DURUM

Chemistry and Technology

Giuseppe Fabriani and Claudia Lintas, editors

Durum Wheat: Chemistry and Technology

Edited by
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PREFACE

Alimentary pasta, the main product of durum wheat technology, is the staple food in many areas. Its consumption is prompted by dietary goals in several different countries and is continuously rising around the world. In spite of that, research on durum wheat chemistry and technology has lagged behind that on other types of wheat, and the available information has remained scattered.

The main aim of this book has been to collect and present in a single work a series of reviews on the chemistry and technology of durum wheat and derived products and also to provide an extensive and updated bibliography.

The present volume is a multiauthored work, with the advantage that each subject is dealt with by an expert in the field but also with some disadvantages inherent in this type of book. In keeping with the different realities in the main areas of durum wheat development, the genetics and breeding and the evaluation of the quality of durum wheat and its products are presented in separate chapters by authors representing major producing and utilizing areas.

In the first part of the book, the origin, distribution, genetics, breeding, and diseases of durum wheat are presented. The chemistry of its components, as well as technological processes such as milling and pasta manufacturing are then discussed. Attention is also given to other durum wheat products and to the nutritional characteristics of pasta, concluding with chapters on marketing and on perspectives in the utilization of durum wheat and its products.

We wish to express our particular thanks and appreciation to the American Association of Cereal Chemists, sponsor of this monograph; to Bert L. D'Appolonia for his suggestions, as well as his invaluable help, both in the selection of some authors and in being the link with them; and to the AACC editorial staff for their technical assistance and their handling of the multitude of details in the preparation of the book for publication.

The Editors
Rome, Italy

Durum Wheat:

Chemistry and Technology

CONTENTS

CHAPTER 1

ORIGIN, DISTRIBUTION, AND PRODUCTION OF DURUM WHEAT IN THE WORLD

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I. INTRODUCTION

A. Origin of Wheats

Wheats evolved from wild grasses found growing in the Eastern Mediterranean and the Near East and Middle East areas and in places where other similar cereal crops such as barley and rye possibly developed. These grasses were adapted to the steppes or semiarid areas, characterized by winter rains and dry summers, developing with available fall-winter moisture and—depending on the elevation of these areas—reaching maturity in late spring or summer. Wheat was probably domesticated around 10,000–15,000 B.C. in the Near East area known as the Fertile Crescent, a mountainous-hilly region in the upper reaches of the Tigris-Euphrates drainage basin. Domestication of wheat and barley, as well as that of other local wild grain legumes, resulted in the settling of local people, thus determining the evolution of humans from the "shepherd-hunter-gatherer" phase to the "farmer" phase. The potential of having a cereal, a food of high energy and quality, all year around made possible the first human settlements. Consequently, higher levels of social life evolved, including specialized activities and the establishment of new types of artisans and tradesmen. Starch and plant proteins represented a source of food easy to store without continuous care and eliminated the need to search for the forage required by domesticated animals, thus making available food that was relatively easy to prepare and of high nutritional value. The first basic step toward development of cereals was made when humans started sowing seeds that had been gathered the previous season, adopting the first measures for soil preparation and tillage, and discovering the best time for seeding.

The availability of special types of grasses, able to grow in large swards, with spikes characterized by relatively large kernels, started the expansion and growth of the western Asian civilization, resulting in the Egyptian and later the European and Western civilizations.

The two basic steps for domestication of these wild grasses were 1) the selection of plants showing a lower degree of spike brittleness (in wild types, spikes disarticulate at maturity into smaller portions, the spikelets, which represent the basic unit of species dissemination, each containing one to two seeds) and 2) the selection of plants showing a larger size of kernel, thus providing a higher quantity of starch and proteins. In addition to these two basic steps of domestication, a third one eventually evolved. In the wild and semidomesticated species, the grain (caryopsis) is closely and tightly covered by the glumes. When the spike is threshed, the kernel is still covered by the glumes. The further step was the selection of plants in which the kernel could be easily separated from the glumes and appear free or "naked," as the seed of durum or bread wheats appears now.

Most likely, wheat straw was collected from the start, representing a precious feed for domestic animals (particularly ruminants) and a component for building dwellings; thus, settlements and agricultural activity became more profitable through cereal cultivation. The successful culture of wheat then spread in every direction from the Middle Eastern part of the world, reaching all continents, and now represents the most important staple food for humans (Percival, 1921).

B. Classification and Evolution of Wheats

All wheats belong to the genus *Triticum*, a member of the grass (Gramineae [Poaceae]) family and the Hordeae tribe, in which one or more flowered spikelets are sessile and alternate on opposite sides of a rachis (the main axis of the inflorescence), forming a true spike.

In 1753, Linneus proposed a first classification of wheats, based on morphological and physiological differences. After Linneus, several botanists proposed a series of classifications of the genus *Triticum*. As a result of the cytogenetic work of Sakamura in 1918, an objective key for classification of wheats came under consideration, based on the number of chromosomes present in each morphologically recognized type. Cytologic and cytogenetic work showed that wheats fall into three basic natural groups, each one characterized by having 14 chromosomes (seven pairs) or a multiple of 14 chromosomes in each somatic cell; diploid wheats have 14, tetraploid wheats 28, and hexaploid wheats 42.

