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THE INFLUENCE OF SELECTED TECHNOLOGICAL PARAMETERS OF THE BEER WORT FERMENTATION PROCESS PRODUCED ON AN INDUSTRIAL SCALE ON THE FILTRATION PROPERTIES OF BEER®

Wpływ wybranych parametrów technologicznych procesu fermentacji brzeczki piwnej produkowanej w technologii wielkozbiornikowej na właściwości filtracyjne piwa®

Celem artykułu jest przedstawienie wyników badań dotyczących wpływu głównych technologicznych parametrów fermentacji brzeczki piwnej produkowanej w technologii wielkozbiornikowej na właściwości filtracyjne piwa. Doświadczenia wykonano w warunkach przemysłowych – fermentacja i dojrzewanie w tankofermentorach o pojemności 3850 hl. Podczas doświadczeń badano wpływ następujących parametrów procesu fermentacji: temperatury fermentacji, początkowej dawki drożdży nastawnych, stopnia napowietrzania oraz czasu napełniania tankofermentorów. Wybrane parametry były poddawane oddzielnym seriom doświadczeń w trzech powtórzeniach. Procesy fermentacji głównej przebiegały w trzech badanych temperaturach: 8,5; 10 i 11,5°C. W przypadku dawki drożdży, do brzeczki dodawano drożdże zebrane po drugiej fermentacji (trzeci pasaż) w ilości 5, 7 i 9 mln komórek na 1 ml brzeczki. Brzeczkę napowietrzano sterylnym powietrzem w ilości 7, 10 i 12 mg na dm^3. Tankofermentory napełniano przez 4,5 oraz 9 i 13,5 godziny. Proces dojrzewania piwa w wymienionych tankofermentorach prowadzono w tych samych warunkach technologicznych. Doświadczenia wykazały, że zróżnicowana temperatura fermentacji, dawka drożdży oraz stopień napowietrzania brzeczki mają istotny wpływ na właściwości filtracyjne piwa. Wraz ze wzrostem temperatury fermentacji obniżała się filtrowalność piwa natomiast większa dawka drożdży przyczyniała się do jej poprawy.

Słowa kluczowe: brzeczka piwna, tankofermentor, temperatura fermentacji, dawka drożdży, napowietrzanie brzeczki, czas napełniania tankofermentora, filtrowalność piwa.

The aim of the article is to present the results of research on the influence of the main technological parameters of fermentation of beer wort produced in the multi-tank technology on the filtration properties of beer. The experiments were carried out in industrial conditions - fermentation and maturation in 3,850 hL tank fermentors. During the experiments, the influence of the following parameters of the fermentation process was investigated: fermentation temperature, initial dose of pitching yeast, degree of aeration and filling time of the fermentors. The selected parameters were subjected to separate series of experiments in triplicate. The main fermentation processes were carried out at the three tested temperatures: 8.5; 10 and 11.5°C. In the case of the yeast dose, the yeast harvested after the second fermentation (third passage) was added to the wort in the amount of 5, 7 and 9 million cells per 1 ml of wort. The wort was aerated with sterile air in the amount of 7, 10 and 12 mg oxygen per 1 L. The fermentors were filled for 4.5, 9 and 13.5 hours. The beer maturation process in the above-mentioned tankfermentors was carried out under the same technological conditions. Experiments have shown that different fermentation temperature, dose of yeast and aeration level have a significant impact on the filtration properties of beer. As the fermentation temperature increased, the beer filterability decreased, while the higher dose of yeast contributed to its improvement.

Key words: beer wort, tankfermentor, fermentation temperature, yeast pitching rate, wort aeration, filling time fermentor, beer filterability.

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INTRODUCTION

Beer nowadays is produced on four steps: malting, wort production, fermentation, and filtration step. After fermentation process beer contain various suspended particles yeast cells, preparations of protein, coagulation matter, resins hops etc., which ruin the taste and should be removed. Filtration is technological process, is separation of the solid phase of the suspension [7].

The filtration technology is used to remove particulate matter including yeast and sediments, which reduce the clarity and stability integrity of the product [1].

