acid	pteroylglutamic acid
30	14.4	20.9	28.4	36.3
60	28.8	36.3	35.8	39.1
90	33.5	37.7	42.8	40.0
120	38.6	39.1	44.2	40.5
150	39.1	40.0	45.7	41.4
180	42.3	43.3	52.1	43.9
210	44.2	46.5	54.9	46.0
240	46.0	50.7	56.7	55.3

Table 2 – Dependence of energy and germination ability of wheat grain on the concentration of organic acids

Acid	Concentration of acid, g/m^3	Germination energy,%	Germination ability,%	Effect, %	
				germination energy	germination ability
Succinic	0.75	86.0	88.0	+7.50	+2.33
	1.50	80.0	84.0	-	-2.33
	2.25	70.0	73.0	-12.5	-15.12
3-pyridinecarboxylic	0.25	79.0	84.0	-1.25	-2.33
	1.25	78.0	83.0	-2.50	-3.49
	2.50	65.0	70.0	-18.75	-18.6
Pteroylglutamic	0.025	81.0	87.0	+1.25	+1.16
	0.125	85.0	88.0	+6.25	+2.33
	0.250	72.0	79.0	-10.0	-8.14

Control	0	80.0	86.0	-	-

Based on the results presented in Table 1, we may conclude that the use of water solutions of succinic, 3-pyridinecarboxylic and pteroylglutamic acids as a growth stimulator allows to achieve the required level of enzyme to increase the moisture level, which is 48, and sometimes 50%, in 1.5–2 times faster than the classical technology. It is possible to explain the increased adsorption capacity of the grain material by creating optimal conditions for the flow of biocatalytic processes, or more precisely, by maintaining a constant acidity, which in turn promotes the synthesis and accumulation of substances accelerating the growth and development of grains.

Based on the data presented in the Table 2, it may be concluded that the most favorable effect on the qualitative indices of wheat is caused by an aqueous solution of succinic acid with a concentration of active substance of 0.75 g / m^3. The increase in energy and germination ability by 7.5 and 2.3%, respectively, indicates the possibility of using the preparation in industrial conditions. The worst result was aqueous solutions of 3-pyridinecarboxylic acid, indicating the need to continue to searcg for their optimal concentrations.

Table 3 – Dependence of energy and germination ability of barley grain on the concentration of organic acids

Acid	Concentration of acid, g/m^3	Germination energy,%	Germination ability,%	Effect, %	
				germination energy	germination ability
Succinic	0.75	75.0	79.0	-7.41	-7.06
	1.50	80.0	84.0	-1.23	-1.18
	2.25	83.0	87.0	+2.47	+2.35
3-pyridinecarboxylic	0.25	81.0	86.0	-	+1.18
	1.25	73.0	80.0	-9.88	-5.88
	2.50	41.0	52.0	-49.38	-38.82
Pteroylglutamic	0.025	85.0	89.0	+4.94	+4.71
	0.125	83.0	86.0	+2.47	+1.18
	0.250	82.0	85.0	+1.23	-
Control	0	81.0	85.	-	-

Having analyzed the experimental data given in Table 3, it may be concluded that the concentrations of 3-pyridinecarboxylic acid chosen for the research do not provide sufficient efficiency of the solodization process. Instead, the use of aqueous solutions of pteroylglutamic acid with a concentration of active substance of 0.025 g/m^3 will increase the quality of barley by 5% compared with control. It should also be noted that all experimental samples treated with its solutions of certain concentrations showed positive dynamics, indicating the efficiency and promising use of acid.

