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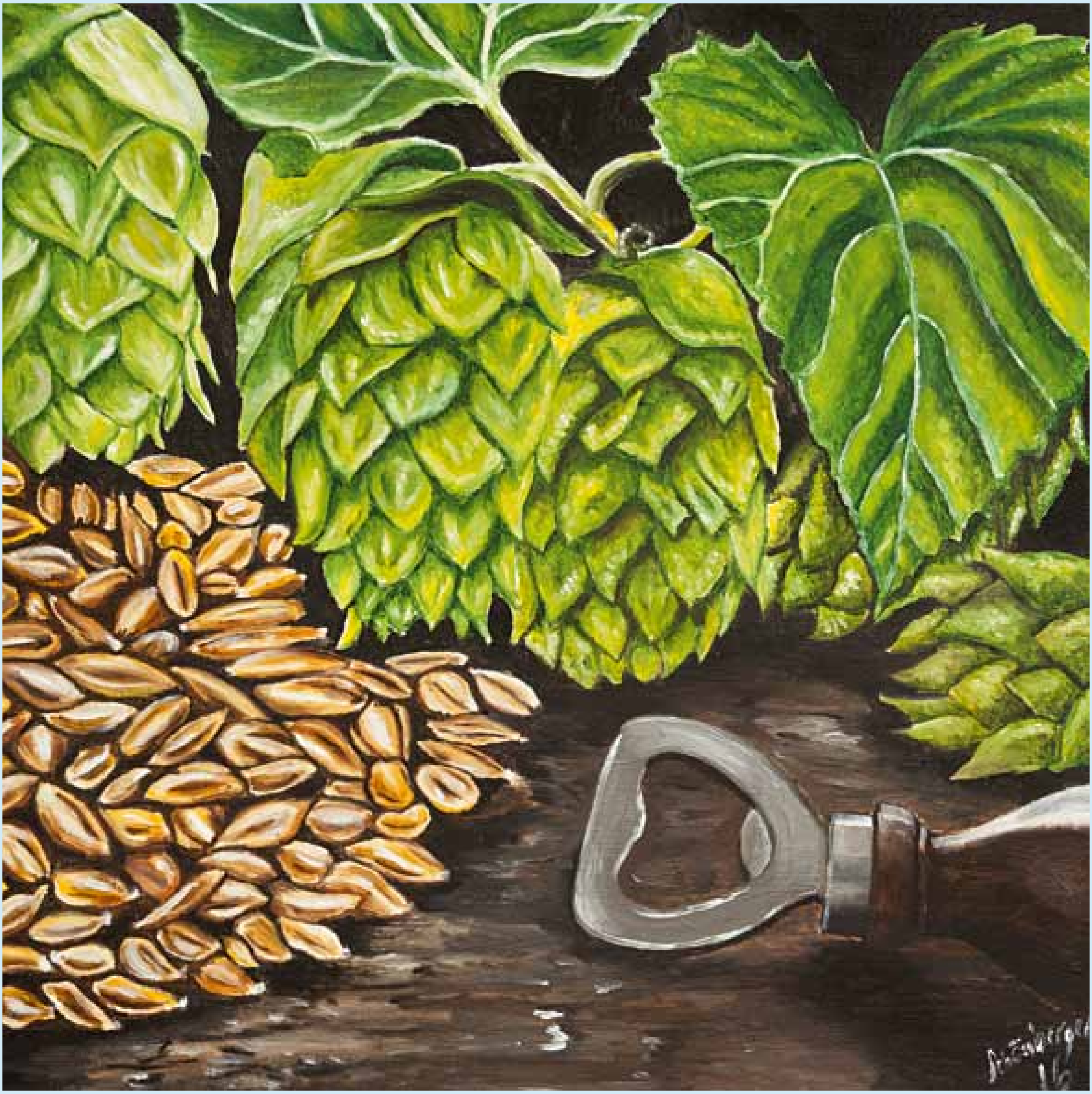
The Comprehensive

Guide to Brewing

From Raw Material to Packaging

G. Basařová, J. Šavel, P. Basař, T. Lejsek



FACHVERLAG HANS CARL

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FOREWORD

The sixteen chapters of this book cover the entire process of the brewing of beer. The beginning focuses on raw materials used in beer production (malt, adjuncts, hop, hop products, water, and auxiliary materials). Subsequent chapters discuss brewers' yeast, microbial contamination, and nomenclature of enzymes important to beer manufacturing. The heart of the book is devoted to fundamental production process stages: hopped wort preparation, primary and secondary fermentation, filtration and membrane technology, pasteurization, and beer packaging. An overview of the properties of different styles of beer is also included. The physico-chemical and sensory stabilities of beer, beer ageing, and assessment of beer quality are discussed. An entire chapter is devoted to the sanitation of process equipment. Yet another chapter focuses on energy, water, and waste management. Finally, the health aspects of beer drinking are briefly touched upon.