The conventional dead-end filtration with filter-aids (kieselguhr) has been the standard industrial practice for more than 100 years and will be increasingly scrutinized from economic, environmental and technical standpoints in the coming century. Kieselguhr is diatomaceous earth, which consists of skeletons of marine algae containing silicon dioxide. Kieselguhr powders for use in brewing are prepared by drying and milling on size of particles 5 – 20 µm [2].

The goal of beer filtration is to separate suspensions that cause turbidity or opalescence, and to give the appropriate clarity and gloss. As a result of filtration, the number of yeast should be reduced to 5 cells per 100 ml of beer, clarity below 0.5 EBC (at an angle of 90°) and the lowest possible oxygenation (below 0.02 mg / L). Beer filtration is most often done using diatomaceous earth, with the exception of membrane and cross-flow techniques. To obtain a clear beer, it is necessary to separate all solids larger than 0.5 µm. Thus, the process covers the area of fine filtration and microfiltration, and recently ultrafiltration techniques have also been applied. During filtration, especially ultrafiltration, the following groups of impurities are separated:

- microbial cells, mainly yeasts and bacteria, with dimensions from approx. 0.5 to 10 µm,
- proteins and protein-tannin compounds up to 5 µm,
- carbohydrate compounds, mainly starches, dextrins, pentosans and β-glucans, particles up to 5 µm in size. It should be noted that fine sediments are compressed during aging and block access to the filtration layer for subsequent beer batches [4].

During the process, beer flows through the filter and over the course of time higher pressure needs to be applied in order to maintain a continuous flow through the filter. Overall filter performance is dependent on the filter eficiency and beer volume through the filter between the recharge and the beer clarity. In the brewing industry, lager beer produced by industrial breweries is usually expected to not exceed 0.5° EBC haze, which is considered a ‘brilliant’ [6].

The aim of the article is to present the results of the impact of selected wort fermentation parameters carried out in industrial conditions on the filtration properties of beer.

MATERIALS AND METHODS

Experimental design

This study investigates the parallel process of beer production in three different cylindro-conical tanks (CCT), sampled during 18 days of the production cycle. Each cylindro-conical tank was filled with three brews (each batch taking 4.5 h) Total filling time for three fermenters was 13.5 h. High Gravity worts (15.5°P) were prepared from the same batch of malt under identical conditions.

Sample collection started after filling the CCT and continued during the following days at the same time every day. Sampling used a device equipped with an installed small pump working in a closed loop, enabling to be taken at vessel. The sampling point was located above the cone, 5 m from the bottom of the tank The CCT had a total capacity of 3850 hL with a 20% headspace. In order to obtain representative samples, the circulation pump was kept running during the process, but was switched off (approximately 24 hours) before yeast cropping.

In this work, a third generation bottom fermenting yeast was used and stored in the same yeast storage tank (YST).

The fermentation was performed at (Fig. 1): 8.5; 10 and 11.5°C. Yeast was pitched (5; 7 and 9 mln cells per 1 mL) using ABER system for rate control (Fig. 2). The wort was aerated (7, 10 and 12 mg/L) with sterile air (Fig. 3). The CCTs were filled by different time - 4,5; 9 and 13.5 hours (Fig. 4). The beer maturation was carried out in the same technological conditions.

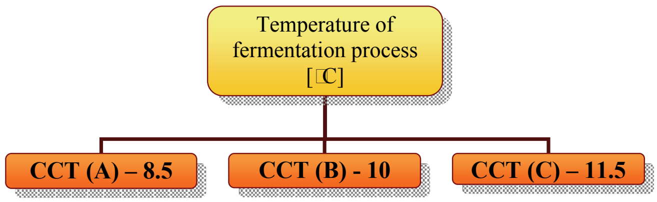

Fig. 1. Temperature of the wort fermentation.
Rys. 1. Temperatura fermentacji brzeczki.

Source: The own study
Źródło: Badania własne

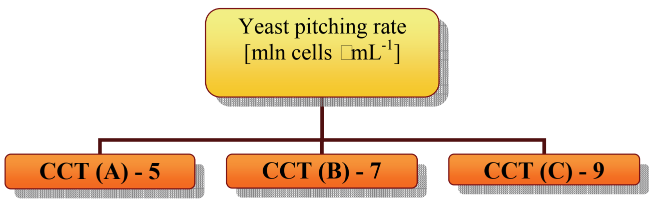

Fig. 2. Yeast pitching rate.
Rys. 2. Dawka drożdży nastawnych.

