# Particles contributing to turbidity in beer

**This article is dedicated to Dr. Karl Raible in honor of his 85th birthday**

**DEMANDS ON QUALITY** | The appearance of a beverage plays a significant role in the enjoyment of the drinking experience. With the advent of transparent, colorless glasses, clarity has become a sign of quality. The following article provides a brief overview of the development of fine, bright filtration and explores the causes for turbidity in beer and the measures employed to correct it.

**CLOUDY BEVERAGES ARE** viewed as unappetizing and spoiled. Indeed, if a product's shelf life is just slightly over their expiration date, that is reason enough for them to be rejected by consumers. Wine is praised as sparkling, beer referred to as bright and water described as crystal clear. Naturally cloudy, trendy beverages are the exception. This desire for clear beverages is rooted in several thousand years of experience. Even in mythical times, Homer's Odysseus, the ingenious son of Laertes, declared: "I will drink life to the lees!" We know from wall paintings from ancient Egypt and clay tablets from Mesopotamia that relatively transparent beer was drunk through narrow tubes or straws. It is also common for indigenous peoples to filter cloudy fermented grain mixtures.

W. Bücheler reported in "Bier und Bierbereitung in den frühen Kulturen und bei den Primitiven" (a book concerning beer in early cultures and among primitive peoples) [1] on the use of plant foliage and bird nests as sieves.

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## "Beautiful clear beer"

Although Thausing [2] was still cursing ten years on that this mess had "opened the flood gates", the modern beer filter was introduced in 1878 by L. Enzinger, and the movement towards fine, bright filtration could no longer be stopped. His words added yet more credence to the concept of filtration: "It should be the pride of every brewer to produce a beautiful clear beer, and he will not find it difficult to do so, if he is a good brewer". Partly clarified beer was already being produced using different techniques in the lager cellar [3]; however, the greatest effort was expended during this period on how to convert sour beer into a drinkable beverage [4, 5]. In the book "Schule der Bierbrauerei" ("School of the Beer Brewery") from 1863, Habich [6] elaborated on the addition of wood chips and glue as modern techniques of the time. This was also recorded in lecture notes from the material taught by Johann

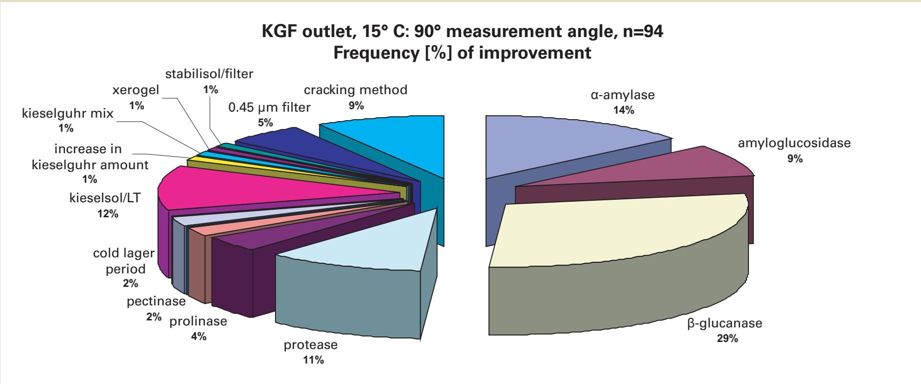


Fig. 1 **Success rate of improvement measures for turbidity problems (measurement angle: 90°)**

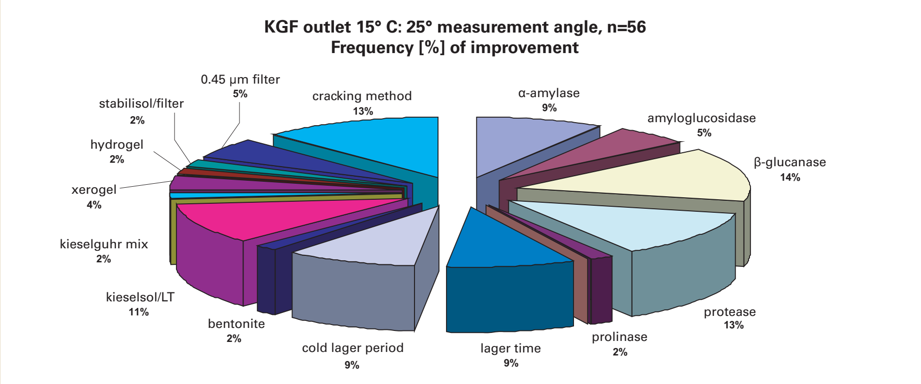


Fig. 2 **Success rate of improvement measures for turbidity problems (measurement angle: 25°)**

Raible in 1874 for the summer course of the Augsburger Brauerschule (Augsburg School for Brewers).

