Research on brewing in a mash brewing and filtering apparatus

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Abstract. The extensive development of craft brewing forms strong demand for technological equipment characterized by compactness, high-energy efficiency and ease of operation. Multifunctional apparatuses of low capacity and a high degree of modularity is becoming widespread. The design of 500-litre mash brewing and filtering apparatus (MBFA) offered in the article allows combining mashing, mash filtering and hopping within one technological unit. This process denies bringing inter-stage transfer of raw material to minimum values, reducing material losses and the length of the technological cycle. Besides, carrying out all brewing technological operations in one apparatus allows significantly reducing heat energy consumption due to the decrease in heat losses while heating relevant apparatuses. The offered design of MBFA is notable for directed circulation of extractant flows that forms optimal conditions for mass-transfer processes at the stage of malt mashing. Conducted brewing tests in a 50-litre apparatus proved the operability and high efficiency of the apparatus. Produced wort matched all controlled physicochemical parameters and was characterized by significant 33% decrease in turbidity and 6.5% reduction of polyphenol concentration that enhanced fermentation and made beer brightening easier improving its consumption properties at the same time. The degustation evaluation of finished beer showed the beer sample obtained from the MBFA-brewed wort had a prime soft and harmonious taste, pure flavour and saturated colour.

1. Introduction

As a rule, traditional brewing technologies, implemented at large-scale enterprises, suggest the production of limited beer selection. It is conditioned by the deep specialization of production which enables us to reduce production costs and improve output quality by the exclusion of equipment readjustment which is usually necessary in case of changing sorts of beer which, in its turn, requires significant highly-qualified staff for both technological and mechanical services. At the same time, the intended variety is obtained by extending interdivisional relations inside a holding company. However, long-time transportation of finished product to a customer requires a more extended expiry period. As a result, there is an absurd contrariety in Russian brewing – beer is produced not for the customer but the trade [1]. In other words, the mentioned above contrariety presupposes that the customer is aware of the particularities of consuming beer as a drink wants to drink fresh beer. In contrast, it is profitable for mass producers and sellers to deal with a product characterized by a long period of storing, which ensures it is selling. The growing escalation of the contrariety gradually formed the market environment for extensive development of craft brewing.
Craft brewing means handicraft, literally. “Craft beer” can be translated as “handicraft beer”. In more common categories, craft beer is a beer brewed by a small independent brewery. Since the moment they appeared in Russia, mini-breweries have provided a sufficient variety of produced beer and other cereal-based fermented drinks [2]. Russian consumers were reintroduced to a fresh just-brewed unfiltered and unpasteurized drink with high organoleptic parameters and all bioactive substances formed during fermentation. Such mini-breweries, as a rule, are located close to the places of consumption. They are often placed in specialized restaurants and cafes, arousing a high degree of trust in a finished drink [3]. At the same time, some cases when a mini-brewery became the basis for the development of the restaurant business are known. The average daily output of such enterprises is from 50 to 6000 litres. Depending on market demands, they are capable of increasing and reducing their output within a short period. Diverse drink assortment effectively meeting customer demands both in quantitative and qualitative terms. This fact is especially actual for the current economic situation characterized by external economic pressure and unstable demand.

The distinguishing characteristic of mini-brewery organization and development is the usage of already existing premises. Thus, the primary requirement for technological equipment is minimal mounting area. Taking it into account, most companies, specialized in the design and manufacturing of equipment for mini-breweries, use such an aggregating method which suggests combining a few apparatuses into one technological unit (an aggregate) [4]. This method allows reducing the spread and duration of inter-stage raw transfer; lower raw material losses, energy costs and metal quantity, and minimize mounting area, as well [5]. This method is especially crucial for brewing where all technological processes (mashing, filtration, hop boiling, wort brightening and its cooling) take place at high temperatures sequentially in special technological units. Additional thermal expenses invariably accompany it on heating each technological unit and connecting pipes. Besides, inter-stage mash and wort transfer requires the usage of additional pumps and is accompanied by extra losses of mentioned intermediate products.

2. The purpose of the study
Based on the above, the purpose of the current research is to design a multifunctional 500-litre mash brewing and filtering apparatus which allows combining mashing, mash filtering and hopping within one technological unit.

3. The object of the study
The designed MBFA is a part of the unit with additionally mounted mini hoist, equipped with a handling device, a circulation pump and an operating console.