The book utilizes valid chemical nomenclature and classification of chemical compounds important to the brewing of beer (particularly polyphenolic compounds). Each chapter begins with a short overview of historical developments. This is followed by the theoretical foundations of processes described in the given chapter, an overview and assessment of current process technology and equipment (including modern trends), a description of process and laboratory controls, and specialized techniques and instrumentation (in some chapters). Each chapter is supplemented with a comprehensive list of literature references drawn mainly from the last ten years.

The scope and implementation of this book make it well suited to bachelor, master, and doctoral students in the field, as well as employees in breweries and associated institutions. Individual parts of chapters can be selected for study depending on the depth of required knowledge.

Gabriela Basařová, Jan Šavel, Petr Basař, Tomáš Lejsek, Pavlína Basařová

FOREWORD

Writing this preamble to The Comprehensive Guide to Brewing is a pleasant task, especially since the book has been authored by Professor Dr. Gabriela Basařová and her colleagues, Dr. Jan Šavel, Petr Basař (M.Sc.), Dr. Tomáš Lejsek and Dr. Pavlína Basařová.

There are various aspects of this book which are quite unique: Dr. Gabriela Basařová has been involved in research as a scientist for 50 years in the Czech Republic, one of the world's most renowned brewing nations. For 35 of those years, she held a position as a university professor. Dr. Šavel is likewise very well known in his own right, and Mr. Basař, a generation on, followed in his mother's footsteps to become a member of the industry as well.

This book reveals the great amount of work Czech scientists have accomplished in exploring a diverse range of topics in brewing. The long list of references in a variety of languages at the end of each chapter demonstrates the meticulous nature and the breadth of the authors' research.

The 16 chapters cover the full range of brewing – from raw materials to packaging – but also include topics such as energy usage, water and wastewater. The biochemical foundations of the ingredients used to brew beer (complete with structural formulas) as well as the individual processes employed in its production are examined in detail. Likewise, the authors competently elucidate the pertinent aspects of process engineering, accompanied by the corresponding formulas and equations. The methods and technology utilized in brewing are communicated clearly and in considerable depth, among them common mashing methods, lautering and sparging equipment, wort boiling systems and, above all, the processes of fermentation and maturation. Additionally, a generous chapter is dedicated to microbiological procedures, including methods for monitoring sources of contamination and how to avoid the proliferation of microbes in practice. The attributes of beer discussed in subsequent chapters encompass both colloidal and flavor stability as well as the complex issue of beer and health. Information on the broad spectrum of modern beer styles and analytical methods required for efficiently monitoring brewery operations round out the book. An abundance of images (diagrams, sketches, photos, electron micrographs, etc.) facilitates comprehension of the material presented in each chapter.

This book will, therefore, serve as an essential reference for those working in brewery operations, as a textbook for students and as a guide for future research. In this spirit, I hope that this book finds its well-deserved place in the library of anyone with an interest in brewing!

Prof. Dr. Ludwig Narziß

PUBLICATION AUTHORS

Prof. Gabriela Basařová, DrSc, MSc, was born on January 17, 1934 in Pilsen to a family of teachers. She graduated from secondary school in Pilsen and the University of Chemistry and Technology (UCT) in Prague (VŠCHT Praha) where she studied malting and beer brewing at the Department of Fermentation Chemistry and Technology (Katedra kvasné chemie a technologie), known today as the Department of Biotechnology (Ústav Biotechnologie). After graduating in 1957, she joined Plzeňské pivovary, where she headed the quality control and research laboratories. In 1967, she transferred to the Research Institute of Brewing and Malting (Výzkumný ústav pivovarský a sladařský) in Prague. Here she founded the biochemistry department and later became the institute director. Between 1981 and 1998, she was the head of the Department of Fermentation Chemistry and Bioengineering (Katedra kvasné chemie a bioinženýrství) at VŠCHT Praha. She taught the following subjects: Malting, Beer Brewing, Winemaking, Modern Biotechnology and Bioecology. The results of her scientific and professional activities have been published in more than 500 articles and six books. She remains an external professor for VŠCHT Praha through this day. She was the first nominee elected into the Hall of Fame of Czech Beer Brewing (Síň slávy českého pivovarství), established in 2002. At VŠCHT Praha, she was awarded the Prof. K. N. J. Balling and Prof. E. Votočka medals. In 2012, the Czech president, Mr. Václav Klaus, conferred the Award of Merit upon Prof. Basařová for her outstanding achievements in science and teaching.