Source: The own study
Źródło: Badania własne

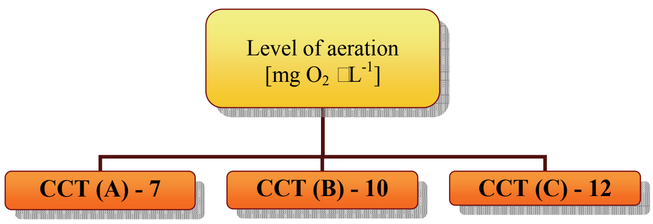

Fig. 3. Level of aeration.
Rys. 3. Stopień napowietrzania.

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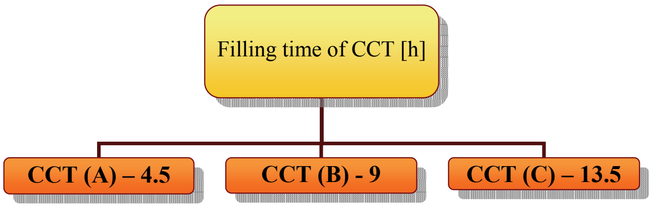

Fig. 4. Filling time of CCT.
Rys. 4. Czas napełniania tankofermentorów.
Source: The own study
Źródło: Badania własne

Measurement of filterability

During the filterability test, the tankfermenters with the selected tested parameters were subjected to the filtration process. The filterability of the beer was assessed on the basis of the pressure increase (dP) – pressure difference between input and output on the candle filter within one hour.

Statistical analysis

The results presented in this work were the average of three independent experiments with the bars representing the standard deviation. The data was analysed by one-way analysis of variance (ANOVA) to test the significance of the different fermentation temperatures on the fast of fermentation and beer losses produced on industrial scale. Significant differences between the means were verified by Duncan test ($P < 0.05$). Analyses of variance ANOVA were made with the use of Statistica v.10 (StatSoft Polska, Kraków, Poland).

RESULTS AND DISCUSSION

After the wort fermentation and maturation processes of the beer in the fermentation tank, the next stage of production is filtration, which is influenced by the parameters and technological conditions of previous post-process events.

For beer filtration, candle filters (Filtrox, Switzerland) were used, in which the filter material was diatomaceous earth, used in the amount of about 100 g · hL^{-1}. The filtering properties of beer are largely influenced by yeast flocculation as well as technological processes taking place in the brewhouse and during beer fermentation and maturation.

In this study, the filtration properties of beer were characterized only in relation to the method of filling the fermentor, wort aeration, dose of pitching yeast and fermentation temperature.

Figures 5-8 show the influence of the tested factors on the filtering properties of beer. The obtained results indicate that the fermentation temperature, dose of pitching yeast and aeration level have a significant impact on the filterability and filtration efficiency of beer.

The filterability of beer, determined by the increase in pressure per unit of time (1 h), indicates that the increase in fermentation temperature (Fig. 5) is related to the increasing filtration pressure. This means that the higher fermentation temperature lowers the filtering properties of the beer. In turn, increasing the dose of yeast contributes to their improvement (Fig. 6).

For the fermentation temperature of 8.5°C, the average pressure increase (Δp) during beer filtration was 0.13 bar·h^{-1}. On the other hand, fermentation of samples at 10 and 11.5°C increased the filtration pressure to 0.21 and 0.27 bar·h^{-1}, respectively.

It should be assumed that the reduced filterability of beer is the result of more intensive multiplication of yeast at higher fermentation temperature.

The increased concentration of especially young cells in the filtered beer causes a greater resistance of the filtration layer. The increased suspension of yeasts is due to their weakened flocculation. Young cells are characterized by a thinner and smoother cell wall and smaller dimensions, which makes it difficult for them to merge into larger conglomerates.

