17 Flour Fortification

17.1 Vitamins and Flour

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17.1.1 Introduction

Long before the vitamins were discovered and their chemical structures analyzed, it was already known that certain diseases and symptoms such as scurvy and night blindness can be prevented by eating specific foods.

But it was not until the end of the 19th century that the vitamins were tracked down as a result of research into *beriberi*, a disease that was especially common in parts of Asia. Specific feeding experiments showed that the feed of the healthy animals in the tests clearly contained some other substances essential to life besides the known constituents such as carbohydrates, proteins and fats. The chemical analysis of one of these substances showed that the compound concerned – it was in fact thiamine (vitamin B_1) – contained an amino group. So in 1912 Casimir Funk suggested adopting the term vitamin (from *vita*, the Latin word for life and *amine*, a chemical compound with an amino group) to designate the entire group of substances. And although most of the other vitamins do not contain an amino group at all, the term has been used to this day.

Even *beriberi* is no longer considered to be a symptom of thiamine deficiency alone, for there is now convincing evidence that one sub-form, at least, may be caused by acute poisoning with the mycotoxin citreoviridine.

However, there is no doubt at all that *pellagra* (Alpine scurvy), another disease that was rampant in the early 20th century, is due to a serious vitamin deficiency. The niacin deficiency that causes it results in skin inflammation, diarrhoea and dementia, and in many cases death. In 1912 the number of persons affected in South Carolina (USA) alone was estimated at 30,000, with a mortality rate of 40%. In the southern states of the USA, especially, *pellagra* was common until well into the 1930*s*, with disastrous results.

Until 1941, systematic research into various symptoms of disease led to the discovery of all 13 vitamins and was acknowledged with numerous Nobel Prizes. Vitamins belong to very different classes of substances and are therefore defined according to their effect rather than their chemical structure. They are divided into two classes: the fat-soluble vitamins A, D, E and K, and the water-soluble vitamins B_1, B_2, B_6, B_{12}, niacin, pantothenic acid, biotin, folic acid and C. Tab. 78 shows the classification and nomenclature of the vitamins and their effective compounds.

Vitamins are needed by the human organism for

Tab. 78: The most important vitamins

Trivial name	IUPAC[a] nomenclature	Effective compounds[b]
Vitamin A	Retinol	Retinol, retinal, retinoic acid
Provitamin A	β–carotene	α–, β–, γ–carotene
Vitamin B_1	Thiamin	Thiamin diphosphate
Vitamin B_2	Riboflavine	Flavin-adenine dinucleotide
Niacin	Niacin	Nicotinic acid, nicotinamide
Pantothenic Acid	Pantothenic acid	D-pantothenic acid
Vitamin B_6	Pyridoxine	Pyridoxol, pyridoxal, pyridoxamine
Vitamin B_{12}	Cobalamin	Cyanocobalamin, hydroxocobalamin
Vitamin C	Ascorbic acid	L-ascorbic acid
Vitamin D	Calciferols	Ergocalciferol, cholecalciferol
Vitamin E	Tocopherols	α–, β–, γ–, δ–tocopherol, tocotrienols
Biotin	Biotin	D+-biotin
Vitamin K	Menadione	Phylloquinon, Menaquinon
Folic acid	Folic acid (folate)	5,6,7,8-tetrahydrofolate

[a] *International Union of Pure and Applied Chemistry*

[b] *Further derivatives may exist*

vital functions, but they cannot be synthesized in sufficient quantities, if at all, in metabolism. They therefore have to be taken in regularly as essential constituents of our food. Since vitamins are mainly involved in enzymatic and hormonal body functions and have no significance as building materials or energy suppliers, only very small amounts are required to achieve the relevant physiological effects.

17.1.2 Vitamins of the Wheat Kernel

69 All the vitamins except A, B_{12} and C are to be found in wheat kernels, although some of them are only present in traces. The water-soluble vitamins B_1, B_2, B_6 as well as niacin and pantothenic acid predominate. The vitamins are not evenly distributed in the grain.
Tab. 79 shows that they are more or less strictly compartmented.

Tab. 79: Distribution of vitamins in wheat kernels. The table shows the percentage (%) of vitamins in the three fractions analyzed.

Vitamin	Bran	Germ	Endosperm
Vitamin E	-	100	-
Vitamin B_1	33	64	3
Vitamin B_2	42	26	32
Vitamin B_6	73	21	6
Niacin	86	2	12
Pantothenic acid	50	7	43

If the weight of the three fractions is considered as a percentage of the total weight of the grain (bran 15%, germ 2-3%, endosperm 83%), the high vitamin content of the bran and germ fractions becomes even more obvious.

