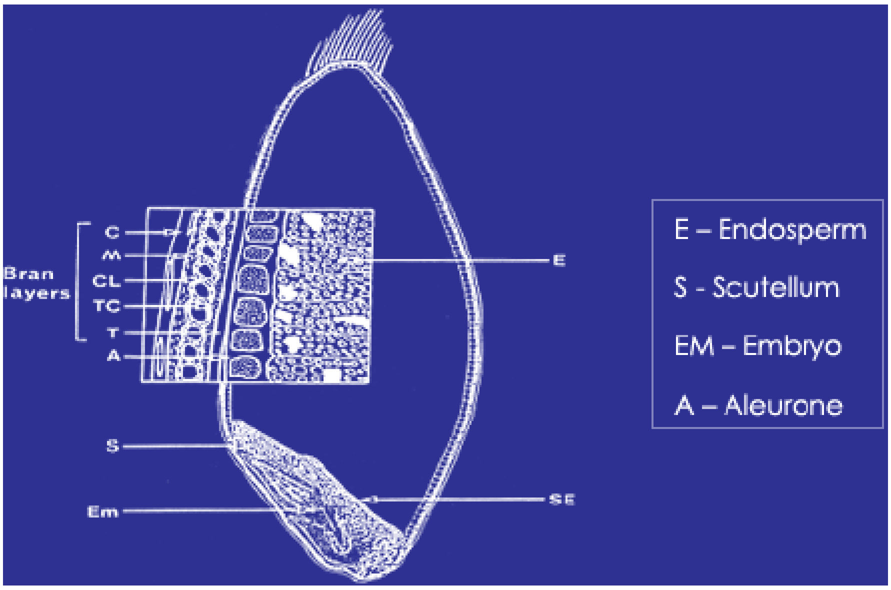
Distribution of nutrients in the grain

To understand how processing affects the nutritional value of grains, an understanding of where the nutrients are located in the grain kernel is required. Although there are slight differences between grains, the distribution of nutrients in the grain kernel is essentially the same for all grains.

Structure and Composition of the wheat grain



Schematic Diagram of a longitudinal section of wheat grain through crease and germ

Source: Mugford, D. C. et al. (1979),

The **Endosperm** contains:

- Mainly starch
- Most of the grain's protein (70-75%), including the gluten complex
- Little fat, except for oats which contain 5-9% fat, of which 80% is found in the endosperm
- Glucofructan, in wheat, which is similar in structure to inulin
- 32% of the grain's riboflavin content and 43% of the grain's pantothenic acid content
- Small amounts of thiamin, niacin and vitamin B6.

The **Aleurone** layers contain:

- High quality protein (19% of grain's content) – it has a higher lysine content than the protein in the endosperm
- No starch
- High content of vitamins and minerals* (more than 70% of the grain's vitamin B6 and niacin content, 50 – 80% of its minerals, 50% pantothenic acid, 42% riboflavin and 33% thiamin).

The **Germ** contains:

- About 30% fat, but this varies widely – two thirds of the fat is unsaturated
- In maize, the germ accounts for about 12% of the total grain, compared to 2 – 3% fat for wheat and barley
- High quality protein (8% of grain's content)

- Vitamins, including vitamin E and most of the grain's thiamin content (64%). Also has riboflavin (26%), vitamin B6 (21%) and small amounts of pantothenic acid and niacin
- Minerals* and trace elements
- Small amounts of sugars, including sucrose, raffinose, stachyose.

The **Bran** layers are high in dietary fibre and contain 2% lignin.

- Minerals found in grains include potassium, phosphorus (as phytic acid), magnesium, iron, zinc, calcium, sodium and manganese.

Phytochemicals, including lignans, phenolic acids and phytic acid are concentrated in the outer layers of the grain (aleurone and bran layers and the germ).

Nutritional implications of Flour Milling

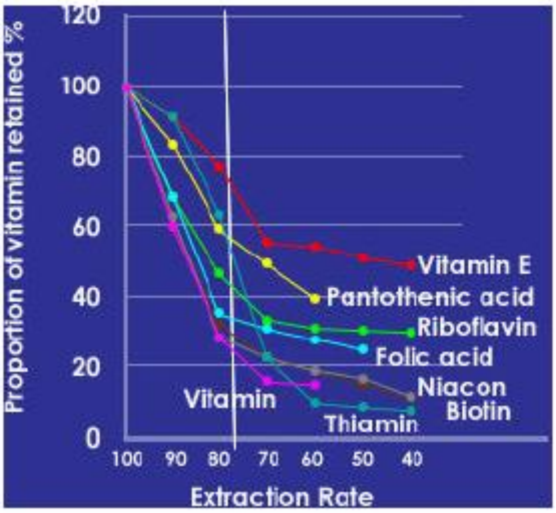
Milling affects the nutritional value of grains in two ways:

1. The physical separation of the different grain components has the greatest impact on the nutrient content of the grain.
2. Grinding reduces the particle size which impacts on the glycaemic index and resistant starch content of grains.