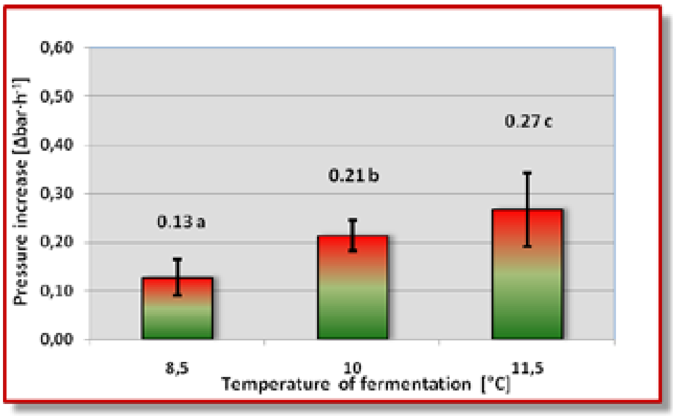

Fig. 5. Filtering properties of beer depending on the fermentation temperature.
Rys. 5. Właściwości filtracyjne piwa w zależności od temperatury fermentacji.
Source: The own study
Źródło: Badania własne

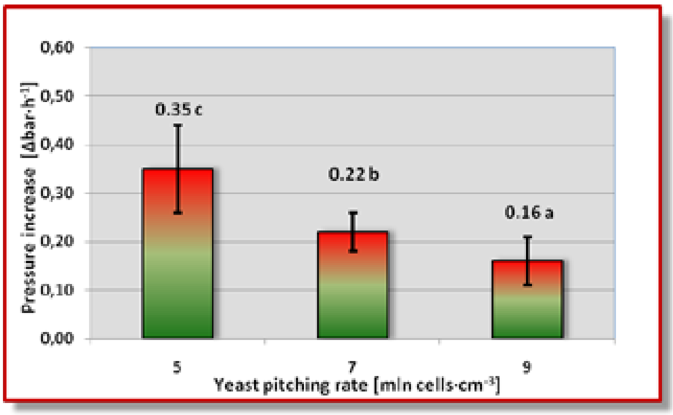

Fig. 6. Filtering properties of beer depending on the yeast pitching rate.
Rys. 6. Właściwości filtracyjne piwa w zależności od dawki drożdży nastawnych.
Source: The own study
Źródło: Badania własne

Fermentation settings with higher doses of yeast were characterized by their lower proliferation, and thus a smaller number of new cells in the beer, which resulted in a clearer drink in the aging process. In the case of the lowest dose of pitching yeast (5 million cells·mL^{-1}), the resistance of the filtration layer increased by 0.35 bar·h^{-1} (Fig. 6). Increasing the initial amount of yeast in fermentation wort improved the filtration properties of beer. The commencement of fermentation with a concentration of yeast of 7 million cells·mL^{-1}, in the subsequent filtration process, contributed to the increase in pressure to 0.22 bar·h^{-1}. A further increase in the amount of inocculum (9 million cells·mL^{-1}) resulted in an extension of the filtration cycle due to the reduction of the pressure difference (0.16 bar·h^{-1}).

Figure 7 shows the effect of the method of filling fermentation tanks on the filterability of beer. Depending on the method of their refilling, the filtration pressure increased from 0.32 to 0.44 bar·h^{-1}.

The lowest pressure increase was observed for tanks filled for 9 hours. This time seems optimal to obtain a longer beer filtration process. In the case of filling the fermentor with successive brews without a break, the filtering properties of the beer are clearly deteriorated. A similarly unfavorable phenomenon occurs when the tanks are filled for too long.

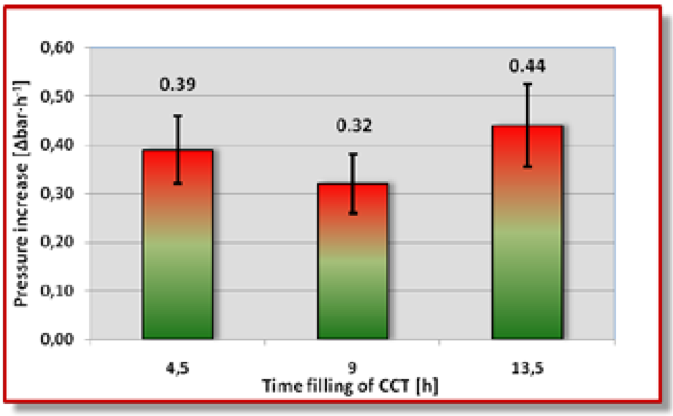

Fig. 7. Filtering properties of beer depending on the time filling CCT.
Rys. 7. Właściwości filtracyjne piwa w zależności od czasu napełniania CKT.
Source: The own study
Źródło: Badania własne

