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РЕГУЛИРОВАНИЕ ТЕХНОЛОГИЧЕСКИХ СВОЙСТВ НЕ СОЛОЖЕНОГО ЗЕРНОВОГО СЫРЬЯ

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Статья посвящена анализу теоретических и экспериментальных исследований российских и зарубежных ученых в области подготовки биополимеров несоложеного зернового сырья методом термопластической экструзии. В работе систематизированы и обобщены результаты научных экспериментов, дающих представление о физических, биохимических и структурных изменениях, происходящих в несоложеном зерне при таком воздействии. На основе анализа многочисленных источников информации определены тенденции развития термопластических методов воздействия на технологический потенциал несоложеного сырья и, как следствие этого – на качество пива.

Ключевые слова: *солод, не соложеное сырье, предварительная подготовка, формирование качества пива.*

Introduction

When brewing beer the most important task of the mashing process is transforming the maximum amount of valuable soluble and insoluble parts of the grain products which provide the necessary level of extract of beer wort and the finished drink from the mixture of malt and non-malted grain products into water solution. Achieving this this goal is due to by various factors and, primarily, by the activity of enzymes accumulating in the malt in the process of malting.

Biopolymers (starch and protein) of non-malted grain products which are used instead of a portion of the malt, are less prepared for enzymatic action than malt biopolymers as they do not undergo the preliminary process of dissolution changing the grain structure, as is the case with grain when malting.

The main differences between the malt and non-malted grain are the presence of cell walls in starch granules. Theoretically, high-quality malt contains a sufficient amount of cytolytic, proteolytic and amylolytic enzymes for efficient hydrolysis of insoluble components both in the malt and non-malted grain products. However, in practice for the productive process of mashing grain products, especially under replacing significant quantities of malt bynon-malted grain (more than 20 %), for many years separate mashing non-malted raw materials and part of the malt mash has been used, and enzyme preparations to provide the normal flow of the mashing process have also been used.

Obviously, the biochemical effects of malt enzymes on biopolymers of non-malted grain products, primarily for starch grains, will be more effective if their preliminary gelatinization takes place. Therefore, for effective use of non-malted grain products in the preparation of wort and obtaining products of high quality, the preliminary preparing biopolymers of grain for bio-transformation is necessary before mashing.

The purpose of this research is the analysis, systematization and synthesis of information data of Russian and foreign researchers about methods of thermal treatment, forming technological potential of non-malted raw materials and commodity characteristics of the beer.

Objects and methods of the research

The research objects were the scientific data of Russian and foreign sources of information. The methods of analysis, synthesis, systematization and generalization were used as research methods.

The results and their discussion

Tough competition in the beer market dictates the need for optimization of process parameters and techniques at each stage of the technology. One of the main technological stages of beer production is the process of mashing raw grain. Replacement of part of the malt by non-malted grain involves using hydrolytic enzyme preparations of microbial origin in the stage of wort production or preliminary preparing non-malted raw materials.

One of the most effective and frequently used technological practices that promote preparation of biopolymers of non-malted grain for the technological process of mashing is thermal treatment whichcan be performed by various methods, including combined methods. For example, combined and simultaneous influence of temperature and moisture, temperature and pressure is possible.

The classification of thermal methods including three groups of temperature treatment: thermal, hydro-thermal, thermos-mechanical was proposed by Afanasyev V.A. [1]. It can be applied to the thermal methods of preparing non-malted raw materials in brewing.

Thermal methods of grain treatment include heating

the grain mass by the dry heated air (convective heating) or heating grain from the heated surface (conductive heating) and heating by high frequency currents and micronization (IC-treatment).

The efficiency of thermal treatment of non-malted grain products when making wort was noticed by researchers more than 40 years ago.