In areas outside of Germany, technology had reached comparable levels. In the 1893 translation by Wilhelm Windisch, Moritz and Harris [7] wrote a chapter about beer clarification using isinglass (made from the swim bladder of the sturgeon) in the "Handbuch der Brauwissenschaft" ("Handbook of Brewing Science"). De Clerk [8] also mentioned it in his textbook from 1964.

Through sterilization and pasteurization, beer is microbiologically stable for the most part, so that the actual preservative effect due to the substances contained in it is limited. The influence of the raw materials, the brewing process and the filling equipment has been extensively investigated. However, to this day, brewing scientists have yet to exhaust the possibilities for further research into the interactions occurring among the proteins, polyphenols, oxygen, their pH, molecular weight and the electrical charges they exchange.

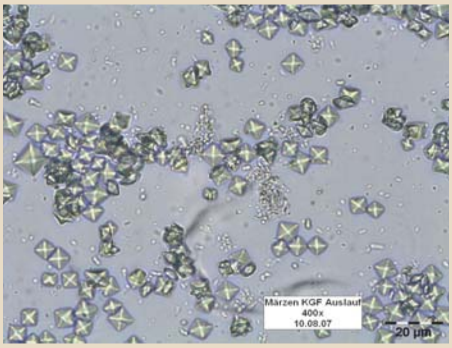


**Fig. 3 Oxalate precipitation**


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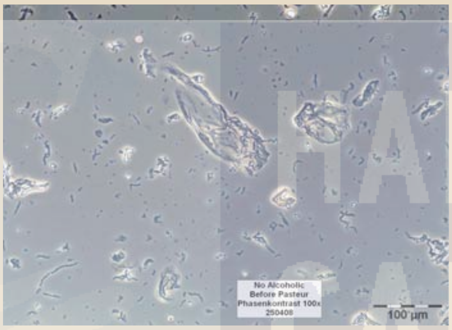


**Fig. 5 Particles before tunnel pasteurization**

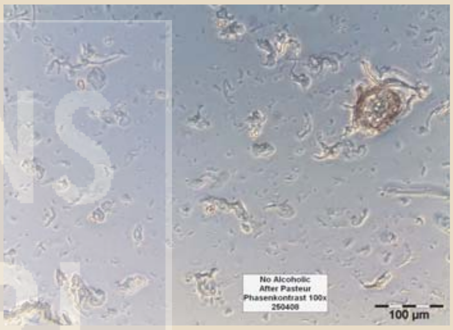


**Fig. 6 Particles before tunnel pasteurization**

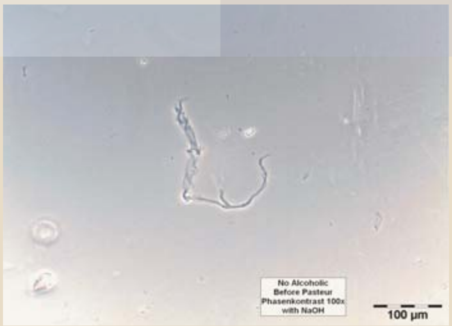


**Fig. 7 Particles before tunnel pasteurization, after treatment with NaOH**


**Fig. 8 Particles after tunnel pasteurization and treatment with NaOH**

## Changes in the demands on quality

The ever wider distribution of food and the corresponding necessity for longer shelf life times has changed the demands placed on quality. This began with the change from an agrarian to industrial society, culminating in the service and trade-based society of today. In the year 1900, 450 farmers provided food for 1000 citizens; today, it is three farmers per 1000 citizens. Parallels can be drawn in the beer market as well: Beer often has an expiration date of a year and more. Turbidity is measured in EBC formazine turbidity units (EBC). According to *Ludwig* et al. [9], a beer is classified as absolutely clear at < 0.2 EBC, clear to < 1 EBC, opalescent to < 4 EBC and cloudy at all higher values; however, the individual visual impression of a beer does not always correspond to the measured values for turbidity. In the technical article "Biertrübung aktuell" [10] about beer turbidity, a guide for localizing the causes of turbidity problems is provided. Both treatment of problem beers with specific enzymes in the laboratory and microscopic examination reveal information about the nature of the specific types of turbidity affecting beer and possible technological applications for use in eliminating its causes. 175 beers with filtration problems were sent to the laboratory of the Stabifix-Brauerei-Technik for analysis. With the exception of beers exhibiting early stability problems, the beers could be divided into three groups on the basis of the following characteristics:

- extremely rapid turbidity development during aging,
- increased turbidity values at the filter outlet,
- visible particles in the packaged beer.