Associate Prof. Jan Šavel, PhD, MSc, was born on July 6, 1944 in České Budějovice. He graduated from secondary school in České Budějovice and University of Chemistry and Technology (UCT) in Prague (VŠCHT Praha), where he studied malting and beer brewing at the Department of Fermentation Chemistry and Technology (Katedra kvasné chemie a technologie). After finishing his studies in 1967, he joined Jihočeské pivovary n. p., where he worked as a microbiologist and headed the quality control department and laboratory. In 1996, he habilitated at VŠCHT Praha in the field of malting and beer brewing. He was an external lecturer at VŠCHT Praha and at the Faculty of Agriculture at the University of South Bohemia (Zemědělská fakulta Jihočeské univerzity) in České Budějovice. He was head of the Research and Development Center (Výzkumné a vývojové pracoviště) at Budějovický Budvar n. p., where he is currently employed. In 2004, he was inducted into the Hall of Fame of Czech Beer Brewing (Síň slávy českého pivovarství). He is the author of the book "Mikrobiologická kontrola v pivovarech" (Microbiological Control in Breweries) (Prague: SNTL, 1980).

Petr Basař, MSc, MBA, was born on September 23, 1964 in Pilsen. He completed secondary school in Prague and went on to study at the University of Chemistry and Technology (UCT) in Prague (VŠCHT Praha). He studied special fermentation production at the Department of Fermentation Chemistry and Bioengineering (Katedra kvasné chemie a bioinženýrství). In 2005-2006, he completed an MBA program at the Prague International Business School (PIBS), part of the University of Economics. After graduating from VŠCHT in 1988, he joined Prague Breweries (Pražské Pivovary). There he went through technical training in all production sectors, and from 1990 to 1991 he worked as assistant to the CEO. Since 1991, he has been at the company Diversey, since they first became established in Czechoslovakia. He has held numerous managerial positions in local and regional offices. At the present time, he is working as the Head of Sector Specialists Beverage & Dairy. He is an external lecturer at the Department of Biotechnology (Ústav Biotechnologie), where he teaches hygiene and sanitation.

Tomáš Lejsek, PhD, MSc, was born on June 24, 1937 in Písek. After graduating from Industrial School in Canning (Průmyslová škola konzervárenská) in Bzenec, he went on to study at the Czech Technical University in Prague (ČVUT Praha), Faculty of Mechanical Engineering (Fakulta strojní), where he specialized in machinery for the chemical and food industries. For many years, he worked in research and development at the Research Institute of Brewing and Malting (Výzkumný ústav pivovarský a sladařský - VÚPS) in Prague and headed the Department of Technical Development at the Central Office of the Trust Breweries and Malt Plants Prague (GŘ Pivovary a sladovny Praha). In 1991, he was appointed director of VÚPS Praha, o. z., and in 1995 he became CEO of the brewery Pivovar Velké Popovice, a. s. Since 2001, he has been an executive of the brewery Žatecký pivovar in Žatec. He has been teaching Brewing Engineering at VŠCHT Praha for more than ten years.

Pavlína Basařová, PhD, MSc, was born on September 19, 1965 in Prague. She graduated from the University of Chemistry and Technology (UCT) in Prague (VŠCHT Praha) where she studied technical physical chemistry, and was later awarded the degree of PhD in this specialization. Since 1996, she has been working for the Department of Chemical Engineering at UCT Prague where she teaches Unit Operations for the chemical and food industries. In addition, she specializes in thermodynamics and multiphase systems. Pavlína has authored or made contributions to more than 70 technical publications.

CONTENTS

1. RAW MATERIALS FOR BEER PRODUCTION

Beer is a weak alcoholic beverage that has been produced for centuries from malted grain, water, and hops with the help of microorganisms – principally brewer's yeast but occasionally other yeast and bacteria. Malt is produced by germinating and drying cereal grains under carefully controlled conditions. In many countries, sugars and adjuncts containing starch are employed as alternatives to malt, particularly during periods of economic hardship, such as in wartime and during the period that follows. Adjuncts continue to be used today because they are less expensive to produce than malt.

