



EDITED BY

CHARLES W.

**BAMFORTH**

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≡ The Oxford Handbook *of*  
**FOOD**  
**FERMENTATIONS**

THE OXFORD HANDBOOK OF

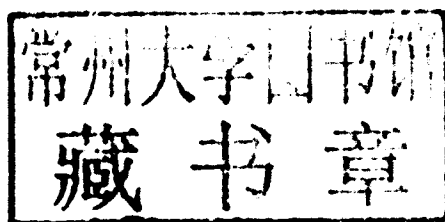
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**FERMENTATIONS**

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*and*  
ROBERT E. WARD



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## PREFACE

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It is impossible to conceive of a world that does not include fermentation. Truly it is at the heart of every society—indeed, it has been convincingly argued that the advent of beer and bread formed the basis of static, agriculture-based civilizations. The workers building the pyramids were paid in bread, beer, and onions.

Few and far between are the days that individuals in all but the most terrible circumstances do not partake of a food whose production and/or preservation has involved the fermentative imperative. A Ukrainian farmhand sipping his kvass and a Korean housewife serving kimchee; the Arctic Inuit preparing fermented walrus (Igunaq) and the Nepalese adoration of the hard yak milk cheese chhurpi; the Californian chugging her beer or the English lord sipping his tea and nibbling cucumber sandwiches—each and every one is a manifestation of processes that, according to Ralph Waldo Emerson, God truly loves.

To delve into fermentation is to variously encounter a rich tapestry of complex science, resolute traditions, sophisticated technology, time-honored skills, faith and religion, tastes and aromas that can both delight and repel depending on individual perceptions. It truly is a journey into culture in both the societal and microbiological senses of the term.

In this volume we have collected together authoritative accounts from many experts on a diversity of fermentation products. There are most definitely some somewhat less widespread foods that do not gain a mention, but we are confident that the main fermentation products and many of the less common ones are addressed comprehensively and authoritatively. We thank all of the contributors for their wisdom and perseverance. Where it was not possible to locate a specialist on a given topic (or, in one instance [cheese] where the author regrettably did not fulfill his commitment to the project), we have attempted to at least give some coverage of the products concerned in the appendices.

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PART I

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FERMENTED  
BEVERAGES

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## CHAPTER 1

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# BEER FERMENTATIONS

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THOMAS H. SHELLHAMMER

### 1.1 INTRODUCTION

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BEER has existed for millennia and has played an important role in the development of humankind. There is evidence that the Sumerians used sophisticated malting and brewing operations as early as 3000 BC, and it is likely that the accidental discovery of beer thousands of years before that led to the development of modern agriculture. Beer held an important role for Egyptians, serving as nourishment, a safe source of hydration, a form of payment, and ceremonial offerings. Consequently, brewsters, the women who brewed beer, held an important position in Egyptian society. Ancient beers have been produced using a wide range of grains and tubers such as millet, maize, cassava, sorghum, rye, rice, barley, squash, and sweet potatoes. Beer was often flavored with various botanicals, some of which were safe to consume, such as rosemary, juniper, nettle, and sage, but in other cases with potentially toxic or psychotropic materials, such as henbane and wormwood (Buhner 1998). The beer that is consumed today looks and tastes very different than its ancient predecessors. First, the herbal flavoring is restricted almost entirely to hops. The exclusive use of hops in brewing is a relatively recent phenomenon in the history of beer occurring roughly 600 years ago. The German Reinheitsgebot, a brewing purity law established in 1516 and still in existence today, decreed that beer could be made only from barley, hops, and water. The active role of yeast would not be confirmed for another 350 years. Second, the type of malt that is used for the world's most common beer today, pale lager beer, was developed in the early 1800s. The pale, Pilsner-styled, lager beer that is popular the world over is hence a relatively recent development in the long history of brewing.

The world consumes roughly 1.8 billion hectoliters of beer annually. Consumption rates vary tremendously by geographical region. For instance, the Czechs drink

approximately 160 liters per person annually, while Americans consume 84 liters and the Chinese consume only 22 liters (Kirin Holdings 2005). Despite the low beer consumption rate by the Chinese, China is the world largest beer-producing country, producing nearly 500 million hectoliters of beer, twice that of the number-two country, the United States. The global beer business is highly consolidated and dominated by a relatively small handful of large brewing companies. The top four of these (Anheuser Busch InBev, South African Breweries-Miller, Heineken, and Carlsberg) control over 50% of the global beer production.

In the United States, the beer market is segmented among three distinct groups. The two large brewers, AB-InBev and MillerCoors, control approximately 83% of the domestic beer market, while imports account for 12% of this market and the craft brewers (also known as micro-brewers) have only 5% of the market. In contrast to the large brewers, the craft beer segment comprises over 2,500 breweries and provides roughly 110,000 brewing-related jobs in the United States (Brewers Association 2013).