The problems were independent of beer style, whereby non-alcoholic beers and beverages containing beer (beermix products) were more frequently affected.

## Correctional Measures and Their Effectiveness

The correctional measures and their frequency in percent are listed in figures 1 and 2. Turbidity measurements were carried out at angles of 90° und 25° at a temperature of 15 °C. It should be noted that during testing, turbidity was found to have been caused most frequently by beta-glucans. This was measured primarily using the 90° measurement. Turbidity caused by beta-glucans was followed in frequency by carbohydrates and proteins, which were recognized by using both measurements. It appears that the influence of proline has been over-estimated, because only four percent of the improvements could be linked to the addition of prolinase.

Since the turbidity values were frequently reduced by the addition of alpha-amylase or amyloglucosidase, it is understandable why merely changing to a finer composition of kieselguhr for the dosage achieved only mixed results.

**Fig. 9 Fine particles in reduced-calorie, reduced-alcohol beer (magnified 40x)**


**Fig. 10 Fine particles in reduced-calorie, reduced-alcohol beer (magnified 100x)**


**Fig. 11 Particles in lager beer**

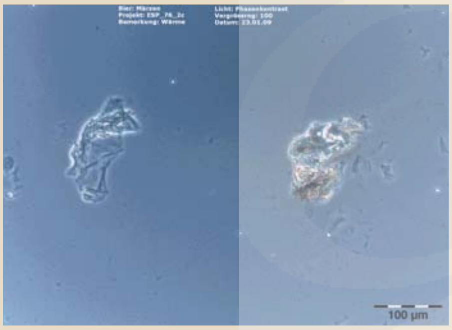


**Fig. 12 Particles in Märzen beer (magnified 100x)**

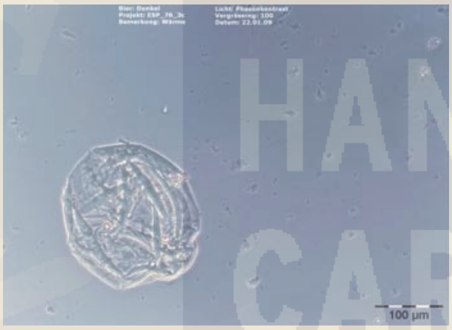


**Fig. 13 Particles in Bavarian Dunkles beer**

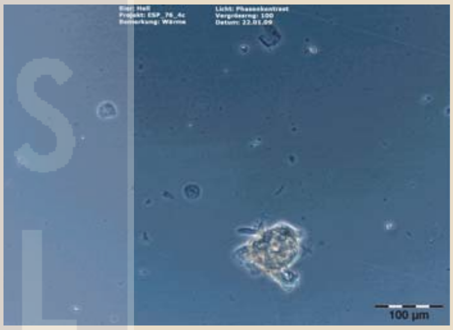


**Fig. 14 Particles in Helles beer**



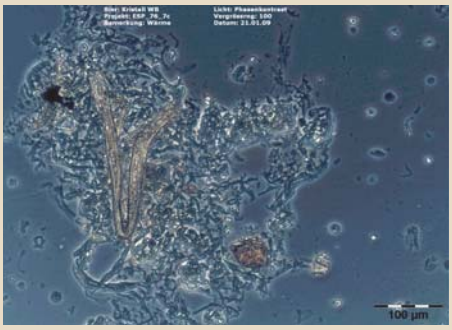


**Fig. 15 Isolate from Kristallweizen beer**


**Fig. 16 Isolate from non-alcoholic Kristallweizen**

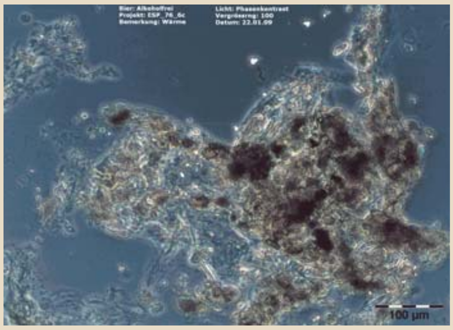


**Fig. 17 Isolate from non-alcoholic Helles**

Lengthening the cold lagering period was successful in nine percent of the cases and was best measured at 25°. Also, a pre-clarification with kieselsol in the lager tank improved the clarity of the filtered beer significantly. In order to assess the influence of the amount and composition of kieselguhr, the samples were also filtered using a membrane with 0.45 µm pore diameter. An improvement in clarity as a result of extremely fine filtration was observed in five percent of the cases. Consequently, it is suspected that up to 95 percent of these turbidity particles consist of glycogen from the yeast [11]. It is known, that in particulate form, glycogen can be extremely small. Even sealing the kieselguhr cake with kieselsol is not always effective.

## Production quality assurance plan

A rapid increase in turbidity in packaged beer and the associated decline in shelf-life can be monitored and controlled using a quality assurance plan in conjunction with the appropriate correctional measures. The currently accepted strategy is to modify brewhouse practices to adapt to the raw materials and to carry out stabilization with silica gel and PVPP. Oxalate precipitation is avoided by adding calcium ions during mashing. Despite this, oxalate precipitation has been observed in bright beer tanks particularly after long periods of storage (see figs. 3, 4).

Of much greater concern is turbidity due to particulate matter, visible in the form of individual flakes, fibers or scales after shaking. If the cause is not microbiological in nature, it is very difficult to identify and even more challenging to prevent. This problem is experienced around the world and much speculation exists as to its source. Some breweries claim it is linked to papain, others point to rice harvested too early, and still others blame six-row winter barley. Several of these phenomena are shown and discussed below.