Table 4 – Dependence of energy and germination ability of rye grain on the concentration of organic acids

Acid	Concentration of acid, g/m^3	Germination energy,%	Germination ability,%	Effect,%	
				germination energy	germination ability
Succinic	0.75	83.0	86.0	-3.49	-5.49
	1.50	89.0	92.0	+3.49	+1.10
	2.25	78.0	82.0	-9.30	-9.89
3-pyridinecarboxylic	0.25	89.0	94.0	+3.49	+3.30
	1.25	76.0	80.0	-11.63	-12.09
	2.50	45.0	52.0	-47.67	-42.86
Pteroylglutamic	0.025	92.0	95.0	+6.98	+4.40
	0.125	88.0	93.0	+2.33	+2.20
	0.250	89.0	93.0	+3.49	+2.20
Control	0	86.0	91.0	-	-

Based on the results presented in Table 4, we may conclude that the aqueous solutions of succinic, 3-pyridinecarboxylic and pteroylglutamic acids with concentrations of active substances of 1.5; 0.25 and 0.025 g/m^3, respectively may be used to intensify germination of rye grain. The only positive effect of the selected organic acids on the indicators of its quality may be explained as follows: rye has the smallest content of protein among the presented cereal crops, and therefore, has low acidity. Thus, a slightly acidic environment created by the organic acids does not harm biochemical processes in the grain.

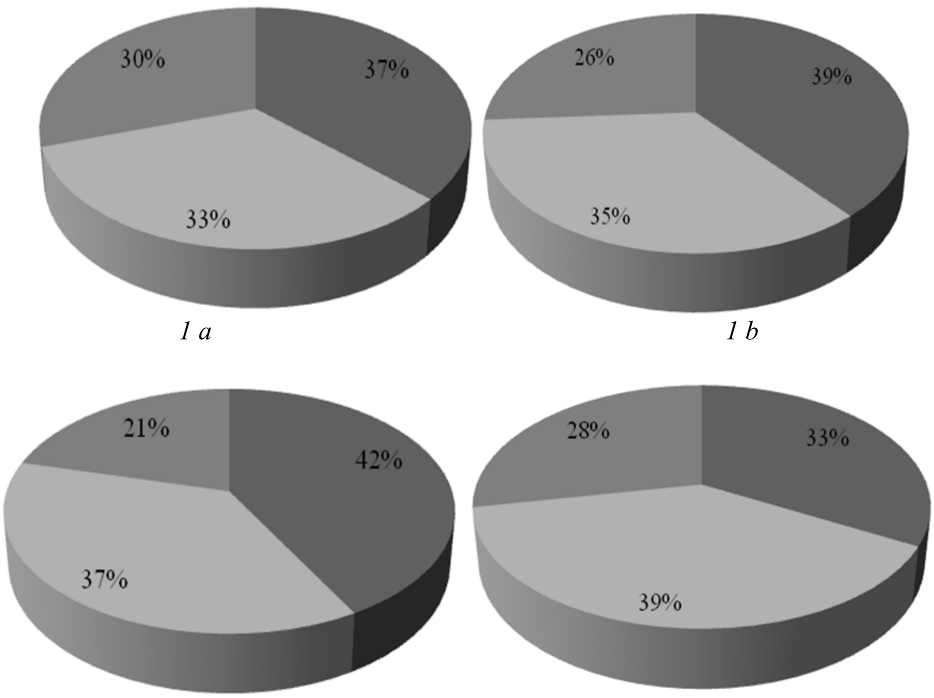
However, the qualitative indicators of triticale, reflected in Table 5, rapidly deteriorated as a result of more aggressive influence of the medium of solutions of succinic and 3-pyridinecarboxylic acids on raw materials. The inhibition of the growth process is due to the over-saturation of the increased acidity grain with the indicated doses of the preparations. The best effect on triticale is caused by an aqueous solution of pteroylglutamic acid with an active substance concentration of 0.025 g/m^3, which indicates the expediency of its use in production.

To determine the effect of organic acids on the consistency of the endosperm, only those samples of grain that showed the maximum increase in the values of the indices studied at the previous stages were selected.

