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Edited by Annie Hill
The purpose of brewing is to produce beer through the hydrolysis of starch from barley malt, together with wheat, maize, rice, sorghum, unmalted barley, sugar/syrups, and the incorporation of hops. These raw materials are mashed into a sugary nitrogenous fermentable liquid called wort. This medium is converted into an alcoholic, carbonated beverage by yeast. The brewing process is essentially a microbiological/biochemical series of reactions, which involves a number of complementary disciplines including plant breeding and cultivation, chemistry, chemical/civil/mechanical/electrical engineering, and also computer control. Although this volume focuses on the positive microbiological aspects of brewing, it does consider, in considerable detail, microbiological contamination of the process starting with raw materials and it concludes with the quality of the finished beer (fresh and not so fresh) in both small pack containers and on draft.

Although there are many excellent text books on brewing, their primary focus has been the entire process with microbiological aspects being integrated into the syntax. As a consequence, the discussion of fermentation tends to be more biochemical in its emphasis than microbiological. This volume’s focus is decidedly microbiological! This applies to both brewer’s yeast strains and contaminating microorganisms—bacteria, wild yeasts, and mycelial fungi.

Five chapters are devoted to brewer’s yeast and they consider, in appropriate detail, their taxonomy and related areas such as identification and characterization. Wort fermentation and metabolism are discussed and, in particular, the metabolic engineering of these organisms. The fact that brewer’s yeast cultures are normally recycled through a number of wort fermentations is emphasized and details of yeast management between fermentations are discussed.

Contaminating fungi, both yeast and mycelial fungi, are discussed in the context of their influence on beer characteristics and quality. It is emphasized, in a number of chapters, that brewing is usually a sterile process (unlike distilling). This is due to the fact that the wort is boiled and in many situations (not all) benefits from the antiseptic properties of hop acids. It is appreciated that often wild yeasts can contaminate pitching yeast cultures and that acid washing does not cleanse the brewing yeast culture of such microorganisms. Also, the stimulation of beer gushing by mycotoxins is discussed.

Most of the remainder of the text focuses on a detailed discussion of contaminating bacteria—both Gram positive and Gram negative that occur in brewing. Sometimes, these bacteria are welcome (e.g., in Lambic beer) but usually this is not the case. This unwelcome contamination can occur on raw materials (particularly malt
and water), during fermentation and maturation and in the final beer. Contamination in all these production stages will influence beer flavor and stability (physical and flavor) and the implications of these bacterial infections are considered in detail.

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Introduction to brewing microbiology

It is an exciting time to be a microbiologist! Now that we are in the postgenome era, we have more answers within reach than ever before. More knowledge brings the realization of how much we still have to learn but also the tools to help alleviate risks, solve problems, and manipulate microbes to improve and develop new products and processes.

Central to brewing is of course a microbiological process and as such a brewing microbiologist needs to understand production strain(s), in terms of flavor and aroma profile, physical stability, handling, and conditions required for optimal fermentation. An appreciation of the vulnerability of the process and product to contamination is also required to ensure quality and consistency. A third aspect that has become increasingly useful in brewing microbiology is the exploitation of microbes to add value to byproducts of the brewing process, to reduce cost of effluent discharges, and also to generate energy. Each of these aspects is covered in detail within this volume, but to provide some background:

Brewing yeast

Over 1500 species of yeast have been identified. These are predominantly single-celled fungal microorganisms able to grow in both the presence and absence of oxygen. Of these, there are basically two major strains used in brewing: *Saccharomyces cerevisiae* (ale) and *Saccharomyces pastorianus* (lager), a hybrid of *S. cerevisiae* and *Saccharomyces eubayanus* (Libkind et al., 2011). Ale yeast operates at around room temperature (18–22 °C), ferments quickly, and produces the “fruitiness” characteristic of most ales. Lager yeast works at colder temperatures (8–15 °C), ferments slowly, and utilizes more wort sugars, leaving a cleaner, crisp taste. Ale and lager yeast are the most commonly used worldwide, but the increase in craft brewing has led to a rise in the use of other yeast strains such as *Brettanomyces* spp., which are traditionally used in Lambic beer production.

The discovery and whole genome sequencing of *S. eubayanus* has caught the imagination of both brewers and research microbiologists alike. It was known for some time that *Saccharomyces pastorianus* was a hybrid organism involving *S. cerevisiae* but the other parent(s) were unknown until the isolation of *S. eubayanus*. Genome sequencing has revealed that it is an almost exact genetic match of the non-*S. cerevisiae* subgenome of lager yeast (Libkind et al., 2011). First isolated in Patagonia, it was thought that the parent *S. eubayanus* strain had its origin in South America but recent