In wheat milling, the bran, aleurone and germ components are separated from the endosperm which is ground into flour.

Since dietary fibre, vitamins, minerals and antinutrients (phytic acid and phenolic acid) are concentrated in the outer bran and aleurone layers of the grain, the extent to which these layers are removed determines the nutrient content of the flour.

Extraction rate is the number of parts by weight of flour that is produced from 100 parts of wheat. The higher the extraction rate, the more bran is included in the wheat flour, and hence the higher the amount of dietary fibre, vitamins and minerals in the flour. Wholemeal flour has an extraction rate of 100%, whereas Australian white flour has an extraction rate of about 78%. The graph below illustrates the impact of extraction rate on nutrient content.



Source: Aykroyd WR, Doughty J. Wheat in human nutrition. Rome: FAO; 1970.

The impact of extraction rate on nutrients:

- **Vitamins**

The vitamin content of flour is highly dependent on the extraction rate. As the extraction rate drops from 87% to 80%, corresponding to the outer layers and bran being removed, there is a sharp drop in the vitamin content of flour. Unfortified white flour therefore has about 40% of the thiamin and riboflavin content of wholemeal flour and around 30% of the content of niacin and folate. Since vitamin E is concentrated in the germ, the vitamin E content of white flour is significantly lower than that of wholemeal flour.

- **Minerals**

As with vitamins, the mineral content of flour drops substantially when all of the outer and germ are removed (80% extraction rate). White flour has around 40% of the iron and 30% of the zinc content of wholemeal flour.

- **Dietary Fibre**

The amount of dietary fibre falls very rapidly when the extraction rate falls below 87% when all of the aleurone and bran layers and the germ are removed. Dietary fibre in white flour is around 30% of that of wholemeal flour.

- **Carbohydrates**

Milling does not substantially affect the carbohydrate content of flour. Since white flour consists mainly of the endosperm which is high in carbohydrate, it has a higher carbohydrate content than wholemeal flour which includes the other grain components as well.

- **Protein**

Protein content is not affected substantially by milling. However, the amino acid composition of the protein changes. Since lysine is present in larger amounts in the outer layers of the grain, removal of these layers and the germ reduces the lysine content of the flour.

- **Fat**

When the grain is crushed during the milling process, some of the fat in the germ and bran is distributed to the other fractions. However, the fat content of the flour hardly changes with extraction rate.

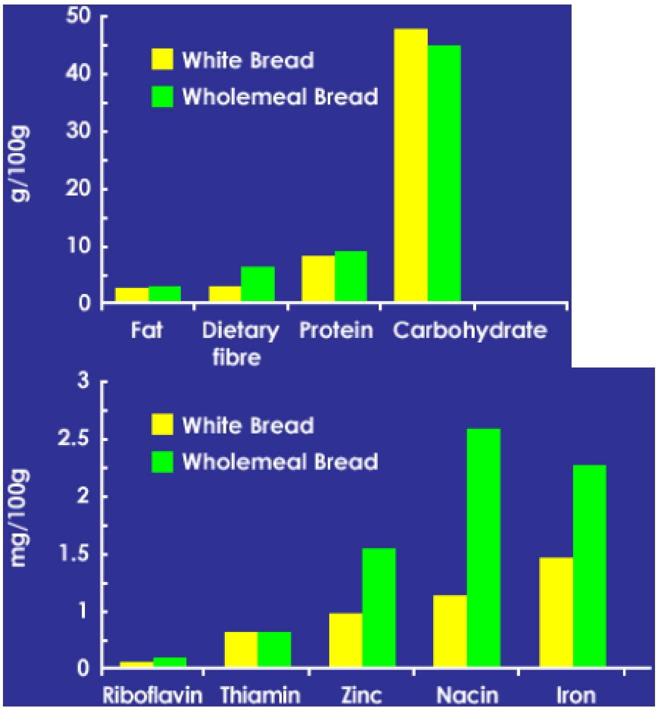
- **Phytochemicals**

Since most of the phytochemicals are concentrated in the outer layers of the grain, they are removed as the extraction rate drops below 80%. For instance, only traces of Phytate are found in white flour.

