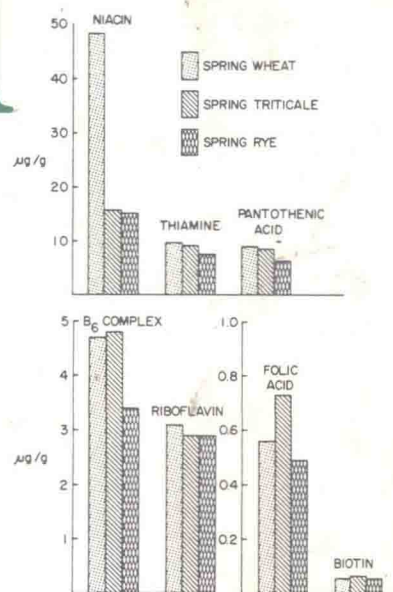


Handbook of Cereal Science and Technology



edited by
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Handbook of Cereal Science and Technology

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PREFACE

This handbook brings together agronomists, cereal scientists and technologists, and chemists and engineering scientists with common interests in the raw materials, processes, and products of the cereals industries, to write a series of reviews on the chemistry and technology of cereals and also to provide an extensive and up-to-date bibliography. The chapters follow a logical sequence. Early chapters deal with the major cereals—wheat, corn, barley, oats, sorghum, millet, rice, rye, triticale, and wild rice. A series of reviews then covers the chemistry of components of these cereals—proteins, carbohydrates, lipids, vitamins, minerals, and enzymes—and the quality evaluation of grains and flours. Subsequent chapters cover the technology of baked products, pasta, breakfast cereals, malted cereals, and snack foods. The last three chapters discuss cereal enrichment, the nutritional quality of cereals, and the methods of ethanol production from cereal grains.

Knowledge of the production and utilization of cereal grains is fundamental to solving the food supply problem facing the majority of the world's population. In many developing areas of the world, as much as 75% of dietary energy comes from cereals, and in more affluent societies, the intake of cereals is seldom less than 25% of calories. Even in the latter case, the nutrient contribution of cereals is substantial. Cereals (including wheat, corn, barley, oats, sorghum, millet, rice, rye, triticale, and wild rice) are therefore not only important direct sources of food for humans, but also make a substantial contribution to the diet, indirectly as fodder, for farm livestock producing meat, milk, and eggs.

Optimal utilization of cereal grains requires knowledge of their structure and composition. The practical implications of kernel structure are numerous. They relate to the various stages of grain production, harvest, storage, marketing, and use. The chemical composition of different cereal grains varies widely, since it is influenced by genetics, soil, and cultural and climatic factors. Variations are encountered in the relative amounts of protein, carbohydrates, lipids, vitamins, minerals, and pigments. The composition, chemistry, and processing aspects of grains are therefore areas of scientific pursuit absolutely fundamental to producing more food for the world's population.

Although new varieties of cereal grains have been developed and there has been one cross of two grains (triticale), no new major cereal crops have been introduced in recent history. Genetic improvements are being made through increased worldwide efforts coordi-

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Although new varieties of cereal grains have been developed and there has been one cross of two grains (triticale), no new major cereal crops have been introduced in recent history. Genetic improvements are being made through increased worldwide efforts coordi-

nated through international centers. New varieties, hopefully with increased yield, must continue to offset the adaptation of disease organisms and stabilize production. At the same time, efforts are directed towards increasing the nutritional value of each crop.

Increasing awareness of nutritional needs presents problems to those responsible for feeding our populations to plan wisely the strategies of food resources development. In this planning, both economically and technologically sound nutritional decisions have to be integrated. To assist in this effort, detailed knowledge of materials and processes for making breads, cakes, cookies, pasta, breakfast cereals, and snack foods—all of which represent highly complex and variable systems from a biochemical and physicochemical point of view—is essential. This text presents a comprehensive, up-to-date examination of these processes in light of current information derived from basic chemical and biochemical studies. In cereal processing, the modifications associated with these improvements have involved, in many instances, a drastic conversion of a time-developed craft into scientifically sound technology. This change has often required major changes in raw materials and processing procedures, occasionally resulting in finished products that are somewhat different from the traditional products.

Establishing enriched cereal food products for potential consumers requires research. There is a need to define the market, to delineate the varying types of consumers, and to interpret correctly their needs, habits, and attitudes so that their requirements can be met in a consistent manner. If consumers are to follow the eating patterns advised in national nutritional policies, it is necessary for them to partly replace caloric intake of alcohol, sugar, and fat with complex carbohydrate foods. The only convenient way of achieving this is to increase the intake of cereals and cereal products. This dietary change would also help to ensure a plentiful supply of dietary fiber, especially if the cereals were consumed as high extraction flour products. We have to communicate and interpret findings of cereal research to the public in concise, understandable terms. If we cannot get our message through to the public, it is the fault of the scientist and technologist and not that of the potential recipient of the information.