In order to improve the quality of the finished beer Glowinsky D.G. patented a method of wort production by using the thermally treated non-malted barley grains. The author proposed to carry out high-temperature heat treatment of non-malted barley moistened to 15 % [2]. At a temperature of 230-250 ° C there is the destruction of tannins, which play a significant role in the formation of colloidal turbidity of beer and the grain structure destroys, this contributes to the increase of the degree of exposure of starch grains by malt enzymes.

It should be noted that tough regime of heat treatment leads to the formation of melanoidin compounds, the intensity of which can be reduced by regulating the thermal treatment of non-malted raw materials. For example, according to Golikova N. V. with co-workers, the thermal treatment of raw materials, carried out in several stages contributes to the significant improvement in the quality of beer. At the first stage the moist barley grain is to be thermally treated at 230-250°C, and then quickly (in a period of 5-10 c) it is to be cooled in a moist condition up to 75-85 % by air at a temperature -5°C to -10°C [3]. The result of the first phase of the impact by contrasting temperatures is the rapid interruption of the reaction of melanoidin formation. Simultaneously, there is a decrease in the degree of coupling of the shell of the grain with the endosperm.

At the second stage, in order to exclude the penetration of moisture from the surface of the grain after the first stage of the treatment to the endosperm of the grain the blowing of the grain mass is doneby dry cold air with temperatures ranging from -5 to -10° C with lower relative humidity (20-25 %) for a short period of 5-10 c. The proposed technological solution enables to save the shell of the grain hydrated, which contributes to its integrity when grinding, and thus makes it possible to form loose, well-draining layer of pellet at filtration of wort, and high speed of mash filtration.

It is stated that the thermal impact on non-malted grain during a short period of time (0,5 to 1,5 min) contributes to the effective improvement of its technological parameters due to the loosening of the endosperm of the grain. As a result of loosening of the endosperm there is an increase in bulk volume of grain products 1.25-2 times [4]. The researchers emphasize the possibility of using the heat-treated non-malted grain with the changed structural properties as a replacement for 15-40 % of malt in the production of beer wort. The proposed method of grain treatment facilitates the output of extractives, which implies an increase in reducing sugars. As a result of yeast fermentation of the increased amount of reducing sugars the greater amount of ethanol is produced that changes the commodity characteristics of the beer.

Using infrared radiation is another way of thermal grain treatment representing scientific and practical interest for brewing.

Infrared radiation is used in the food industry to intensify chemical and biochemical processes during baking, drying, frying, blanching, cooking and pasteurization.

The basis of this method of treatment is the ability of the infrared radiation with a wavelength of 0,8 to 6 μm to penetrate into the grain and cause intense vibration of molecules. There is a well-known method in which thermal grain treatment with standard humidity is carried out by acting on it with the flow of infrared radiationwith a wavelength of 0,8 to 3,2 μm until the grain temperature is 150-200°C. As a result of this treatment the grain becomes soft; it expands and cracks [5].

The mechanism of this process is due to the diffusion of moisture from the surface of the processed grain to the middle of the caryopsis by high steam pressure inside the caryopsis when the temperature is 150-200°C, which leads to «bang». A significant increase in the content of dextrins and glucose, which are the products of the destruction of grain starch, indicates the changes in biochemical parameters of the micronized grain. In addition, the influence of infrared radiation leads to the improvement of physical properties of grain. Barley increases in volume 2-3 times its density decreases its hygroscopicity increases 3-4 times. The change in grain structure makes it possibleto use it in the technology of production of products of fermentation without using the process of mashing. As a result of effective influence of malt enzymes on the «blown up» grain the output of the extract increases.

The results of studies of grain treatment by infrared radiation with modified parameters are given in the works of other authors [6, 7]. In order to improve the quality of the finished product it was proposed to use crushed barley malt and non-malted raw materials treated with electromagnetic radiation in the wavelength range of 0.6-1.5 μm. According to this method the grain is treated within 10-15 c at a flow density of 10-15 kW/cm². Application of the proposed method of wort preparation causes an increase of reducing sugars in the wort content by 4,8-20,2 % the α-amine nitrogen by 0,36-7,2% and a mass fraction of dry substances by 5,8-12,2 %, which, ultimately, contributes to the intensification of the fermentation process. Thermal grain treatment using infrared radiation, according to these authors, enables to obtain beer with high quality parameters when replacing the malt from 15% to 40 % of non-malted raw materials.