The impact of flour milling on the bioavailability of nutrients

Phytate and dietary fibre bind minerals, particularly calcium, iron, magnesium and zinc, reducing their absorption into the body. Since white flour has a lower Phytate content than wholemeal flour, the absorption of minerals is not affected to the same degree as when wholemeal flour is consumed. However, because wholemeal flour is higher in minerals, overall they provide more minerals to the body than white flour.

Nutrient content of white versus wholemeal bread



Oats, rye and barley

Losses of dietary fibre, vitamins and minerals are small in flours milled from grains such as oats, rye and barley, where it is difficult to separate the bran from the endosperm.

Oats are essentially wholegrain products because they include the bran, aleurone and germ.

In barley, the (-glucans are in the endosperm which means they are less affected by the milling process. In oats, the (-glucans are concentrated around the periphery of the grains.

Nutritional implications of rice milling

In rice milling, the bran layers and germ removed during polishing are high in fibre, vitamins and minerals as well as protein. Their removal results in loss of nutrients, especially in substantial losses of B vitamins (Table 1). Polishing rice reduces the thiamin content of rice by over 80%.

Table 1. Nutrient content of rice

Mg/100 g	Paddy Rice	Brown Rice	Polished Rice	Parboiled Rice
Thiamin	0.4	0.34	0.07	0.44
Riboflavin	0.05	0.05	0.03	0.03
Niacin	5.5	4.7	1.6	3.5
Iron	2.8	1.9	0.5	3.1
Magnesium	118	187	13	143

Garrow JS et al (ed) Human Nutrition and Dietetics. 2000: Harcourt Publishers; London.

Nutritional implications of preparing and cooking grains

Germination

Grains are germinated by soaking the seeds in water for at least 24 – 72 hours. Larger sprouts are achieved when seeds are soaked for 7 – 10 days. The water enters the seed and activates different enzymes which bring about biochemical changes.

Germination improves the nutritional quality and digestibility of grains:

- Phytic acid and Phytate are degraded, making minerals such as zinc, calcium, phosphorus and magnesium (which are bound to Phytate) available for absorption into the body. Some iron leaches into the water.
- Germination also causes degradation of antinutrients, such as trypsin inhibitors.
- The fat content decreases by 17 – 60%, whilst the fibre content increases by 50%.
- Vitamin C and riboflavin content increase substantially in germinating seeds.

Cooking/Baking

Cooking can affect the nutritional value of grains in several ways:

i. **Nutrient content and bioavailability:**

- Boiling and extrusion cooking (in the manufacture of breakfast cereals) can result in losses of around 40% for most B vitamins and 50% of folate. Boiling milled rice results in significant loss of B vitamins, especially vitamins B1 and B6, and also of minerals.
- Losses from baking are generally low for riboflavin and niacin, around 5 – 10% for pyridoxine, 20 – 30% for thiamin and higher for folate.
- In the production of leavened bread, phytases in the yeast breaks down Phytate and in so doing, increases the availability of minerals. In some parts of the Middle East, where unleavened bread is a dietary staple, Phytate has been reported to cause zinc deficiency possibly by inhibiting its absorption into the body.
- During the manufacture of ready-to-eat breakfast cereals, 70% of Phytate is destroyed in puffing and 33% in flaking.
- Toasting destroys thiamin – up to 25% of the thiamin in bread may be destroyed during toasting, depending on the length of toasting and thickness of the slice.
- The preparation of tortillas improves niacin availability but results in losses of thiamin, riboflavin and niacin (60%, 52% and 32% respectively). Maize contains little niacin or the amino acid tryptophan (precursor of niacin). The traditional alkali cooking method for tortillas (using a lime cooking step) increases the availability of niacin and may have prevented pellagra in populations relying on maize tortillas as a staple food.
- Maillard reactions or nonenzymatic browning takes place when high levels of heat are applied to sugars such as glucose, fructose and lysine making the lysine unavailable and hence reducing he quality of the protein (e.g. in the formation of crusts in bread-making).

ii. **Increase amount of resistant starch**

Depending on the chemical and physical composition of the grain, cooking can decrease the availability of starch, making it harder to digest and hence increase the resistant starch content.

iii. Lower the GI of Food

Similarly, cooking can decrease the availability of starch, decreasing the glycaemic index of the grain.