Extract losses in beer production process

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Abstract

Continuous changes in economic conditions and the development of technology are forcing production companies to seek and implement solutions to reduce losses. Product losses occurring in the technological process of beer production in a brewery are converted into extract losses and expressed as a percentage of losses for the entire technological process or for each operation in the beer production process. Losses arising in the production process make up the cost of the manufactured product, so it is important, to analyze the production process, identify the resulting losses and implement technical and technological solutions to minimize them and achieve greater efficiency and profit growth for the company. In addition, extract losses arising in the beer production process affect the increased consumption of water, electricity and heating, as well as on the increased waste production. The challenge for the brewery is to provide the market with a repeatable product of the highest quality. Therefore, beer production should be characterized by stability, repeatability, and subject to easy control thus ensuring production safety and savings.

The purpose of this study was to evaluate the beer production process to identify process steps characterized by high extract losses and implement measures to minimize losses without adversely affecting beer quality, yeast physiological state and plant productivity.

Extract losses arising in the beer production process can be divided into operational and technological losses. Operational losses are affected by the scale of production and the level of automation of the brewery. Technical losses result from leaks in technological installations, liquids remaining in tanks and installations, improper operation of equipment control and measurement equipment, as well as poor technical infrastructure. Operational losses are also significantly affected by production planning, the organization of the enterprise and the location of individual production departments. In addition, the level of employee awareness and competence plays an important role in reducing losses.

Technical losses of the brewhouse can be caused by the depletion of spare parts of the hammer grinder and wet milling grinder, as well as components of the of the mash filter, such as filter cloths and membranes.

It was noted that the implementations used to reduce wort and beer extract losses also lead to reduction in the loss of chemicals, water and electricity during washing in the CIP system, as well as carbon dioxide losses during the filling of BBT tanks with beer.

Technological losses result from the application of beer production technology. These are mainly due to extract remaining in the post-production materials, too high an increase in yeast biomass, excessive beer removal during the centrifugation process, and too high a beer extract content in the finished product.

The study included an analysis of the possibility of using malt dust for mashing. The addition of malt dust in the amount of 80 kg per brew resulted in a reduction in wort extract losses by 0.5 and 0.6 pp., respectively, in the production of 16.5 °Plato wort using grist with a particle size of 2.5 mm and a water to grist ratio of 2.50:1 and 2.65:1.

Optimization of the process of milling malt and unmalted raw materials was carried out. In the conducted research, the worts produced using finer milling, regardless of the assumed extract content in the wort and raw material composition in the recipe, were characterized by higher extract yield. Finer milling adversely affected the filtration time of worts with 45% barley in the charge and caused faster clogging of the filter cloths, while it did not affect the turbidity of cold wort, with the exception of the 17.1 ºPlato wort.

The effect of replacing worn-out hammers in the hammer grinder on the efficiency of extract extraction from raw materials was analyzed. Regardless of the process carried out, the washable extract content and moisture content of the spent grain differed between the mash filter chambers. In contrast, the content of non-washable extract was stable for each process. It was assumed that this could be indicative of malfunctioning membranes or depleted membrane fabrics. The highest levels of non-extractable extract were recorded before the replacement of the hammers, when the mash was prepared from malt grist with a particle size of 2.5 mm. The depleted hammers probably contributed to improper milling of the raw material, which resulted in elevated levels of non-washable extract in the spent grains. In addition, coarser milling of the raw material contributed to elevated amounts of non-washable extract probably due to weak extraction of compounds from the grist.

As part of the study, the mash density was optimized. Increasing the mash density led to reduced extract losses in the wort for both mash filter and lauter tun filtration. However, increasing the grist to water ratio in wort production by 45% barley content led to prolonged filtration of the mash due to clogging of the filter cloths. Lowest extract losses during wort production 17.1 °Plato, was obtained when the mash was prepared in the course of decoction mashing from grist mixed with water in a ratio of 2.75:1 and filtered in a mash filter and 2.85:1 when it was filtered in a lauter tun.

The possibility of adding hot trub to the spent grains in the lauter tun during sparging was analyzed. The study found that the addition of hot trub to the mash tun during the spent grain's sparging, however, had no effect on increasing the amount of extract in the wort. The difference in extract loss was 0.1 pp. The addition of hot trub also caused an increase in the turbidity of cold wort, but did not result in an increase in the turbidity of the beer after fermentation. After fermentation, there was a higher yeast biomass growth in the sample with the addition of hot sludge, which accelerated the fermentation process by 0.5 days. During the research, sensory evaluation of the beers produced with and without the addition of hot trub to spent grain during clarification in the lauter tun was carried out. In the beers after main fermentation, no differences were noted between the produced beer batches.