Processing vegetable raw material by infrared rays influences several other its properties. Tretyak L. N. showed the possibility of almost complete destruction of the grain contaminants during brief exposure of infrared irradiation of moist grain in combination with exposure to ultraviolet waves, the wavelength being 240-370 nm. In addition to this effect, the author found a significant increase in the enzymatic attacking starch of the treated grain and a significant increase in the amount of fermentable sugars. The results of the research indicate

that the amount of dextrins increases more than 70 times after micronization, and the amount of reducing sugars – 2 times, the degree of gelatinization of starch increased 25 times, and its enzymatic attacking – more than 3 times [8].

Khristyuk V.T. with coworkers suggested preparing mash with application of barley and malt treatment by electromagnetic field of low frequency in the range of 3-30 Hz during 35-45 minutes [9]. The preliminary treatment of grain products by this way provides the increasing of extractives and improving the quality of the finished product. It was stated that changing the speed of biochemical transformations depends on the frequency, intensity and duration of exposure to electromagnetic field.

It should be noted that effective treatment by infrared radiation is possible only in a relatively thin layer of grain.

Methods of hydrothermal treatment are associated with heat, water or steam exposure to grain.

Aimed at increasing the output of extract of grain products and improving the quality of wort the thermal treatment of non-malted grain at 120-400 °C is applied. Next, the grain is exposed to gradually increased pressure from 0.1 to 100 MPa within 10-200 c, which contributes to the preparation of biopolymers of the applied non-malted barley for enzymatic hydrolysis in the mashing process combined with malt [10]. The parameters of the thermal treatment depend on the type and characteristics of non-malted grain. This treatment provides degradation of the extracellular and cellular membranes of the starch granules while reducing grain moisture content from 15% to 8%.

In the scientific literature there is information about improving technological properties of barley by mashing non-malted materials under pressure [11, 12, 13].

Bukin A.A. experimentally examined the influence of preliminary preparation of the amaranth meal on the degree of hydrolysis of amaranth starch and carbohydrate composition of the wort. In this case, the author found that, by changing the parameters of water-thermal treatment it is possible to affect the quantitative and qualitative composition of mash [11]. According to other researchers, by regulation of parameters of mashing under pressure, one can influence not only the output of extract and qualitative composition of the products of starch hydrolysis of non-malted grain materials, but also regulate the viscosity of mash and duration of filtering [12]. The author of this work notes that thermal treatment of non-malted barley under pressure leads to the increase of total soluble nitrogen in the wort, but these changes are not as significant as the increase in the number of hydrolysis products of starch. Preliminary thermal treatment of non-malted barley at raised temperatures (under pressure) in its preparation for the processes of hydrolysis during mashing, enables to use non-malted barley in the amount of up to 40% to the weight of grain products.

Similar findings are made by Kokonova M. B., when exploring the possibility of temperature treatment of non-malted barley and non-malted buckwheat used to replace part of the barley malt in the production of beer of wort and beer [13].

About the need to loosen the structure of non-malted barley in order to improve the technological potential of grain in the process of the impact of hydrothermal treatment is confirmed by the other authors [14].

A convincing proof of the effectiveness of preliminary preparation of non-malted grain for hydrolytic processes when mashing by high temperature treatment of grain products under pressure can be found in the works by Fertman G. I. and Kosminsky G.I. [15, 16, 17, 18]. As a result of barley thermal treatment at 120-140 ° C and in the pressure from 0.1 to 0, 5 MPa, there are changes in its structural-mechanical and technological properties. The authors propose to apply the treated barley by this method as a replacement for the brewing of malt up to 40 % by weight of grain products. It should be emphasized that to improve quality-related indicators of non-malted grain is possible for the researchers without using additional sources of hydrolytic enzymes, only by using physical methods of influence on the grain – higher temperature and pressure.