Beer styles are driven by choice of raw materials and historical traditions. With only four principal ingredients to work with (water, malted barley, hops, and yeast), one might think the stylistic choices are limited. But the Beer Judge Certification Program identifies 78 beer styles (Beer Judge Certification Program 2011). The world's most popular styles are lager beers such as Munich Helles, German and Bohemian Pilsner, and light and standard American lager. All of these are characterized by pale color, light malt flavor, varying degrees of bitterness, and a Germanic hop aroma. Pale lager beer is light, refreshing, thirst quenching, and brightly carbonated and tends to be nonsatiating, hence its wide popularity. These styles have German and Czech origins. In contrast to this type of beer, amber ales and stouts are darkly colored, have an emphasis on malt flavor, and tend to be lower in carbonation, depending on where they are brewed. These styles trace their origin to the British Isles. The craft-brewing scene in America, as well as in some other parts of the globe, does not necessarily adhere to traditional brewing styles at all times. Some of the beers produced by craft brewers are often expressive of both the creativity of the brewer and the drive to create new beer flavors. A case in point is the interest in hoppy beers in the United States and the creation of a new style called the double IPA. This style plays off the features of the India Pale Ale (IPA) that once differentiated it from pale ales, including high hop usage and higher than average alcohol level. The double IPA is described by some as an extreme beer with alcohol levels approaching that of wine and hop usage levels at or above the solubility of the hop components in beer.

## 1.2 MALTING

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Beer is a grain-based beverage, and the principle grain used worldwide is barley. While there are beers made principally of malted wheat or malted sorghum, barley is the starting point for most commercial beer production. Therefore, the discussion of malting in



this chapter focuses on barley. Barley is an annual grass belonging to the Poaceae family and genus *Hordeum*. Cultivated barley is *H. vulgare* whereas wild types are *H. spontaneum*. The chief taxonomic feature of *Hordeum* is its one-flowered spikelet (Nilan and Ullrich 1993). Three spikelets alternate on opposite sides at each node on the rachis of the spike or head to form a triplet with one central and two laterals. When all spikelets are fertile, and because of the alternating nature of the triplets, the spike is called six-rowed. If only the central spikelet is fertile then the spike is referred to as two-row (Figure 1.1) and is classified as *H. distichon*. While there are some generalizations about six-rowed versus two-rowed barley, for instance the former tend to be higher in enzymic power and lower in total extract, either can be bred to match desired malting and brewing qualities. The predominant type of barley used for brewing worldwide is two-row while North American brewers who utilize high amounts of nonbarley adjunct use six-row varieties because of their desire for high enzyme content. Brewing with nonbarley adjunct requires a separate enzyme source to hydrolyze the adjunct's starches during mashing and the exceptionally high enzymatic power of six-row barley suits this purpose. Regardless of whether the barley is two-row or six-row, malting barley must be low in protein (11.5%–13.5%) and plump, where greater than 80% should not pass through a 6/64-inch (0.24 mm) screen. High levels of protein affect the ease with which the barley proceeds through the malting process as well as its suitability for brewing. If protein levels are too high or the kernels too thin, the barley is relegated to feed barley.

After water, malted barley is the main ingredient used to make beer. It provides four very important qualities to the beer-making process: starch, enzymes suitable for converting that starch into a fermentable extract, flavor, and color. Without the malting process, beer cannot be made unless exogenous enzymes are employed to break down starches and protein in a grain-based mash.

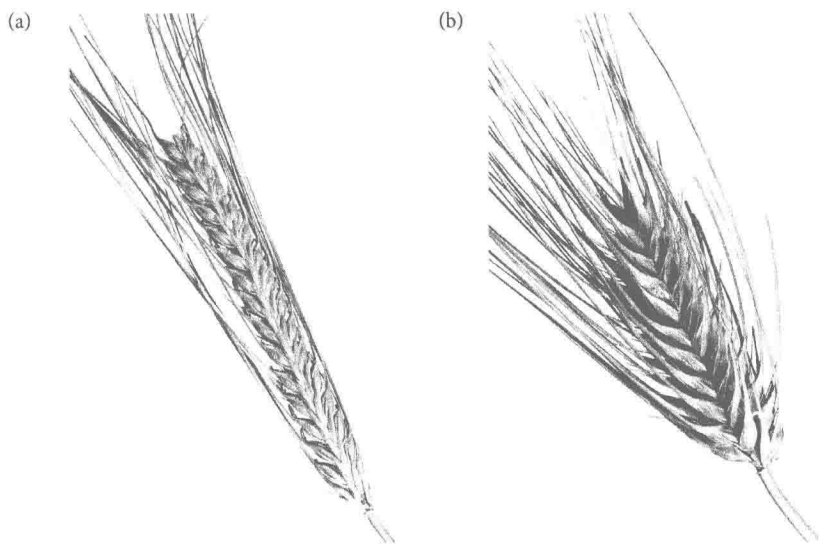


FIGURE 1.1 Two-row (a) and six-row (b) barley.