1.1 BREWER'S MALT

1.1.1 Historical development

In the past, malt was prepared from a variety of cereals. Aside from water, barley (*Hordeum vulgare* L.) is the primary raw material used in beer production, at least in traditional brewing countries. It is also one of the oldest cultivated crops and is thought to have been utilized for malt preparation for the past several thousand years. The first botanical description of barley *(Hordeum sativum,* Poaceae*)* was made in 1753 by Carl von Linné in his work *Species Plantarum* [Bothmer and Jacobsen 1985]. The botanical classification of barley has not been completely standardized, and according to the *Code of Nomenclature for Cultivated Plants* [Brickell et al., 2009], it is divided into a number of categories, including subspecies (ssp.), convarietas (conv.), varietas (var.) and forma (f.).

In prehistoric times, malt was prepared from both six-rowed and four-rowed barleys (*Hordeum vulgare* L., convar. *vulgare* L., f. *hexastichon* and f. *tetrastichon*). In Europe during the Middle Ages, species of six-rowed and two-rowed (*Hordeum vulgare* L., convar. *distichon* (L.) Alef.) barleys were preferred for malting. Today, two-rowed nodding barley (*Hordeum vulgare* L., convar. *distichon* (L.) Alef., var. *nutans* Alef.) is the most commonly cultivated malting barley across Europe, including in Bohemia, Moravia, and Silesia. It replaced erect-eared barley (*Hordeum vulgare* L., convar. *distichon* (L.) Alef., var. *erectum* (Rode) Alef.) and the less common peacock's barley (*Hordeum vulgare* L., convar. *distichon, var. breve* Alef. *(zeocriton* L.) (Figure 1.1). Malting barley varieties grown in what is now the Czech Republic and in other regions of Europe as well as in some countries overseas, can be traced back to the cultivation of this crop in Haná (Moravia) in the 11th century.

Figure 1.1 Six-rowed and two-rowed barley ears (http://vfu-www.vfu.cz/)

Wheat (*Triticum aestivum* L.) was the primary grain used for malt production in Europe until the end of the 18th century (including in the region of today's Czech Republic). Top-fermented beers (white beers) were prepared from wheat malts. Beer produced using barley malt was less common, though a few quality beers were brewed with it at that time. They were known as Märzen (March) beers because they were only brewed during the winter months. Even oats (*Avena sativa*, L.) were utilized in the production of specialty beers, but this practice disappeared from our area during the 17th century. Thanks to the Czech brewing revolutionary, František Ondřej Poupě (1753-1805), who coined the phrase "wheat for cakes, oats for horses, barley for beer", malt has been produced in Bohemia almost exclusively from barley since the 18th century, though it can be made using other cereals. The production of wheat malt, and likewise top-fermented beers began to decline, while the production of bottom-fermented beers grew.

Originally, each brewery produced its own malt. Raw barley was the only commodity that was sold and exported. Malt production took a significant step forward in the middle of the 19th century during the Industrial Revolution with the advent of so-called industrial breweries. Separate commercial malthouses were built, and started selling malt to domestic breweries. These malthouses flourished, and not long afterwards, their malt was also exported to breweries around the globe. Malt production thus became a new branch of the brewing industry [Chodounský 1891; Basařová and Hlaváček 1999].

1.1.2 Specific types of malt

Distinctive malt types exhibiting unique characteristics are created by adjusting the processes of steeping and germination during malting. The biosynthesis and activity of malt enzymes is regulated over the course of these processes. Malt enzymes act on specific substances in the kernel and define the degree of degradation of the high molecular weight compounds, as well as the redox potential and acidity of malt. The degree to which the formation of color and aromatic compounds occurs can be regulated by adjusting the malt kilning process. To ensure reproducibility in beer production and the quality of the final product, it is important to use malt lots prepared from only one or at most two genetically similar barley varieties.

Worldwide, pilsner malts and Munich malts are the predominant malt types used for the production of pale and dark beers, respectively. Other types of specialty malt are utilized to highlight certain characteristics of both pale and dark beers and likewise to create a range of distinctive products (Figure 1.2).

Figure 1.2 Kernels of various malts
(Archive of the malthouse Soufflet, a. s., Prostějov, part of The Soufflet Group)

a – Czech pilsner b – pale caramel c – caramel pilsen d – chocolate