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Review

Technological possibilities to prevent and suppress primary gushing of beer

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ABSTRACT

Background: Beer gushing is an uncontrolled escape of wet foam when opening a beer bottle, which is not caused by high temperature or shaking. Primary gushing is associated with fungal contamination of barley but the main role in gushing is played by carbon dioxide and surface active proteins called hydrophobins produced by fungi. Secondary gushing is understood as the effect of non-hydrophobin related factors, which either provoke gushing independently and/or can support the expression/intensity of primary gushing. So far there, there is no fully functional gushing suppression strategy at industrial scale.
Scope and approach: This review article aims to clarify the underlying mechanism of primary gushing and simultaneously provide an overview of knowledge concerning different strategies of suppressing primary gushing. The published methods of reducing and suppressing primary gushing were analyzed and structured according to various technological sections of beer production. Emphasis was placed on the aspects of applicability in industrial practice.
Key findings and conclusions: By analyzing the available data, the following strategies of reducing the risk of beer gushing were identified as the most promising (i) germination of barley in the presence of microorganisms inhibiting the hydrophobin producing fungi, (ii) use of hop oil and products with antigushing effect, and (iii) coating of the glass bottle necks with hydrophobin binding layers. This study intends to inspire research and promote application of new approaches to control gushing.

1. Introduction

Scientists are often criticized for putting too much emphasis on understanding the basic mechanisms that explain interesting processes and phenomena but neglecting how to finally use the knowledge for practical applications. In fact this is not always easy as industry and commercial institutions subsequently expect immediate and most miraculous solutions. This situation occurs in the brewing community with respect to the phenomenon of beer gushing. Beer gushing is one of those negative phenomena that divide approaches to solve the problem into those based on fundamental understanding of the process and subsequent solutions and those based on commercial reflections and low cost trial and error proposals.

To study gushing it must be kept in mind that there are two types of gushing: primary and secondary gushing (Casey, 1996; Pellaud, 2002). In the past few years the origin of primary gushing has been greatly unraveled after it was found that the main compounds, which are responsible for gushing (Sarlin, Nakari-Setälä, Linder, Penttilä, & Haikara, 2005), are small hydrophobic proteins called hydrophobins characterized by high affinity for CO_2 (Deckers et al., 2010). The mechanism of primary gushing involves the formation of hydrophobin stabilized nanobubbles, which serve as nucleation sites or explosive “nanobombs” provoking gushing (Casey, 1996; Christian et al., 2009; Deckers et al., 2010; Deckers

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et al., 2012; Draeger, 1996; Fisher, Hauser, & Sommer, 1999; Sahu, Hazama, & Ishihara, 2006). In contrast, secondary gushing is understood as the effect of factors such as haze particles, metal ions, calcium oxalate crystals, bottle cleaning agents, excess of gas in bottled beer, crown cork, filter aids and bottle surface roughnesses (Garbe, Schwarz, & Ehmer, 2009; Sarlin et al., 2005). These factors may influence each other and their effects may differ in each particular brewery. They can lead to gushing on their own or may support the manifestation of primary gushing. Simultaneously many methods to measure primary and secondary gushing have been developed and improved and various solutions to decrease gushing in beer were scrutinized. However, such proposed anti-gushing procedures are still not frequently used at industrial scale. The cautious attitude of the brewers towards these interventions is governed by fears of a decline in product quality and the seasonal character of gushing. This paper provides an overview of technological interventions with potential for prevention and/or suppression of beer gushing.

2. Anti-gushing interventions during barley cultivation and storage

It is now widely recognized that the most important factor in inducing primary gushing is the infection of barley by filamentous fungi (Fig. 1). The most frequent contaminant is *Fusarium* sp., but also others genera can be involved such as *Alternaria*, *Aspergillus*, *Nigrospora*, *Penicillium*, *Stemphylium*, *Trichoderma* etc. These fungi can produce highly surface active proteins (hydrophobins) now recognized as gushing factors (Pellaud, 2002).

Hydrophobins are small extracellular, self-assembling, strong surface active proteins, precursors of primary gushing. They are divided in two classes I and II. Only class II proteins interact with CO_2, creating structures acting as “nanobombs”, which contain CO_2 and can result in a sudden release of the gas and induce gushing. In different stages of fungal life, different hydrophobins can be produced (Linder, Szilvay, Nakari-Setälä, & Penttilä, 2005) and different fungi produce a different type of hydrophobin (e.g. HFB I, HFB II, HFB-2a-2 from *Trichoderma harzianum* and *Trichoderma ressei*, FcHyd5p from *Fusarium culmorum*, etc.) (Khalesi, 2015; Lutterschmid, Stübner, Vogel, & Niessen, 2010; Shokribousjein, 2014). The best anti-gushing method would be the prevention of growth of fungi producing hydrophobins, an intervention at the stage of barley growth on the field.