We extend credit and appreciation to the contributors to this book. Authorities in many fields, who hold responsible positions in universities, government, and industry, contributed chapters or reviewed the manuscripts. We are very grateful to them for giving much of their time and expert knowledge.

In editing this handbook, we have attempted to achieve some uniformity among the chapters and to eliminate obvious duplication. We appreciate the authors' cooperation, care, and patience in the preparation of their manuscripts.

This book contains the most up-to-date technical and scientific information. We hope that it will serve as a valuable text and reference book for both the student and the researcher involved in the cereal industry.

Sincere thanks go to Mrs. Inez Kwiatkowski and Ms. B. Martin for typing, and to Lisa A. Sisley of the Ruth Emerson Library, American Institute of Baking, for her expert proofreading.

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1

WHEAT

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University of Nebraska–Lincoln, Lincoln, Nebraska

I. CEREAL GRAINS OF THE WORLD

A. Origin of Wheat

Wheat has been used as a food by man since prehistoric times, however, we do not have adequate records on its early history. It is generally believed that wheat evolved from wild grasses somewhere in the Near East. Humans probably first gathered wheat from the wild as long as 12,000–17,000 years ago. Types collected may have been *Triticum monococcum* (einkorn) or *T. dicoccum* (emmer) (8,48).

Triticum aestivum (common wheat), *T. compactum* (club wheat), and *T. sphaerococcum* (shot wheat) descended in several steps from emmer about 3000–4000 B.C. For the most recent information on the evolution of the cultivated wheats, see Ref. 35.

B. Classification of Wheat

Wheats belong to the grass family *Gramineae* (*Poaceae*) and to the tribe *Hordeae* (6), genus *Triticum*, species *aestivum*, and are given cultivar (variety) names by their plant breeders.

Linnaeus in 1753 made significant contributions to the classification of wheat, however, Sakamura (47) identified the chromosome numbers for commonly recognized wheat (*Triticum*) types. The diploids were found to contain 14 chromosomes ($n = 7$), the tetraploids had 28 chromosomes ($n = 14$), and the hexaploids had 42 chromosomes ($n = 21$). The three chromosome sets (or genomes), combined to form the cultivated wheats, have been the subject of intensive cytological research.

Common wheat (*T. aestivum*) consists of three genomes identified as A, B, and D. The source of the A and D genomes was clearly established as coming from *T. monococcum* and *T. tauschii* (*Aegilops squarrosa*). The source of the B genome has posed a difficult research problem in recent years. *Triticum searsii* is reported as the probable source of the B genome in common wheat (35).

Triticum durum, a tetraploid, is derived from a hybrid of diploid *T. boeoticum* and an unknown wild grass. Each contributed a set of seven chromosomes (or a genome). Natural hybridization of a similar tetraploid with the diploid *T. tauschii* produced common wheat, *T. aestivum*, and club wheat, *T. compactum*.

Most of the wheat currently grown consists of three species of *Triticum*. *Triticum aestivum* L., a hexaploid, dominates world production. In the United States it is divided into

four classes for marketing purposes. Hard Red Winter and Hard Red Spring classes are used primarily for leavened bread production. Soft Red Winter and Common White wheat classes are used primarily for pastries, crackers, and cookies. *Triticum compactum* Host, a club wheat, also a hexaploid type, is used for pastries in a similar manner as the Soft Red Winter wheats. Durum wheat, *Triticum durum* Desf., is a tetraploid species with extremely hard grain which is used for macaroni, spaghetti, and other pasta products. It is often used for arabic flat bread in North Africa and the Near East.

To facilitate marketing, plant breeders have kept distinctive combinations of grain protein and hardness. The common wheats can be produced with a wide combination of hardness and protein. However, to complement their normal end uses, bread wheats are selected to have a desired combination of hardness, protein level, and protein quality.

Soft wheat hexaploids are selected to have soft endosperm texture and low protein. Production in areas of high rainfall helps to promote the soft texture and low protein content.

The tetraploids are reported (68) to be associated with hard grain types. Diploids have soft grains and hexaploids can be variable. The club wheats, as hexaploids, could be selected as hard types, but have been maintained as a soft market class.

C. Morphology and Grain Characteristics

Wheat cultivars (varieties) are annual grasses which vary in habit, form, and structure. The wheat plant consists of roots, culms (stems), leaves, and spikes (heads). The spike is the inflorescence (flowering part). Plant parts may vary considerably among cultivars. A comprehensive review on the morphology of the wheat plant is given in Refs. 5 and 6.

