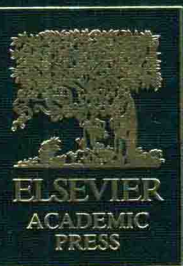


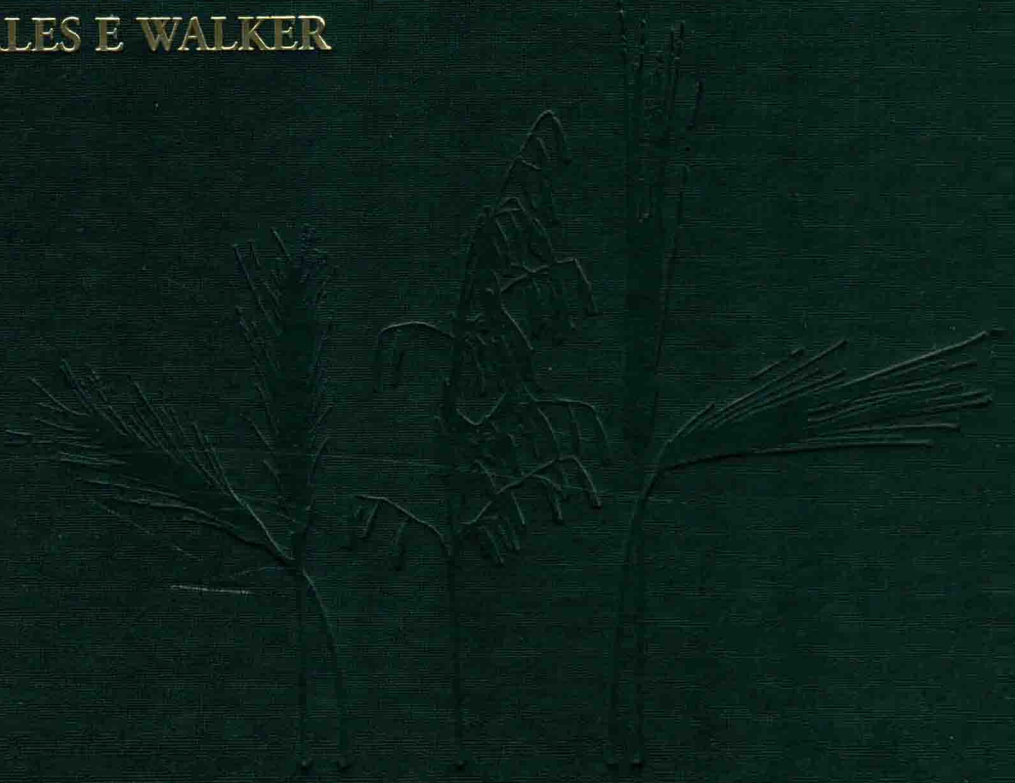
VOLUME TWO



ENCYCLOPEDIA OF GRAIN SCIENCE

EDITED BY

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ENCYCLOPEDIA OF GRAIN SCIENCE

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FOREWORD

Grains are the staff of life. Mindful of this, it is impossible to contemplate a world devoid of grain. The efficient production and processing of grain are critical activities that are sustained by science. Indeed, it has been said that efficient technology is essentially the science that works.

Grain science is the driving force behind the efficient use of grain. The beginnings of grain science are lost in antiquity. However, the research literature and the practices used for processing all the grains of the world are wide-ranging, disparate, and complex. The transfer of scientific knowledge that relates to food raw materials is essential and important for the improvement of world health. In order to collate and present current knowledge and the future potential of grain science to the world, a group of distinguished experts were assembled to produce this *Encyclopedia of Grain Science*.

This remarkable and unique work of science and scholarship comes in three volumes and covers all aspects of grain science. It is always important that scientific information is presented in a logical and reader-friendly manner. The *Encyclopedia of Grain Science* is beautifully produced and easy to read. Related chapters are cross-referenced and the authors have presented the science and associated technology of their chapters in a manner that is accurate, informative, and clear.

It is difficult to predict how often this encyclopedia will be consulted for ideas, information, and clarification of any aspect of the production, processing, and use of grains worldwide. However, with regard to a complex and wide-ranging subject such as grain science, a readily available single source of information is an essential requirement for all those who produce and process grains in industries such as food-making, farming, animal-feeding, grain-breeding, baking, brewing, distilling, and marketing. This book is a uniquely important source of reference for teachers and academics involved in teaching, and research and development of grain science and technology. Students, consultants, politicians, historians, and the general public will find this publication useful as regards the accessing of information on grain that would require an extensive search of literature that is not readily available. Those involved in related sciences and industries should regard this book as a valuable source of comparative information on biotechnology and processing, especially as regards foods, drinks, and beverages. The reference section of each chapter is designed to direct users to important articles that will elaborate further on the science, technology, and methodology of summarized information.