2.1. Transgenic barley

One of the most effective solutions against the fungal infection is the use of GMO barley. The process leading to GMO barley includes integration of a gene responsible for fungal resistance, e.g. to *Fusarium*, into barley genome. Such resistance can reside at the level of (i) initial resistance to the penetration of the fungal hyphae, (ii) resistance to the spread of fungi, and (iii) ability to degrade or conjugate some of the mycotoxins (such as DON). Unfortunately, the resistance-involved genes are closely linked to the genes responsible for the important morphological characteristics of barley. For this reason, there is a high risk of reduced barley quality and yield due to undesirable side effects of gene manipulation. Another possibility is the incorporation of insect-resistant traits, avoiding a large number of fungal spores to infect plants through insect-inflicted wounds (Linko, Haikara, Ritala, & Penttila, 1998). However, producing high quality GMO barley is not an easy task, considering the time and resources necessary for a GMO product being approved by the European Committee together with the risk of negative public opinion.

2.2. Barley cultivation

A most frequently used method for the suppression of fungal activity is crop rotation. It has been reported that corn is rather susceptible to fungal infections and barley sown on a field previously occupied by corn was contaminated to a much higher extent than barley sown after barley or wheat sow. Because fungal spores can endure adverse conditions in the soil, the total amount of spores in the soil after a corn harvest is much higher than for any other crops. If the soil is re-sown by corn, the amount of fungal spores increases every year. Such soil is unsuitable for cultivation of malting barley (Jouany, 2007). Also the method of fertilization may affect the fungal growth. Thus the use of urea as nitrogen source resulted in a reduction of fungal growth compared to the use of nitrates. Sufficient depth of tillage reduces the risk of fungal contamination as well (Edwards, 2004).

Fungal growth is increased through the occurrence of weeds in the field. Their suppression by using herbicides, or other forms of weed destruction, however, does not lead to better results probably because dead organic material in the field promotes fungal growth (Edwards, 2004). Fungal growth can be restricted by using fungicides. A great care has to be taken when chemicals are used to fight fungal contamination. When the effect is not lethal but only suppressive, the fungus becomes stressed, which rapidly increases mycotoxin production (Jouany, 2007). Residues from fungicides are also being monitored as a potential health risk (Navarro, Vela, & Navarro, 2011).

2.3. Post-harvest treatment and barley storage

In some countries the high moisture of barley during and after harvest cannot be avoided and additional drying is needed, which must be done carefully to obviate changes in the technological properties of barley. Due to energy consumption in the traditional drying process the focus is on finding alternatives. One option is the spontaneous post-harvest barley fermentation, which lowers the pH by the growth of lactic acid bacteria. This approach is not really efficient due to the competition between bacteria and yeasts residing on the barley grains (Olstorpe, Schnurer, & Passoth, 2010).

Physical methods were used to sterilize the barley grains and contaminated barley was subjected to electron beam processing (electron irradiation) before its use in the malting process. Although a large amount of the fungal organisms was eradicated, those that survived produced much more mycotoxins. Furthermore, the irradiated barley showed significantly reduced germination energy, reduced extract yield and decreased amount of many important enzymes (Kottapalli, Wolf-Hall, & Schwarz, 2006).

Another physical method tested was using static magnetic field (SMF) for the inhibition of *F. culmorum*. The exposure to SMF inhibited the growth and germination of *F. culmorum* conidia and it was accompanied by either morphological or biochemical changes of the fungi (Albertini et al., 2003). SMF can be use during the storage of barley to suppress the fungal contamination, but since the fungi is not fully inhibited by SMF, it can spread again during malting process.

3. Anti-gushing interventions in the malt-house

The weather conditions during the growing season of barley can have a substantial effect on the fungal contamination (Fig. 2). Similarly, if the barley harvest proceeds under optimal weather conditions, the fungi does not create as much adverse compounds as when the harvest proceeds under poor conditions. Nevertheless, barley always carries a potential fungal contamination and during the malting process it has a good opportunity to grow and secrete