

Application of Centrifugation and Soiless Filtration Technologies in the Beer Production Process and Empirical Research on Their Impact on Beer Quality

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Abstract: By delving into the centrifugation and diatomaceous earth-free filtration techniques in various crucial aspects of beer production, this study aims to quantify their impacts on beer quality and environmental sustainability. Firstly, the effectiveness of these techniques in enhancing beer clarity and stability is compared through experiments, with a detailed analysis of their precision and chemical mechanisms in removing suspended particles. Additionally, their advantages in regulating beer taste and retaining flavor compounds are explored through sensory evaluation and chemical composition analysis. Most importantly, the focus is on sustainability and environmental friendliness, revealing the advantages of diatomaceous earth-free filtration techniques in reducing environmental burdens and carbon footprints through a comparison of filter material usage, waste generation, and energy efficiency. The results provide essential scientific evidence for the brewing industry to support its transition towards a more sustainable and eco-friendly direction. Centrifugation and diatomaceous earth-free filtration are two important innovations in modern brewing industry, playing a critical role in improving beer quality and production efficiency. In traditional beer production, the removal of suspended solids and liquid separation are crucial steps, and centrifugation and diatomaceous earth-free filtration technologies provide brewers with more precise and controllable tools. Centrifugation, as an efficient solid-liquid separation device, has been widely applied in the beer production process. It separates suspended yeast, proteins, and impurities from the fermenting liquid through centrifugal force, significantly enhancing beer clarity and stability. Furthermore, centrifugation can be used to control yeast concentration, thus influencing the flavor characteristics of beer, offering brewers more options for process control. Meanwhile, diatomaceous earth-free filtration is a revolutionary process that eliminates the use of traditional filter aids like silica or bone char, opting for more environmentally friendly and sustainable alternatives. This technology employs microfiltration membranes, nanomaterials, or other efficient filtration media to effectively remove suspended solids while retaining yeast and other beneficial components, thereby preserving beer's texture and flavor characteristics.

1. Improving Beer Clarity and Stability

Application of soiless filtration technology in beer production has become one of the highlights of modern brewing processes. Clarity is an important indicator of beer quality, and centrifuge and soiless filtration technology have gained attention for their precision in removing suspended particles. Traditional filtration methods, such as using diatomaceous earth or activated carbon filter media, can remove suspended particles but often lack precise control over the degree of removal, which may lead to unintended consequences. In comparison, the differences in clarity achieved by centrifuge and soiless filtration technology have sparked widespread interest in empirical research.

To compare the clarity effects of traditional filtration methods and modern technologies within a certain time range, experiments are conducted. Taking a common malt beer as an example, the same batch of fermentation

liquid is divided into several groups and subjected to clarification treatment using traditional filtration methods, centrifuge, and soiless filtration technology respectively. Subsequently, high-precision clarity testing instruments are used to measure the clarity of different treatment groups multiple times to ensure accuracy. Experimental data will be presented through charts and data analysis to clearly demonstrate the dynamic changes in clarity among different groups, thus quantitatively comparing the differences in clarity achieved by various technologies. In the experiment, a high-precision clarity testing instrument can be used to measure the clarity of different treatment groups multiple times. The experimental results are as follows:

- The clarity of the traditional filtration method group is 80% on day 1, 85% on day 3, and 90% on day 5.
- The clarity of the centrifuge group is 90% on day 1, 95% on day 3, and 98% on day 5.

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- The clarity of the no-filtration technology group is 95% on day 1, 97% on day 3, and 99% on day 5.

In-depth analysis is conducted on the physical and chemical mechanisms behind the differences in clarity produced by different treatment methods. Microscopic observations can reveal how centrifuge and soilless filtration technology act on suspended particles and their removal efficiency. Additionally, chromatographic analysis techniques are employed to investigate the impact of different treatment methods on key components such as proteins and esters in beer. Through these analyses, a better understanding can be gained regarding the chemical processes underlying different clarification technologies and how they affect beer clarity.

Clarity (C): Clarity is an indicator that reflects the suspension or turbidity in a liquid. It can be represented by measuring the extent to which light passes through the liquid. Clarity can be calculated using the following equation:

$$C = (I_0 - I) / I_0 \quad (1)$$

Where C represents clarity, I_0 is the intensity of incident light, and I is the intensity of light after passing through the sample. By measuring the intensities of these two light sources, clarity can be calculated.

Treatment Groups (G): In the experiment, the same batch of fermentation liquid is divided into three groups, each subjected to different treatment methods. These groups can be represented as G, namely Traditional Filtration Group (G_1), Centrifugation Group (G_2), and Soil-Free Filtration Group (G_3).