Having had the privilege to be involved in grain science and technology for a long time, I have been associated with many books that deal with grain science. The *Encyclopedia of Grain Science*, without doubt, will take its place as one of the great books of the world of grain science. It is written by experts dedicated to the important aim of improving grain quality and availability in a world that regards grains as its primary food source.



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PREFACE

Grains have always been critical to mankind's existence. The word "bread," the most obvious product of grains, has become synonymous with food, as indicated by the motto of the United Nation's Food and Agriculture Organization: "Fiat panis," meaning "Let there be bread." Primitive humans relied on grain found wherever it grew until the dramatic discovery that some of this grain, if planted and nurtured, would produce a crop that could be harvested and stored to sustain the family from one harvest to the next. The cultivation of grains was thus the critical development that changed human from the hunter-gatherer nomad into the settled agriculturalist, leading in turn to opportunities for cultural activities. The accompanying breakthroughs were the discoveries of tools and processes to make the harvested grains more tasty and nutritious, namely, the processes of crushing and sieving, and of mixing the resulting flour with water and baking the dough to make primitive forms of bread or porridge.

Since those early days, there have been great improvements in all aspects of grain science and technology. Today, a wide range of grain species is exploited in all countries of the world. These include the cereal grains, the legumes, and the oilseeds. Their breeding, production, transport, and processing are very big business worldwide, irrespective of whether the country is a net importer or exporter. Although much of world grain production is consumed close to the site of production, large excesses of production over consumption in several regions mean that world trade in grains is also very big business. Methods of processing in today's world cover the full range from traditional methods, handed down through many generations, to very sophisticated large-scale factories. Throughout this diversity of approaches to grain utilization, grains supply a great proportion of the world's food – both as energy and protein sources. Grains also make a major contribution to our diet via grain-based feedstuffs for animals. A significant proportion of grain production goes for industrial uses, thereby contributing to the wider range of our foods (e.g., margarine, sweeteners in drinks, and protein supplements in meats and in synthetic milk drinks), as well as entering an amazing diversity of non-food applications (e.g., adhesives, plastics and paper products).

Our main aim, in compiling this encyclopedia, was to cover everything in the complex range of topics that a true *Encyclopedia of Grain Science* should offer. This diversity is three dimensional:

1. One axis covers the wide range of grain species, especially those of economic value to mankind and his general environment. These include the cereal grains, the oilseeds, the pulses (grain legumes), the soybean (which is both a pulse and an oilseed), the pseudocereals, as well as amaranth and quinoa.
2. The second dimension covers the sequence of events that is common to all grains, namely, breeding and selection, the production of seed for sowing and the grain for harvest, harvesting, storage, transport and marketing of the grain, and finally processing of the grain to produce food and feed products.
3. A third axis also considered involves the diversity of scientific disciplines used to investigate the questions arising from the study of grains at all stages of their production and utilization.

By the use of a comprehensive review process and the careful selection of authors, every effort has been made by the Editors and the distinguished Editorial Advisory Board to ensure that the *Encyclopedia of Grain Science* covers this wide diversity of topics and is accurate, readable, and up-to-date. The work is also extensively cross-referenced and indexed to ensure that the reader is able to easily locate information as needed.

Readers are invited to enjoy using this encyclopedia. We hope that they be rewarded by the discovery of valuable information, authoritative answers to perplexing questions, and pictures – in words and in actual illustrations – pictures that take the reader to the ends of the Earth, or maybe just down the street.

So, bite into a slice of freshly baked bread, spread with canola margarine or peanut butter, washed down with barley-brewed beer and consider that in this encyclopedia all the known answers are provided to tell the story of how these appetizing foods reach your dinner table.

Colin Wrigley
Charles E Walker
Harold Corke

GUIDE TO USE OF THE ENCYCLOPEDIA

Structure of the Encyclopedia

The material in the Encyclopedia is arranged as a series of entries in alphabetical order. Most entries consist of several articles that deal with various aspects of a topic and are arranged in a logical sequence within an entry. Some entries comprise a single article.

To help you realize the full potential of the material in the Encyclopedia we have provided three features to help you find the topic of your choice: a Contents List, Cross-References and an Index.