After this basic discovery, a number of botanists and geneticists proposed a series of classifications (Peterson, 1965). I prefer to retain the classification of Mac Key (1954, 1966, 1975) since it seems to be the one respecting most of the rules of botanical nomenclature and the one giving equal importance to morphological, physiological, cytologic, genetic, biochemical, and evolutionary components, all of which must be carefully considered in a modern classification.

The classification of wheat (Table I), however, does not explain the development of the *Triticum* polyploid series (diploid, tetraploid, and hexaploid species). More detailed cytologic, cytogenetic, and genetic analyses have given the key to understanding the evolution of several basic *Triticum* taxonomic entities. The studies have included both the wild and the domesticated species or subspecies of *Triticum*, as well as some species belonging to the genus *Aegilops*, wild grasses that actively contributed to the evolution and speciation of wheat.

Two species are recognized at the diploid level: *T. monococcum*, with both wild and cultivated types, and *T. urartu*, a wild species different from *T. monococcum* on genetic, morphological, and biochemical bases but having in common a basic genome, the A genome. At the tetraploid level, again two main species have been recognized: *T. timopheevi* and *T. turgidum*. Both have in common the A genome, which surely comes from the *T. monococcum* complex, but the second genome is different in the two species. It has been given the letter G (or Bt by some authors) in *T. timopheevi* and the letter B in *T. turgidum* (Giorgi and Bozzini, 1969). The origin of both the G and B genomes is still debated, but most likely they derive from ancestor species belonging to a section of the genus *Aegilops* (*Sitopsis*) or from a modified genome A. At the hexaploid level, again two basic species are recognized. The first is *T. zhukovskyi*, in which genome A is represented twice and genome G once. Apparently, it derives from a cross, followed by the doubling of chromosomes, between *T. timopheevi* and a diploid *T. monococcum*. The second species is represented by *T. aestivum*, derived from a cross between a *T. turgidum* (genome AB) and an *Ae. speltoides* (genome D).

Figure 1 could be called a simplified "genealogical tree" of the genus *Triticum*, as it is accepted today by most scientists.

Domestication and cultivation in large areas, often very different from the agroecological point of view, have induced great variability through thousands and thousands of generations. This variability has been increased in tetraploid and hexaploid wheats by their ploidy level and by the survival possibility of mutations, which could permit progress in human utilization of these cereals. Tetraploid wheats are certainly allopolyploid in nature (in other words, they do not have four sets of seven basically similar chromosomes, as autotetraploid organisms do, but two sets each of chromosomes only remotely related to each other by having an ancient, common ancestor). This allopolyploid nature allows a disomic type of chromosome pairing at meiosis. In tetraploid wheats, 14 pairs of chromosomes are then identified.

Genetic and cytogenetic analyses conducted mainly at the hexaploid level have demonstrated that the chromosomes of the three basic genomes in hexaploids (ABD) or two basic genomes in tetraploids (AB) can be grouped into seven basic types. One pair of chromosomes of genome A is at least partially able to substitute for a specific pair of the genomes B (in tetraploids) or B and D in hexaploids. Therefore, in wheat, the corresponding chromosomes in all three genomes have been identified and a so-called homoeologous series established as follows:

1A	2A	3A	4A	5A	6A	7A	2n		
								4n	
1B	2B	3B	4B	5B	6B	7B			6n
1D	2D	3D	4D	5D	6D	7D			

Very often, similar mutations (or variations) can be found in all of the three types of genomes, in corresponding (homoeologous) chromosomes. This phenomenon is easily explained by the fact that the three genomes (A, B, and D) had a common ancestor in the past.

TABLE I
Classification of the Genus *Triticum* (L.)[a]

***Monococca* Flaksb.** 2n = 14	***Dicoccoidea* Flaksb.** 2n = 28	***Speltoidea* Flaksb.** 2n = 42
T. monococcum (L.) Mk.	*T. timopheevi* (Zhuk.) Mk.	*T. zhukovskyi* Men. & Er.
einkorn wheat	zanduri wheat	timon wheat
ssp. *boeoticum* (Zoiss.) Mk.	ssp. *araraticum* (Jakubz.) Mk.	
wild einkorn wheat	wild zanduri wheat	*T. aestivum* (L.) Thell.
var. *aegilopoides* (Bal. ex	ssp. *timopheevi*	dinkel wheat
Körn.) Mk.	zanduri wheat	ssp. *spelta* (L.) Thell.
var. *thaoudar* (Reut.) Perc.		spelt wheat
ssp. *monococcum*	*T. turgidum* (L.) Thell.	ssp. *macha* (Dek. & Men.) Mk.
einkorn wheat	emmer wheat	macha wheat
	ssp. *dicoccoides* (Körn.) Thell.	ssp. *vulgare* (Vill.) Mk.
T. urartu Tum.	wild emmer wheat	bread wheat
zwelkorn	ssp. *dicoccum* (Schrank) Thell.	ssp. *compactum* (Host) Mk.
	(true) emmer wheat	club wheat
	ssp. *paleocolchicum* (Men.) Mk.	ssp. *sphaerococcum* (Perc.) Mk.
	kolchis wheat	Indian dwarf wheat
	ssp. *turgidum*	
	conv. *turgidum* (L.)	
	rivet wheat	
	conv. *durum* (Desf.) Mk.	
	macaroni wheat	
	conv. *turanicum* (Jakub.) Mk.	
	khorosan wheat	
	conv. *polonicum* (L.) Mk.	
	Polish wheat	
	ssp. *carthlicum* (Nevski) Mk.	
	Persian wheat	

[a] Data from Mac Key (1975).