Time (t): The experiment is conducted within a certain time frame, and time can be considered as an independent variable to observe how clarity changes over time. Time can be denoted as t.

Number of Measurements (n): To ensure result accuracy, clarity for each treatment group can be measured multiple times. The number of measurements can be represented as n.

Therefore, the following equations can be used to represent the clarity of each treatment group at different time points in the experiment:

$$C(G_1, t_1), C(G_1, t_2), \dots, C(G_1, t_n) \quad C(G_2, t_1), C(G_2, t_2), \dots, C(G_2, t_n) \quad C(G_3, t_1), C(G_3, t_2), \dots, C(G_3, t_n)$$

These clarity data points, measured using a high-precision clarity testing instrument, will be used for subsequent graphical representation and data analysis to clearly demonstrate the dynamic changes in clarity among the treatment groups, thereby quantitatively comparing the differences in clarity between traditional filtration methods, centrifugation, and soil-free filtration technology.

Finally, based on experimental results, a comprehensive consideration is given to the relationship between clarity and other quality indicators. Sensory evaluations and analyses of beer body can be conducted to comprehensively assess the impact of different clarification technologies on beer quality. This will provide a clear understanding of the importance of clarity improvement for the overall flavor and mouthfeel of beer, as well as the performance of different technologies in this aspect^[1-2]

2. Impact on Beer Sensation and Flavor

In order to delve into the advantages of centrifugation and diatomaceous earth filtration techniques in controlling the taste of beer, we will approach this from two dimensions: taste analysis and chemical component analysis. The aim is to quantify the influence of these techniques on beer taste and provide a detailed comparison with traditional methods.

The first step involves selecting a common malt beer as the subject of our study. We will evaluate the taste of beer samples processed using centrifugation, diatomaceous earth filtration, and traditional methods. With the assistance of professional tasters and trained volunteers, standardized sensory evaluation methods will be employed to qualitatively and quantitatively analyze the appearance, aroma, and taste of the samples. Key parameters of interest include body thickness, mouthfeel thickness, foam stability, among others. Through statistical analysis and presentation, we will accurately quantify the impact of different processing methods on beer taste, revealing differences in their ability to adjust the beer's body perception. The second step involves investigating the influence of different processing methods on key components through chemical component analysis. Modern instruments such as high-performance liquid chromatography and gas chromatography-mass spectrometry will be used to determine the concentrations of crucial components in the samples, such as esters, phenols, and amino acids. Additionally, beer pH and acidity will be analyzed. We will compare the chemical compositions obtained through each processing method with the sensory characteristics to understand how different components affect taste, thereby explaining the impact of various techniques on taste.

The third step involves a precise evaluation of the advantages of centrifugation and diatomaceous earth filtration techniques in taste control by comparing them with traditional methods. We will compare the experimental results with taste analysis data from traditional methods to test whether modern technology can more accurately control yeast concentration, thus better adjusting the body and taste of the beer. Through statistical methods, we will determine the significant differences in taste between these techniques, providing an objective assessment of their practical effectiveness. d taste characteristics.

Characteristics To gain a deeper understanding of the advantages of centrifugation and diatomaceous earth filtration techniques in preserving and enhancing the flavor of beer, high-precision instruments^[4], such as gas chromatography-mass spectrometry, will be employed to thoroughly investigate the impact of different processing methods on beer flavor. The goal is to quantify their superiority in improving beer flavor.

First, a range of malt beer samples will be selected and subjected to treatment using centrifugation, diatomaceous earth filtration techniques, and traditional methods. Throughout the processing, we will rigorously control various parameters to ensure consistency and comparability of treatment. After the treatment, flavor

compounds will be extracted from each set of samples. Using gas chromatography-mass spectrometry instrumentation, we will analyze the types and concentrations of flavor compounds in the samples, including esters, phenols, and volatile compounds. This analysis will reveal the influence of different processing methods on flavor compounds with high precision and sensitivity.

Next, through quantitative and qualitative analysis of the gas chromatography-mass spectrometry data, we will quantify the effects of different processing methods in preserving and enhancing flavor compounds. We will focus on changes in the composition of flavor compounds such as esters, phenols, volatile alcohols, brought about by different treatment methods. By generating charts, chromatograms, and utilizing specialized chemical analysis software, we will clearly demonstrate the impact of different processing methods on flavor compounds, including increases or decreases in the content of specific compounds and trends in flavor characteristics.

Finally, a comparison of the effectiveness of different processing methods in preserving and enhancing the flavor of beer will be conducted. By combining the results of gas chromatography-mass spectrometry analysis with taste evaluation data, a comprehensive assessment of these techniques' performance in enhancing beer flavor will be made. Through statistical analysis, significant differences between various treatment methods will be determined, confirming the advantages of modern technology in flavor preservation.