The work carried out optimized the wort aeration process and the dose of pitching yeast used in the fermentation process. Increasing the dose of pitching yeast and decreasing the amount of air introduced decreased the growth of yeast biomass and the number of cells suspended in the fermenting beer. As the yeast dose increased, the speed of the fermentation process, expressed as a daily decrease in the amount of extract, increased. The use of a high dose of inoculum made it possible to reduce the loss of extract. In the yeast slurry harvested after the fermentation process of beers made with a high dose of yeast, the number of dead cells did not exceed 5%. The study concluded, that decreasing the aeration of the wort and increasing the dose of pitching yeast within the tested ranges had no significant effect on the sensory quality of the final product. In the conducted studies, the size of the inoculum had no effect on either the taste of the beer, nor on ethanol concentration. Despite large differences in yeast biomass growth, alcohol concentration and apparent attenuation rate were similar. The higher pH of the beer was probably associated with more dead cells and the release of the contents of these cells into the beer. After all, the percentage of dead yeast cells was not elevated at higher yeast doses, but the number of dead cells might be increased if the doses of pitching yeast were even higher. The elevated contents of higher alcohols, esters and acetaldehyde were obtained when yeast was used for fermentation at 1.0 kg/hl and the amount of air introduced was reduced from 15 m3 to 12 m^3. While reducing the amount of air and increasing the dose of pitching yeast (yeast dose from 1.0 to 1.3 kg/hl) resulted in the lowest concentrations of these compounds. Reducing aeration and increasing the yeast dose from 1.0 kg/hl to 1.3 kg/hl reduced the content of higher alcohols, esters and acetaldehyde by 52%, 32% and 15%, respectively.

The multiple use of yeast for the fermentation process was also optimized. The research found that the use of large doses of yeast reduces yeast growth, but has no effect on the dead cell content of the yeast biomass up to the fifth generation. The effect of the batch of yeast harvested on the lenght fermentation process was evaluated. Within the conducted research, it was found, that beer fermentation time depends on the dose of pitching yeast, stress factors during fermentation and the batch of yeast used for fermentation. In addition, the raw material composition of the wort is important for the serial repitching of yeast into subsequent worts, including the possibility of inhibiting the adsorption of maltose and maltotriose due to the presence of a repression mechanism by glucose. In the course of the research, it was found that the fermentation process with yeast from the first harvest occurred faster than with yeast from the second harvest due to the higher content of old and young yeast cells. In the research conducted as part of the dissertation, the fermentation time was shorter when successive generations of yeast were used except for the fifth generation. The fermentation time of beer using fifth-generation yeast was affected by the prolonged fermentation of A and C beers made from wort without the addition of glucose syrup. The utilization rate of FAN in fermentations carried out with successive generations of yeast ranged from 41-50%. It is likely that the high dose of yeast was the main growth-limiting factor in the studies conducted. In yeast generations two through five, there were no statistically significant differences in dead cell content from one generation to the next. The highest dead cell content was 4.5%, thus achieving the criteria for pitching yeast. The study found that the content of esters as well as higher alcohols in beer was similar regardless of the yeast pitch used. The content of higher alcohols depended on the composition of the wort and was significantly higher for beer B obtained from malt, glucose syrup and corn grits. The content of acetaldehyde depended on the raw material composition of the beer and the generation of yeast used.

As part of the work carried out, the conditions for centrifugation of young beer were optimized. In order to reduce losses during the centrifugation process, it is important to determine such parameters as the yeast cell content of the beer directed to centrifugation, the beer temperature and calcium dosage, and the moment when the beer is transferred to centrifugation. A calcium dose of 60 to 80 mg/dm^3 was found to be sufficient to maintain proper yeast flocculation. Centrifugation of the beer at a fermentation temperature of 13^{o}C and during cooling at a temperature of 5 to 9^{o}C resulted in the lowest extract losses. To reduce beer losses at the centrifugation stage, consider centrifuging the entire volume of the tank. Beer in the higher layers of the CCT can be clear and meet the requirements of beer directed for the filtration process, and centrifuging the entire beer volume may result in additional losses. Lower beer turbidity can be achieved by using a high dose of yeast.

The results presented in this study provide valuable insight into the haze-forming potential of lager beers brewed with various raw materials and process aids. The impact of partial substitution of malt with corn grist and sugar syrup or with unmalted barley was assessed. We also examined how the addition of exogenous proteases and carrageenan affected colloidal stability. Predicting haze formation during storage based on total nitrogen content (by the Kjeldahl method) and polyphenol content (by spectrophotometry) in the fnal beer after bottling was found to be diffcult. However, measuring and adjusting the content of coagulable nitrogen offers a powerful way to estimate and reduce hazeforming potential. The colloidal stability of beer produced from unmalted barley can be improved by supplementing the mash/wort and/or pitching wort with exogenous proteases and carrageenan. The beers with added corn grist and starch syrup also showed signifcantly enhanced physical shelf life. The results of this study show that careful selection of raw materials and process aids can signifcantly improve the colloidal stability of beers produced on an industrial scale.

As part of the work carried out, the recovery of beer from yeast not used in the fermentation process was implemented, reducing beer extract losses by 0.3 p.p. per year. In addition, beer extract losses in the filtration department were divided into those caused by operator mistake or improper calibration of measuring equipment and the production of beer with a higher than declared beer extract content due to the achievement of a minimum alcohol content. Accordingly, the minimum extract content for the produced beers was determined so that the alcohol content would be within the range of permissible deviation, which allowed a reduction in technological losses to -1.74%. As a result of research, beers whose production result in increased extract losses were determined to have insufficient alcohol content after standardization of concentrated beer. In the course of the work carried out, new parameters were determined for concentrated beers and procedures were implemented for the production of beers with extract losses.

Implementation of the above measures made it possible to reduce extract losses in the beer production process by 1.7% per year, with a 13% increase in production without changing the infrastructure of the brewing and fermentation department.