The principal scheme of the designed apparatus is given in Figure 1. The apparatus has a vertical cylindrical vessel with a flat bottom and diameter: height” ration from 1:1 to 1:1.5 depending on customer demands, specified by the conditions of future exploitation. On the external surface of the vessel, there is a steam jacket with blocks of electric tube heaters, mounted in its bottom. Each heater is mounted in a separate cylindrical camera and fixed lower the bottom level. The offered layout arrangement enables us to exclude the exposure of heating elements during operation as a result of the transition of water into a vaporous state and its level drop. The external surface of the steam jacket is covered with ultra-thick thermal insulation “Korund-classic” manufactured by Scientific production association Fullerene, city Volgograd. The insulation provides the decrease in heat losses and safe exploitation of the brew kettle.

The cylindrical basket which diameter is three-quarters of the vessel diameter is mounted coaxially in the vessel. The basket is fixed with pin 16, going through plates 5 and 6 perforated with cylindrical holes of 2.5 mm diameter. The diameter of the plates corresponds to the internal diameter of the basket. The lower plate is fixed on the surface of the circular basket flange at 80 mm height from the basket bottom that ensures even distribution of circulating water along the cross-section of the basket. The upper plate is mounted on pin 16 covering the mashed malt layer. For preventing the floating of the upper plate, it is fixed with clamp 14, resting on the upper-end wall of the basket, and pin 16. The
system is fixed with packing nut 15. Thus, the basket divides the operating space of the apparatus into two sections: central (cylindrical) and peripheral (circular). Each section is equipped with appropriate connecting pipes for water supply and drain.

Figure 1. Mash brewing and filtering apparatus: 1 – vessel; 2 – steam jacket; 3 – cover; 4 – basket; 5 – upper filtering plate; 6 – lower filtering plate; 7 – level tap; 8 – water inlet/outlet connecting pipe; 9 – water supply connecting pipe; 10 – product outlet tap; 11 – vapour drain tap; 12 – safety valve; 13 – pressure gage; 14 – clamp; 15 – packing nut; 16 – pin.

The operation procedures are the following. Basket 4 is mounted in the apparatus and centred with plate six relatively pin 16. The formed central section is loaded with mashed malt and covered with filtering plate 5. Then, clamp 14 is mounted, and the system is fixed with nut 15. The leaves of cover three are closed, and water is supplied through connecting pipe nine under the lower plate. Leaching of extractive substances takes place in ascending water flow when it flows throw the internal section of the apparatus. Then the water flows into the circular section. There is an intake pipe equipped with a pump in the lower part of the section. The process is accompanied by constant heating of processed mash with time delays essential for full-fledged saccharification of starch-containing raw material. The suggested scheme of water circulation inside the apparatus provides favourable conditions for the extraction of water-soluble grain substances. Unlike mash apparatuses equipped with mechanical stirrers, additional mashing and extra turbidity are not observed here.

After the mashing is finished, the basket is removed from the apparatus with the help of mini handling device and is fixed above it to let the extract drain. Then, the mash is washed with a calculated amount of water, thereby finishing the leaching. Next, spent hops are inserted, and wort boiling starts with the closed cover of the apparatus. The hopped wort is pumped to the hydro-cyclone for hops to precipitate. After being cooled in a plate-type heat exchanger, it is transferred for fermentation. In case of using low capacity apparatuses (up to 100 litres) the final operations of wort procession (hop precipitation and cooling) can be held in the designed apparatus.
4. Materials and methods

The Boiling tests were carried out in the designed MBFA of 50-litre capacity. The research was conducted using light barley malt according to GOST 29294-2014, water corresponding to Sanitary and epidemiological standard 2.1.4.10749-01 and hop granulated according to GOST 32912-2014. Physicochemical and organoleptic parameters of the produced wort were defined using generally recognized methods [6]. Analytical definitions of qualitative characteristics were found in three directions. Only replicable experimental results were estimated.

