There are substantial variations in published figures for the vitamin content of wheat, but the grain is known to be a significant source of thiamin, niacin, and B_6. The vitamin content of 406 wheat cultivars from five market classes was reported by Davis *et al.* (1981). Mean values, in mg per kg, were thiamin 4.6, riboflavin 1.3, niacin 55, and pyridoxine 4.6. Ranges were 3.3 to 6.5, 1.0 to 1.7, 38 to 93, and 1.6 to 7.9, respectively.

Table 1.6. MINERAL AND PHYTATE CONTENT OF WHEAT KERNELS[1]

Element or compound and unit	Content in kernel or part				
	Whole kernel	Germ	Endosperm	Aleurone	Hull
Total P,%	0.42	1.66	0.11	1.39	0.08
Phytate P, %	0.32	1.10	0.001	1.16	0
Zn, ppm	40.4	222.	14.1	119.	88.7
Fe, ppm	54.6	235.	21.5	186.	110.
Mn, ppm	56.4	402.	8.80	130.	182.
Cu, ppm	4.25	18.	2.80	12.	22.6
Ca, ppm	335.	1760.	173.	730.	2570.
Mg, %	0.15	0.54	0.02	0.58	0.13
K, %	0.37	0.91	0.12	1.10	0.24

[1] O'Dell et al. (1972). The kernel was composed of 3.5% germ, 70.5% endosperm, 23% aleurone, and 3% hull. All analyses reported on an air dry weight.

Fiber.—In all discussions of dietary fiber, quantitative presentations are clouded by the almost continual changes in definition and concept of this category of substances which have occurred over the past decade, as well as by the lack of standardization in test conditions which existed until quite recently. It is very clear, however, that wheat endosperm contains only minor amounts of substances which could be called fiber even by the most liberal definition, and this condition carries through to white flour. "Wheat flour" (containing some of the outer layers) and whole wheat flour (containing all the fractions in the same proportion as in the kernel) are somewhat better, but not superior, sources of dietary fiber. White flour, whole wheat flour, and wheat bran contain, on the average, 2.78%, 12.57%, and 42.65% dietary fiber (dry matter basis) according to Cummings and Englyst (1987).

Pigments.—Ripe wheat grain varies from light buff or yellow to red-brown, according to the concentration of red pigments in the seed coat. The color will vary little in true breeding cultivars, allowing wheat varieties to be reliably classified as red or white. Red pigmentation is controlled by three genetic loci, with the result that depth of color can differ between varieties classified as red. The amber color of some durum wheats results from endosperm pigments seen through the translucent exterior layers. Nearly

flour, but its significance is somewhat less certain in the case of wheat. In the author's opinion, the real value of the ash test is that it gives another clue to the uniformity of the flour, compared with previous deliveries, and provides a check on the miller's control of his process. The test is simple and inexpensive and not very labor intensive, so it should be routinely applied to incoming flour shipments unless there is some valid reason not to do so.

Starch damage is a subject of concern to wheat processors and to the baker. The extent of starch damage alters flour characteristics and can affect final product quality. The amylase activity of wheat and flour can be measured or estimated by the Falling Number test, the Blish-Sandstedt method, and the amylograph evaluation. Descriptions of these tests can be found in test compilations previously cited.

Tests of gluten quality.—The meaning of "quantity of protein" in a wheat or flour is readily understood since the protein determination is a standardized procedure that can be duplicated in almost any cereal laboratory. The meaning of gluten "quality" is not as uniformly defined, because the definition is affected by characteristics inherent in the wheat kernel and by the purposes for which the flour is to be used. However, there are three rather clearly delimited categories of gluten quality: strong (hard wheat) gluten, weak (soft wheat) gluten, and durum-type gluten. The last is not considered satisfactory for bread dough, but it is ideal for pasta.

Many attempts have been made to appraise flour quality on the basis of the amino acid composition of gluten. Determining the amino acid composition of a sample of protein is no longer a tedious and labor intensive procedure (though it still requires expensive equipment), so it might not be impractical as a quality control test, but various investigators have failed to find essential differences in the amino acid profiles of good and bad flours. It appears much more work is needed before evaluations based on the amino acid distribution will tell the baker what he needs to know about the baking quality of flour. The value of the test to wheat breeders and cereal scientists is more obvious.

A large number of tests based on the imbibitional properties of wheat proteins have been developed and, in some cases, used fairly extensively to estimate the bakery potential of wheat and flour. In this category are measurements of viscosity, sedimentation, and swelling properties of gluten. The Zeleny sedimentation test consists of suspending flour particles in a graduated cylinder containing dilute lactic acid. The rate of sedimentation is a measure of the hydration capacity of the flour proteins and, thus, supposedly is an index of quality. Sedimentation test values obtained from 360 cargoes of wheat in world commerce showed a correlation of 0.726 with the overall quality scores of the wheat. This was a significantly higher correlation than that between protein contents and quality scores.

Although there is wide agreement that many properties of a dough are reflections of the gluten characteristics, most cereal chemists prefer to study the properties of doughs rather than to separate gluten and then

levels of about 8% in rye, compared to about 3% in wheat. Crude fiber content is similar to wheat kernels, perhaps slightly less, depending on the cultivar and the method used for determining fiber.