Wheat is a self-pollinated crop. However, some cross-pollination can occur, but this is usually less than 1%. New wheat cultivars arise as rare combinations due to the hybridization between selected parents (49).

Plant breeders have made tremendous changes in wheat varieties. Increased production for this important food source has come about with shorter plant heights, which reduce lodging with fertilization and/or irrigation. Improved winter hardiness along with resistance to diseases and insects has stabilized production. In addition, the breeder has selected wheats for desired end use quality.

Red color of common hexaploid wheat grains is controlled by three independent genes. They are independently inherited and cumulative, but not equal, in effect. Total absence produces white wheat (38).

Durum grain also may be white or red. High-protein vitreous white durum is called amber durum. Red durum was preferred for producing puffed wheat at one time, but currently it is not an important U.S. crop.

Kernels of common wheats range from 5 to 8 mm in length and 2.5 to 4.5 mm in width; their average weight is reported at 37 mg, but it is not unusual in kernels of diverse genetic material to find a range of 20–60 mg. A longitudinal and cross section of a wheat grain along with an identification of components is shown in Figure 1. Proportions of the wheat grain components are given in Table 1.

D. Growing Conditions

Wheat is a cool weather plant and was considered for many years to require a low-humidity climate. Currently wheat is grown over a wide range of climates on diverse soil types. This adaptation contributes to its success as a major world crop (7).

Wheat has become important in crop rotations involving double-cropping with soybean or grain sorghum in the southeastern United States. Wheat production in this area requires

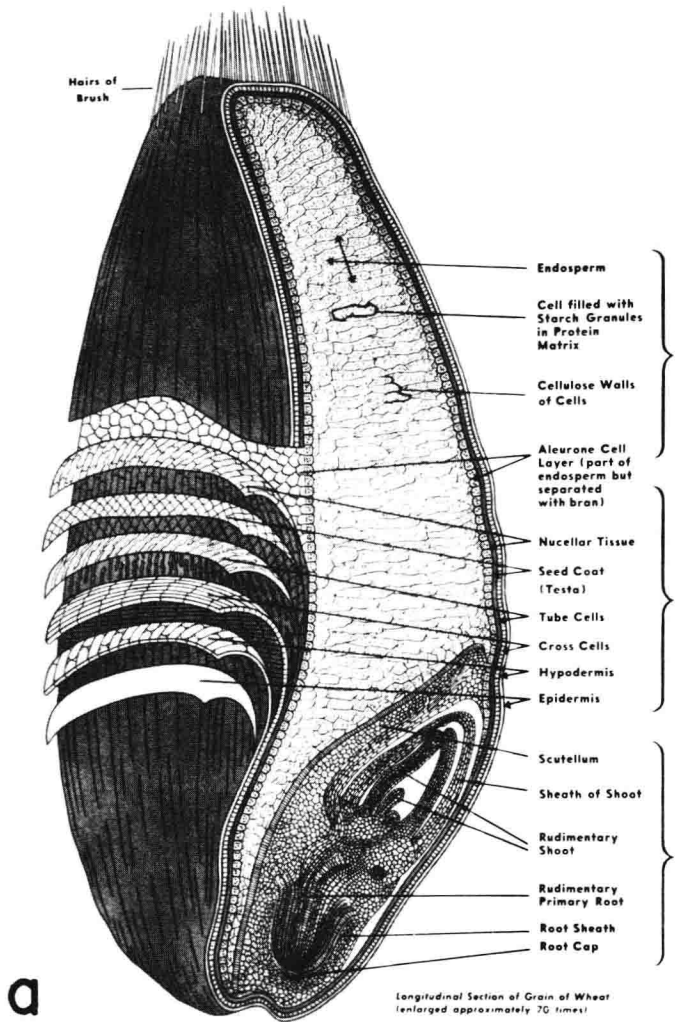


FIGURE 1 View of a wheat grain. In longitudinal section enlarged approximately 70 times (a), and in cross section (b). *Source:* Wheat Flour Institute, Washington, D.C.

proper cultivars, weed, insect, and disease control. In addition, adequate fertilization with macro- and micronutrients is essential.

Winter wheats must be fall planted and require a period of low temperature (vernalization). If spring planted, the growth usually remains prostrate on the ground and does not produce a flowering spike. Spring wheats do not require vernalization and are spring planted. They can be fall planted successfully in regions of mild winter temperatures. Wheat types range from true spring to true winter types. The expression of the trait depends on temperature, length of day, and time of seeding (8).

An in-depth report on all aspects of wheat improvement and associated topics can be found in Refs. 26, 29, and 45.