## Turbidity caused by particulate matter

Figures 5 and 6 are images of particles before and after tunnel pasteurization. Figures 7 and 8 show the same samples after treatment with sodium hydroxide. The samples are of a non-alcoholic beer, stabilized with 70 g/hl xerogel and 50 g/hl PVPP. It is evident that the pasteurization caused some sort of change, altering their ability to completely dissolve in NaOH. A similar "denaturation" was also observed after flash pasteurization in lager beer.

A reduced-alcohol, reduced-calorie beer, which was produced by dilution, was also examined microscopically. Although the original beer with 12 percent original gravity exhibited no particles at all, the diluted beer contained distinctly visible, fine particles (see figs. 9 and 10, magnified 40 and 100 times). The particles appear to resemble carbohydrates; however, neither a stain nor an acid treatment for purposes of detection was successful. It is suspected that the particles consist of a complex made up of proteins, polyphenols and carbohydrates. The reaction mechanism and origin in the brewing process could not be identified.

*Briem* [12] recently proposed this theory: Foam can dry on the inside of the neck of a freshly filled beer bottle, if the beer is immediately tunnel pasteurized after filling. Later, these residues are washed back into the beer.

This was observed in seven different freshly filled beers. Foaming was induced, then the beers were held at 60 °C for two days, subsequently centrifuged and examined microscopically.

The particle found in lager beer pictured in figure 11 could very well originate from the type of complex mentioned above. The isolate from Märzen beer (see fig. 12) exhibits a similar structure, albeit at a magnification factor of 100. The particle (see fig. 13) from a Bavarian Dunkles is significantly more compact and could have a higher proportion of carbohydrate, as would be expected given the beer style. In any case, sample 12 from a Helles beer (see fig. 14) exhibits certain similarities as well.

The isolate (see fig. 15) from Kristallweizen beer appears to be completely different, lacking the obvious compact characteristic of a complex, as seen in the other samples. Figures 16 and 17 are images of two different non-alcoholic beers; one is a Kristallweizen and the other is a Helles. These particles are comparable to those in figure 6.

## Summary

The problem of turbidity in beer brought about by individual particles, in as far as one can even speak of turbidity, has not been solved; however, a groundwork for further research has been laid. The notion that residues of foam clinging to the wall of a bright beer tank, from the bowl of the filler or from the neck of a bottle wash back down into the filled beer is probable and should not be ignored. This phenomenon is independent of beer style; however, non-alcoholic and reduced-alcohol beers appear to be more strongly affected. Analysis of beverages containing beer (beermix products) or wort-based beverages yield similar results, although the influence of the diverse base materials is more complex. ■

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