At the stage of mashing the malt was mixed with water in the ratio of 1 to 3. The wort was produced by adhering to the following temperature-time regime [7, 8]:

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45^\circ C \rightarrow 52^\circ C \rightarrow 63^\circ C \rightarrow 72^\circ C \rightarrow 78^\circ C \rightarrow \text{filtration} \rightarrow \text{hop boiling} \rightarrow \text{spent hops sedimentation} \rightarrow \text{cooling} 8^\circ C
\]

The process was accompanied by constant circulation of the liquid phase through the basket at mash heating rate 1°C/min. After the mashing is finished, the basket is removed from the apparatus. The extract flows down gravitationally.

The hopped wort was fermented with Safale S-33 yeast in order to control the fermentation process. Initial extract content of hopped wort in both test and check samples was 11%, the duration of fermentation was six days.

The check sample was obtained following the described above regime and using two-device brewing house, assembled on the base of mash brewing copperСВА-500, equipped with filterΦВА-500, manufactured serially by Scientific production association Era, city St. Petersburg.

5. Discussion of the results

Reasoning Malt mashing and wort boiling are the major processes in beer brewing. The processes aim to dissolve the grain carbohydrates and to saturate the obtained extract with wort aromatic compounds. For reasons of profitability, the producers try to gain the maximum extraction of solubles during the mashing with their simultaneous destruction, which creates favourable conditions for future yeast fermentation. However, according to modern technology, it is not only the quantitative content that matters but also the quality of extract. For instance, the presence of particular compounds such as tannin is quite undesirable, whereas particular sugar compounds and products of protein breakdown are essential. As for hopping, it is characterized by high thermal energy consumption caused by long-term wort boiling. The qualitative parameters of check wort and test wort obtained in the designed MBFA are given in Table 1.

| Parameter                                      | Check sample | Test sample |
|------------------------------------------------|--------------|-------------|
| Dry substance concentration                    | 11.0         | 11.0        |
| Amine nitrogen concentration, mg/100 gdry substances | 273.3        | 275.1       |
| Protein A fraction concentration, mg/100 gdry substances | 180.3        | 176.4       |
| Polyphenol concentration, mg/100 gdry substances | 1548.6       | 1438.5      |
| Titra table acidity, units                      | 1.62         | 1.60        |
| pH                                              | 5.82         | 5.78        |
| Iodinetest, colour                              | yellow       | yellow      |
| Colour, units                                   | 1.40         | 1.32        |
| Turbidity, opt.density units                    | 0.46         | 0.31        |
| Final fermentation degree, %                    | 57.35        | 62.58       |

The analysis of physicochemical parameters of the hopped wort produced during the trial of the designed MBFA showed that most parameters correspond to the values of the check sample. It should
be noted that the wort produced in the designed apparatus is characterized by 6.5% decrease in polyphenol concentration that can be caused by the soft mode of grain stirring during mashing, excluding its additional destruction. However, special attention should be paid to the turbidity of the wort, which lowered by 33%. It is explained by the fact that due to the constant and directed circulation of the mash through the perforated plates in the basket, a multilayer filtering partition is formed there. It provides trapping offline-dispersed particles of malt and flour along the almost whole process of mashing.

The fermentation was conducted at an initial temperature of 8°C within 6 days. Actual extract content, alcoholic content and generation of yeast bio-mass in beer samples were daily estimated by standard methods [6]. Calculated values of fermentation degree in the check and test wort showed that the fermentation degree value of the wort produced in the designed MBFA is 9% higher. The result can be explained by the decrease in the output of polyphenol substances from malt coat into the extract. The degustation evaluation of finished beer showed the beer sample obtained from the MBFA-brewed wort had a prime soft and harmonious taste, pure flavour and saturated colour. It should be underlined that the test sample had higher transparency and brightness than the sample obtained from the wort brewed using traditional equipment.

The listed above results in conjunction with accelerated mash filtration are significant advantages of suggested MBFA having a positive impact on both qualitative parameters of produced beer and the profitability of the apparatus on the whole on account of positive effects typical of multifunctional technological units with a high degree of modularity.

6. Conclusion
A new design of 500-litre mash brewing and filtering apparatus characterized by a high degree of modularity was worked out. It allows reducing the manufacturing area, losses of raw material, semi-finished products and energy expenses on beer wort production. Conducted brewing tests in a 50-litre apparatus proved the operability and high efficiency of the apparatus. The produced wort corresponded to all check physicochemical parameters and was characterized by significantly minor turbidity, which increased the fermentation degree by 9% and made beer brightening easier improving its consumption characteristics at the same time.

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