The expanded experiments helped Kosminsky G. I. to establish the positive impact of the main technological factors of preliminary thermal treatment of non-malted barley (treatment temperature, duration and pH of non-malted parts of the mash) in its preparation for the processes of hydrolysis when mashing to the processes of sugaring, filtration of mash, the output of the extract, carbohydrate and fraction nitrogenous composition of wort. Theoretically proved The optimal conditions of this processing are theoretically proved: acidification of non-malted mash before thermal treatment with lactic acid to a pH of 5.4, its thermal treatment at temperatures 133-138 °C, the processing time being 30-45 min [19].

The logical continuation of these experimental and theoretical data is the treatment of non-malted barley in hyperbaric-hydrothermal regime. The hyperbaric-hydrothermal treatment is proposed to be carried out at a temperature of not more than 200°C under steam pressure not lower than 0.5 MPa for a period of not more than 60 c. The method of grain treatment which enables to improve the technological properties of non-malted barley (increasing extractive power, the activity of α-and β-amylase) was patented in Russia [20].

The analysis of advanced methods of increasing functional and technological properties of grain by thermal exposure in different sectors of the food processing industry shows a considerable increase of interest of researchers in recent years to the process of thermoplastic extrusion [21-33].

This interest is, probably, due to the possibility of effective preparation of raw materials of vegetable and animal origin aimed at, firstly, improving the safety of technological processes of food production, and secondly, improving the functional and technological properties both of raw materials for food production and the foodstuffs.

The possibilities of extrusion processing of food raw materials, semi-finished and finished products are

widely used in the food industry. By using extrusion processing, cereals [22, 27, 28], cooking meat products and meat products [34, 35], bakery and confectionery products are produced. [25, 36, 37, 38].

Meanwhile, studies of thermoplastic extrusion of raw grain in Russian brewing industry have not been properly developed yet and the results presented in the scientific literature, are fragmentary.

For example, Morgunova Ye. M. and co-authors proposed a technology of producing new beer brands for special purposes with the application of unconventional raw materials instead of malt portion: extruded barley flour in the amount of 20% and 5% of potato flour. The basis of this solution method is the prolonged mashing, resulting in a large number of degradation products of starch, which provides the intensive fermentation of the wort extract by the yeast. In the result, the main task – more complete fermentation of low molecular substances when getting beer beverages is solved [39].

There is information about producing beer wort with the use of extruded buckwheat cereals in brewing without parameters of the extrusion treatment [40].

At the same time, there are the results of the effective application of non-malted barley, sorghum, wheat and corn, processed by thermoplastic extrusion, in beer production when replacing the portion of malts in numerous international publications [41, 42, 43, 44, 45, 46].

These works prove that the use of extruded grains when mashing enables to obtain higher output of extractives than when using raw grain products. Thus it is concluded that the quality of beer (taste, aroma, stability) when using extruded non-malted raw materials does not become worse [42, 43].

Almost all foreign researchers agree that the extrusion process can lead to the degradation of protein and carbohydrate polymers of grain. In some works there is concern about possible problems in filtering due to the increased viscosity of the mash. However, some drawbacks associated with the use of the extrudates of non-malted raw materials, according to most authors, can be easily eliminated.

According to a number scientists extrusion processing which creates the conditions of dry gelatinization, leads to more profound changes in grain starch than wet gelatinization. It is considered proven that multi-parametric extrusion process of impact on starchy raw materials contributes to the destruction of the starch grains, characterized by the breakup of both the valence and hydrogen bonds, resulting in formation of polymers with a smaller particle size [47, 48].