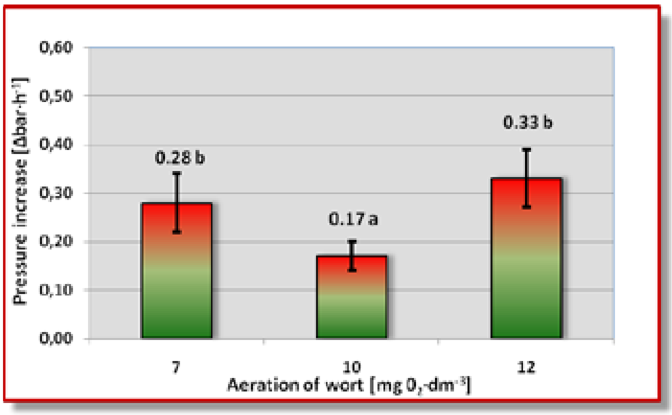

Fig. 8. Filtering properties of beer depending on the aeration of wort.
Rys. 8. Właściwości filtracyjne piwa w zależności od napowietrzania brzeczki.
Source: The own study
Źródło: Badania własne

The different degree of aeration caused the pressure increase from 0.17 to 0.33 bar·h^{-1} (Fig. 8). The research showed a significant influence of the aeration degree on the filtering properties of beer. Lower and higher initial doses of oxygen in relation to aeration at the level of 10 mg of oxygen per L have a negative impact on the efficiency of the filtration process. Experiments have shown that the degree of air entrainment may double or shorten the filtration batch.

Due to the unique approach to determining the impact of selected parameters of the fermentation process on the subsequent beer filtration process, the collected literature in this field is very little popular. One of the Authors who took up this topic is Pinguli et al. [3, 5]. Authors stated, that filtration process is controlled by yeast, proteins and carbohydrates. If yeast cell number is less than a million, filterability is dependent mainly from physico-chemical beer characteristics. Beer filterability is strongly depended by malt quality, especially β-glucans content that impact directly on beer viscosity. If beer or wort has a high viscosity it is strongly recommended to use enzymes to control carbohydrates that dominate filtration characteristics such as unmodified starch, dextrins, pentosans, and β-glucans.

Summarizing the filtering properties of beer, it should be stated that the selection of the parameters of the fermentation process affects the multiplication and sedimentation of yeast. Conditions affecting the deterioration of the yeast flocculation ability, such as an increased growth of fresh biomass or a greater share of young cells in the yeast population, reduce the permeability of the filtration layer and thus reduce the filtration efficiency.

WNIOSKI

1. Stwierdzono istotny wpływ temperatury fermentacji na właściwości filtracyjne piwa. Wyższe temperatury fermentacji powodują większe przyrosty ciśnienia podczas filtracji piwa.
2. Badania wykazały, że w doświadczeniach prowadzonych w warunkach przemysłowych, dawka drożdży nastawnych ma istotny wpływ na właściwości filtracyjne piwa. Wraz ze wzrostem dawki drożdży następowało wydłużenie szarży filtracyjnej.
3. Sposób napełniania i stopień napowietrzania brzeczki również wpływają na właściwości filtracyjne piwa. Czas napełniania tankofermentora przez 9 godzin jak również dawka tlenu w ilosci 10 mg/L zapewniają mniejsze przyrosty ciśnienia podczas filtracji piwa a tym samym zapewniają wydłużenie szarży filtracyjnej.

CONCLUSION

1. A significant influence of the fermentation temperature on the filtering properties of beer was found. Higher fermentation temperatures result in higher pressure increase during beer filtration.
2. Research has shown that in experiments carried out in industrial conditions, the dose of yeast has a significant impact on the filtering properties of beer. With the increase in the dose of yeast, the filtration cycle was extended.
3. The method of filling and the degree of aeration of the wort

also affect the filtration properties of the beer. The time of filling the fermentor for 9 hours as well as the dose of oxygen in the amount of 10 mg / L ensure lower pressure increase during beer filtration and thus extend the filtration batch.

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