Rye has a significant content of a few micronutrients such as thiamin, nicotinic acid, riboflavin, pyridoxine, pantothenic, and tocopherol. These substances are present mainly in the embryo, scutellum, and aleurone. Typical figures on content in the whole kernel, in mg per 100 g dry basis, are thiamin 0.44, riboflavin, 0.18, niacin 1.5, pantothenic acid 0.77, and pyridoxine 0.33. Rye is essentially devoid of vitamin C and vitamin A.

Typical mineral content of rye grain in mg per kg includes calcium 60, iron 10, magnesium 120, phosphorus 340, potassium 460, sodium 1, copper 0.78, manganese 6.7, and zinc 3.0 (Lockhart and Nesheim 1978).

There are, of course, many enzymes in fresh rye kernels (i.e., those not damaged by heat or long storage). Many of these enzymes are substantially inactive in mature dry grain. Some of the enzymes that have received a great deal of researchers' attention are α-amylase, proteases, esterases, and beta glucosidases.

In summary, the analytical report for a typical sample of rye kernels might be expected to show 13.4% protein, 1.8% ether extract, 2.6% crude fiber, 2.1% ash, and 80.1% nitrogen free extract, all on a moisture-free basis.

There appear to be anti-nutritional factors in the grain. When rye is fed as a high percentage of the diet to domestic animals, such as chickens, deleterious physiological effects are often observed. Studies have shown that these effects are the result, at least in part, of the presence of relatively high amounts of such toxic substances as 5-alkyl resorcinols. Phytic acid and its salts also occur, and act as anti-nutritional factors by chelating calcium, iron, magnesium, and zinc. Anti-trypsin factors have been reported by a number of authors. Further details about toxic substances in rye can be found in the article by Hulse and Laing (1974).

TRITICALE

Triticale is a hybrid of wheat and rye that has been known for over 100 years. It is planted on about four million acres worldwide, most of it in France, Russia, and Poland. A much smaller acreage is planted in the U.S. The plants currently cultivated as triticale apparently breed true, and seed can be used through numerous generations, unlike usual hybrids.

General Characteristics

Triticale plants are generally similar to wheat plants, except the former have larger spikes and kernels and show greater vigor of growth. Both winter and spring types are known. The plant appears to be more resistant than rye to ergot infection but less resistant than wheat. Triticale grain has few, if any, advantages over wheat for food manufacturing purposes. It doesn't yield bread that tastes better, looks better, or has better

tribes of the grass family, the Chlorideae and the Paniceae. The tribe Chlorideae includes *Eleusine coracana*, finger millet, as the only species of economic importance. It is grown in India, and there is called "ragi."

Pearl millet, *Pennisetum americanum* (L.) K. Schum, syn. *P. typhoides*, is the species having the largest seeds and is probably the most widely grown of all these grains. *Panicum milaceum*, called hog millet or proso, is not raised for grain to any extent in the U.S. except in the northern plains where the growing season is too short for grain sorghum production. Foxtail millet, *Setaria italica* (L.), is grown in Russia and China, and is a staple food crop for many people in India (Naren and Virupaksha 1990). Its seed head is a long, compacted cylindrical spike, similar to that of pearl millet. Other varieties, such as German millet and Siberian millet, are grown in China and Russia for human use, but in the U.S. only for forage.

Sorghum vulgare has been erroneously called pearl millet, and in some parts of the world all varieties of sorghum and millet are known by the latter name, but sorghums belong to one genus (*Sorghum*) in one tribe (Andropogoneae) of the grass family.

Structure of the Seed

The generally tear-shaped kernels of pearl millet are about a third the size of sorghum kernels and weigh an average of 9 mg. Size of the seed does vary substantially because of variety, cultural conditions, etc. Shellenberger (1980) lists average length (mm), width (mm), and weight (mg) for millet kernels as 1.5, 1.5, and 8.5, compared to sorghum 4, 3.5, and 23, and wheat 7, 3.5, and 35. Colors range from yellow to black in different cultivars, but most varieties yield slate-gray seeds. Hand dissection of kernels gave the following proportions: 75.1% endosperm, 17.4% germ, and 7.5% pericarp plus endosperm. There was a large variation in thickness and weight of the pericarp in different pearl millet lines (Abdelrahman and Hoseney 1984).

Food Uses

In the U.S., food use of millet constitutes a very small fraction of the cereal's total disappearance and an insignificant amount of all grain used for food. It is known that millet is offered in many health food stores, but the total value of these sales cannot be determined. It is believed that some millet is sold in stores having substantial patronage by recent immigrants from the areas in Africa and Asia where the grain constitutes a major part of the diet. The small amount of millet that enters the food distribution chain, i.e., its status as a specialty food, inevitably causes it to sell at a higher price per pound than any of the common food grains.

In some parts of Africa and India, where millet has for centuries been an important cereal crop, the grain has multiple applications. It may be boiled and pounded into a porridge or mush, or it can be ground into a flour, formed into thin disks with water, then cooked on a hot surface to make one