There is an assumption that significant enough changes of starch grains take place at the moment of the outflow of the extruded raw material from the filter of the extruder. It is shown that in the process of the grain extrusion processing at the moment of decompression there is a decrease of the total starch content because of splitting of amylose and amylopectin and the amount of oligosaccharides and dextrins increases [49].

There are quite a number of publications about the growing interest to the extrusion method of processing agricultural raw materials and their application in food technology [26, 27, 50, 51]. Products of extrusion processing are used in the production of alcohol. The research on the development of extrusion-hydrolytic technology with the maximum integration of thermo-mechanical and bio-chemical treatment of grain raw materials for ethanol production is carried out in a uniform reactor system – extruder-hydrolizator [52, 53, 54].

According to the information in scientific literature, during extrusion processing the crystal structure of starch grains is destroyed and the structure of amorphous substances is formed.

Thermal and mechanical treatment of starch not only destroys the structure of its grains, but also leads to the destruction of large molecules of starch polysaccharides that significantly alters its rheological properties of starch pastes [55].

The cited in the scientific literature results of changes of starch in the process of extrusion treatment reason the use of grain extrudates in brewing for the preparation of the grain before mashing and making wort. It should be expected that in the conditions of brewing gelatinized starch will be more accessible to enzymatic systems of malt.

There is a disorder in the internal structure of the molecule, quantitatively determined by changes in physical-chemical properties of proteins: solubility, ability to hydration, viscosity of solutions, resistance to the action of enzymes, biological activity, etc. This phenomenon is due to the presence of large the number of fragile links in the protein molecules [56].

It is assumed that the globular proteins in the native state are resistant to the action of enzymes. In result of extrusion processing the globular structure of the protein molecule is converted into fibrillar structure with the unfolding of peptide chains and the release of functional groups accessible to enzymes [32].

It is stated that extrusion processing of vegetable proteins increases their nutritional value and improves persistence, since there is a partial inactivation of enzymes that worsen the taste and lower the quality of the product during storage. In general, the chemical composition of the protein does not change.

The authors of the article present data on the changes taking place carbohydrate and protein complexes of the extruded barley [57, 58, 59, 60], and also they have proved the possibility of regulating functional-technological and structural properties of extrudates of starch-containing grain raw materials due to changes of technological factors in the extrusion process and technical parameters of the extruder [61–68]. Based on the results of the research the authors proposed and patented a method for the production of extrudates [69], and on its basis the technology of beer production was developed. This technology has features of novelty, confirmed by the patent for the invention «Method of beer production» [70].

In addition to the main components (starch, protein)

in raw grains there are small amount of fats, fiber, minerals, mono - and disaccharides. The transformations of these elements in the process of extrusion are not indicative in changes of the physical-mechanical properties of the main components.

Conclusions

The reliable facts stated by Russian and foreign researchers about substantial changes in the structure of starch grain and destruction of molecules of polysaccharides under the influence of extrusion treatment in starchy raw grains are scientific conception of possible applications of the extruded barley in brewing. These developments contribute to the improvement of fermentation impact on raw materials in the process of making beer wort, and contribute further to producing beer of high quality parameters.

The information above leads to the conclusion that extrusion treatment of grain products is an effective means to solve the problem of expanding the range of products of the brewing industry, and the research in this area is relevant direction.

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CONTROL OF TECHNOLOGICAL PROPERTIES OF UNMALTED GRAIN RAW MATERIALS

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The article is devoted to the analysis of theoretical and experimental studies of Russian and foreign scientists in the field of preparation of biopolymers of uncooked grain raw materials by thermoplastic extrusion. The paper systematizes and summarizes the results of scientific experiments that give an idea of the physical, biochemical and structural changes occurring in the non-malted grain under such influence. On the basis of the analysis of numerous sources of information the tendencies of development of thermoplastic methods of influence on technological potential of not salted raw materials and, as a consequence – on quality of beer are defined.

Keywords: *wort, non-malted grain, preliminary preparation, the formation of beer quality.*

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