Table 5 – Dependence of energy and germination ability of triticale grain on the concentration of organic acids

Acis	Concentration of acid, g/m^3	Germination energy,%	Germination ability,%	Effect,%	
				germination energy	germination ability
Succinic	0.75	83.0	85.0	-2.35	-5.56
	1.50	80.0	83.0	-5.88	-7.78
	2.25	63.0	69.0	-25.88	-23.33
3-pyridine carboxylic	0.25	80.0	87.0	-5.88	-3.33
	1.25	66.0	74.0	-22.35	-17.78
	2.50	60.0	65.0	-29.41	-27.78
Pteroylglutamic	0.025	94.0	97.0	+10.59	+7.78
	0.125	85.0	91.0	-	+1.11
	0.250	81.0	87.0	-4.71	-3.33
Control	0	85.0	90.0	-	-

The results of quantitative and qualitative changes occurring in the endosperm of malt grain during germination are reflected in Fig. 1. Experimental samples treated with certain concentrations of the proposed acids are distinguished by an increased content of mealy grains: when using solutions of succinic acid, their amount increased by 4.0% in comparison with the control; when using solutions of 3-pyridinecarboxylic acid and pteroylglutamic acid – by 6,0 and 9,0%, respectively, while the content of chalky grains is reduced by 2.0 and 7.0%.



1 a *1 b*

1 c *1 d*

■ Mealy grain   Semi-chalky grain   ■ Mealy grain

Fig. 1. Changes in the mealiness of malt grain depending on the type of organic acid:
***a* – succinic acid; *b* – 3-pyridine carboxylic acid; *c* – pteroylglutamic acid; *d* – control**

Conclusions

The technology of malt production using organic acids allows to obtain a high quality product in a shorter time (3–5 days, depending on the grain crop), enriched with the organic acids needed by the human body in safe quantities. It was found that:

1. The maximum effect in wheat germination may be achieved using a solution of succinic acid with an active substance content of 0.75 g/m^3; when germinating barley, rye and triticale – a solution of pteroylglutamic acid at a concentration of 0.025 g/m^3.

2. Energy and ability of cereals to germinate increases by 5–11% on average when using solutions of pteroylglutamic acid; by 3–7% when using succinic acid; by 1–4% when adding 3-pyridinecarboxylic acid.

3. The aqueous solutions of 3-pyridinecarboxylic, succinic and pteroylglutamic acids have properties that make it possible to accelerate the adsorption of moisture by grain and, as a consequence, reduce the malt growing process by a factor of 1.5–2 times. Acceleration of biochemical processes in the sprouted material leading to an increase in the content of mealy grains, is an important technological result in the further production of a variety of products from semi-chalky malt and indicates more complete dissolution of the components of grain material.

4. The introduction of this method of stimulation of germinating grain material at the scale of industrial production does not require significant hardware and material costs, in addition, it leads to an increase in the percentage of output of finished products, which proves to be expedient from an economic point of view.

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ОСОБЕННОСТИ ПОЛУЧЕНИЯ СОЛОДА С ИСПОЛЬЗОВАНИЕМ ВОДНЫХ РАСТВОРОВ ОРГАНИЧЕСКИХ КИСЛОТ

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Аннотация. Приведены особенности производства солода с использованием органических кислот разной концентрации. Проанализировано и исследовано процесс производства солода, предусматривающий мойку, дезинфекцию, поочередное воздушно-водяное замачивание зерна злаковых культур, его проращивание и сушку. Особенностью исследуемой технологии является использование в качестве дезинфектанта и стимулятора роста на этапе замачивания зернового материала водных растворов бутандиовой, 3-пиридинкарбоновой и птероилглютаминовой кислоты. Приведены результаты исследования влияния указанных органических кислот на энергию и способность прорастания зерна. Приведены оптимальные значения концентраций действующих веществ в растворах. Исследовано влияние органических кислот на процесс поглощения зерном злаковых культур влаги. Определено, что по сравнению с классической технологией, использование данных кислот в качестве стимулятора роста позволяет сократить общую продолжительность процесса проращивания материала в 1,5-2 раза и увеличить выход мучнистых зерен в партии солода.

Ключевые слова: злаковые культуры, стимулятор роста, бутандиовая кислота, 3-пиридинкарбоновая кислота, птероилглютаминовая кислота, энергия прорастания, способность прорастания, мучнистость зерна.

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