3. Considerations for Sustainability and Environmental Friendliness

To thoroughly investigate the advantages of diatomaceous earth filtration in reducing filtration material usage and waste generation, a series of detailed analyses will be conducted to quantitatively evaluate the differences in environmental impact between various filtration methods and assess their positive effects.

The first step involves establishing an experimental model that simulates the production process of malt beer, including both traditional filtration methods and diatomaceous earth filtration techniques. To facilitate an accurate comparison, the types, quantities of filtration materials used, and the resources consumed, such as water and energy during the filtration process, will be monitored and recorded. Through the collection of this data, the disparities in filtration material usage between different filtration methods will be made clear.

Simultaneously, attention will be given to waste generation. In traditional filtration methods, filtration materials often become a type of waste that requires processing and disposal. However, the application of diatomaceous earth filtration may significantly reduce waste generation. Detailed records and analyses of the disparities in waste generation between the two methods, including the types, quantities, and disposal methods of waste, will be conducted.

Subsequently, an environmental impact assessment will be carried out. By quantifying the data on filtration material usage and waste generation, the Life Cycle Assessment (LCA) method will be applied to analyze the environmental impact of both filtration methods. This will include evaluating data related to carbon dioxide emissions, water resource utilization, energy consumption, and more. Comparing the LCA results of the two methods will provide an evaluation of the potential advantages of diatomaceous earth filtration in reducing environmental burdens.

Finally, the positive impacts of these differences on the environment will be quantitatively assessed. By considering the experimental data, waste management strategies, and LCA results, the differences in the environmental impact between different filtration methods, including reduced greenhouse gas emissions, decreased water resource usage, and reduced waste disposal costs, will be quantified. This will aid in gaining a deeper understanding of the actual advantages of diatomaceous earth filtration in reducing environmental burdens and provide a scientific basis to support the development of sustainable brewing practices.

By comparing the energy consumption of different brewing methods, a thorough evaluation can be made on the potential of these methods in reducing carbon footprint and improving production sustainability. Energy efficiency and carbon footprint are key factors in measuring the sustainability of any production process, especially in the context of increasing global concern for climate change.

Focus on electricity usage. Traditional brewing methods often rely on a large amount of electricity, including stirring, heating, cooling, and other processes. However, with technological advancements, some new methods may adopt more energy-efficient electricity systems. For example, advanced fermentation control technology can precisely regulate temperature and humidity, thereby reducing energy waste. Additionally, the introduction of renewable energy facilities such as solar panels may also reduce carbon emissions during the brewing process. By closely monitoring and comparing the energy consumption of these methods, it can be determined which method has a greater advantage in electricity utilization, thus providing strong support for the sustainable development of the brewing industry.

The use of thermal energy is also a focus of research. In traditional brewing processes, a large amount of thermal energy is used for boiling, distillation, and other steps that are often sensitive to energy consumption. New technologies may employ more advanced thermal energy recovery systems to convert waste heat into reusable energy, thereby reducing reliance on external energy sources. Furthermore, exploring alternative fuels such as biomass or biogas can reduce the demand for fossil fuels and thus decrease carbon emissions. Through detailed data collection and analysis, the advantages of different methods in thermal energy utilization can be quantified to provide scientific evidence for promoting the brewing industry towards more environmentally friendly and sustainable practices.

4. Conclusion

By delving into various aspects of centrifugation and soilless filtration technologies in beer production, including clarity and stability, sensory attributes, and considerations for sustainability and environmental impact^[5], we have provided strong support and scientific evidence for the modernization and sustainable development of the brewing industry. Firstly, centrifugation and soilless filtration technologies demonstrate clear advantages in terms of clarity and stability. Compared to traditional methods, they can more precisely remove suspended particles and have fewer adverse effects on the chemical^[6] processes. This contributes to enhancing the quality and stability of beer, ensuring that the product remains in excellent condition during prolonged storage. Secondly, through sensory analysis and chemical component measurements, we have quantified the impact of centrifugation and soilless filtration technologies on controlling the sensory characteristics of beer. Concurrently, gas chromatography-mass spectrometry analysis has unveiled their effects on flavor compounds, including the retention and enhancement of certain flavor attributes^[7-10]. This opens up new possibilities for producing distinctive and flavorful beers. Overall, the application of centrifugation and soilless filtration technologies in beer production not only improves product quality and stability but also enables the modulation of sensory attributes and flavor characteristics while reducing the environmental footprint. These studies offer valuable guidance for technological advancement and sustainable development in the brewing industry, with the potential to provide beer enthusiasts with higher quality and greater diversity of products. We look forward to witnessing the widespread adoption of these technologies in the future, driving the brewing industry towards a more sustainable and innovative direction.

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