I. Contents Lists

Your first point of reference will probably be the contents list. The complete contents list, which appears at the front of each volume will provide you with both the volume number and the page number of the entry. On the opening page of an entry a contents list is provided so that the full details of the articles within the entry are immediately available.

Alternatively you may choose to browse through a volume using the alphabetical order of the entries as your guide. To assist you in identifying your location within the Encyclopedia a running headline indicates the current entry and the current article within that entry.

You will find 'dummy entries' where obvious synonyms exist for entries or where we have grouped together related topics. Dummy entries appear in both the contents list and the body of the text.

Example

If you were attempting to locate material on the Protein Chemistry of Cereals via the contents list:

Protein Chemistry of Cereals *see* CEREALS: Protein Chemistry

The dummy entry directs you to the Protein Chemistry article, in the CEREALS entry. At the appropriate location in the contents list, the page numbers for articles under Cereals are given.

If you were trying to locate the material by browsing through the text and you looked up Protein Chemistry then the following information would be provided in the dummy entry:

Alternatively, if you were looking up Cereals the following information would be provided:

Protein Chemistry of Cereals <i>see</i> Cereals : Protein Chemistry.
--

CEREALS

Contents

Overview

Breakfast Cereals

Chemistry of Nonstarch Polysaccharides

Grain Defects

Grain Diseases

Grain – Quality Attributes

Protein Chemistry

Evolution of Species

2. Cross-References

All of the articles in the Encyclopedia have been extensively cross-referenced.

The cross-references, which appear at the end of an article, serve three different functions. For example, at the end of the **FOOD SAFETY THROUGH THE PRODUCTION CHAIN** article, cross-references are used:

- i. To indicate if a topic is discussed in greater detail elsewhere.

See also: **Cereals:** Grain Defects; Grain Diseases. **Chemicals for Grain Production and Protection.** **Consumer Trends in Consumption.** **Contaminants of Grain.** **Cultural Differences in Processing and Consumption.** **Fortification of Grain-Based Foods.** **Genetically Modified Grains and the Consumer.** **Labeling of Grain-Based Foods.** **Nutraceuticals from Grains.** **Nutrition:** Beriberi, A Deficiency Related to Grains; Guidelines for Grain-Based Foods; Effects of Food Processing. **Organic Growing of Grains.** **Stored Grain:** Handling from Farm to Storage Terminal; Invertebrate Pests; Physico-Chemical Treatment. **Appendix:** Foods for Celiac Diets.

- ii. To draw the reader's attention to parallel discussions in other articles.

See also: **Cereals:** Grain Defects; Grain Diseases. **Chemicals for Grain Production and Protection.** **Consumer Trends in Consumption.** **Contaminants of Grain.** **Cultural Differences in Processing and Consumption.** **Fortification of Grain-Based Foods.** **Genetically Modified Grains and the Consumer.** **Labeling of Grain-Based Foods.** **Nutraceuticals from Grains.** **Nutrition:** Beriberi, A Deficiency Related to Grains; Guidelines for Grain-Based Foods; Effects of Food Processing. **Organic Growing of Grains.** **Stored Grain:** Handling from Farm to Storage Terminal; Invertebrate Pests; Physico-Chemical Treatment. **Appendix:** Foods for Celiac Diets.

- iii. To indicate material that broadens the discussion.

See also: **Cereals:** Grain Defects; Grain Diseases. **Chemicals for Grain Production and Protection.** **Consumer Trends in Consumption.** **Contaminants of Grain.** **Cultural Differences in Processing and Consumption.** **Fortification of Grain-Based Foods.** **Genetically Modified Grains and the Consumer.** **Labeling of Grain-Based Foods.** **Nutraceuticals from Grains.** **Nutrition:** Beriberi, A Deficiency Related to Grains; Guidelines for Grain-Based Foods; Effects of Food Processing. **Organic Growing of Grains.** **Stored Grain:** Handling from Farm to Storage Terminal; Invertebrate Pests; Physico-Chemical Treatment. **Appendix:** Foods for Celiac Diets.

3. Index

The index will provide you with the volume number and page number of where the material is to be located, and the index entries differentiate between material that is a whole article, is part of an article or is data presented in a table. Detailed notes are provided on the opening page of the index.

4. Glossary

A glossary of terms used within the Encyclopedia appears in Volume 3, before the index. This is organised alphabetically and features explanations of many of the specialist terms used throughout this publication.

5. Contributors

A full list of contributors appears at the beginning of each volume.

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