If undamaged wheat kernels are stored under appropriate conditions, their vitamin content remains practically unchanged for years. But if the cereal grains are subjected to processing at a mill, their vitamin content is inevitably reduced since vitamins are sensitive to outside influences such as pH, atmospheric oxygen, light and temperature. Therefore, under unfavourable conditions, particularly sensitive vitamins such as natural folic acid may be lost altogether. Different methods are used to analyze the various vitamins, depending on their chemical properties. All fat-soluble vitamins and some water-soluble vitamins can be detected and measured by high-pressure liquid chromatography (HPLC). But some water-soluble vitamins are still determined with the aid of microbiological tests in which the vitamin-dependent growth of indicator micro-organisms is measured.

Tab. 80 compares some of the vitamins contained in wheat and two types of flour as examples.

Tab. 80: Vitamin content in µg per 100 g of wheat and flour [a]

Vitamin	Wheat	Flour, Type 1700	Flour, Type 550
Vitamin E	1,400	2,100	340
Vitamin B_1	462	470	110
Vitamin B_2	94	170	
Vitamin B_6	269	460	100
Niacin	5,100	5,000	500
Pantothenic acid	1,200	1,200	400
Biotin	6	8.3	1.1
Folic acid	87	50	16

[a] *Souci et al., 2000*

The vitamin losses of baker's flour published in the literature are all in the region of 70 - 90%. An exception is pantothenic acid, only 50% of which is said to be lost. Because of their uneven distribution in the wheat kernels, the losses observed for the individual vitamins depend to a large extent on the degree of extraction of the flour. In general it may be said that the vitamin content increases continuously in the direction of wholemeal flour.

The following section deals in greater detail with folic acid because of its high value in preventive medicine and its degree of availability, which is felt to be critical.

17.1.3 Folic Acid (Folate)

74 Folic acid was discovered in 1941 as the last of the 13 known vitamins. For a long time it led a rather shadowy existence compared to other vitamins, but it has now moved into the focus of scientific and nutritional interest. The biologically active form of folic acid is 5,6,7,8-tetrahydrofolate. As co-enzymer folates are involved in a large number of metabolic processes, acting as acceptors and transmitters of so-called C1 groups (hydro-xymethyl and formyl groups) in metabolism. Through this function, folic acid is also involved in amino acid metabolism and DNA and choline synthesis.

It is now known for certain that an optimum supply of folic acid before and during pregnancy can prevent the occurrence of neural tube defects. The neural tube of the embryo, the precursor of the brain and spinal cord, normally closes between the 21st and 28th day of pregnancy. Incomplete closure at its upper or lower end results in neural tube defects which then manifest in the form of anencephaly (absence or degeneration of important parts of the brain) or *spina bifida* (gap in the backbone). The reasons for the protective influence of folic acid are still being discussed, but it is known that about 75% of all neural tube defects could be prevented by the timely administration of folic acid.

Because of its involvement in homocysteine metabolism, folic acid also plays an important role in preventing cardiovascular disease. Homocysteine is formed in the body through the breakdown of methionine and is known to be a risk factor in its own right for the occurrence of arteriosclerosis. Extensive studies have shown that an elevated homocysteine level can be reduced by the regular intake of folic acid.
Further positive effects of folic acid are also being discussed in connection with the prevention of hare lip, cleft jaw and cleft palate and minimization of the risk of certain forms of cancer. According to recent findings, the use of folic acid has also proved effective in treating cognitive disorders of old age such as depression and Alzheimer's disease.

In view of the medical background, an increased intake of folic acid by wide sections of the population would be desirable from the point of view of nutrition policy. In the form in which folates occur in natural foods, they are highly sensitive, and because of their chemical structure they are only about 50% bio available to the human body. It therefore takes considerable effort to meet daily folic acid requirements with normal food of vegetable and animal origin. A valuable alternative is staple foods such as flour fortified with folic acid. A special form of folic acid is used for such fortification; it is very stable in flour and bakery products made from flour and also fully available to the human body. Data from the USA show just how effective such a measure can be: since mandatory flour fortification with folic acid started in 1998, the incidence of neural tube defects has fallen by 19%. Encouraged by these promising results, German experts are urgently demanding flour fortification with folic acid (www.ak-folsaure.de).

17.1.4 Fortification of Flour with Vitamins

Fortification of flour with the aim of creating a balanced food was practised as early as the late 19th century. At that time, however, the supplementation carried out was rather unspecific since the chemical structure of the constituents assumed to be essential was not known. The substances added included wheat germs, yeasts and also milk powder, since these were known to have favourable nutritional properties.
Specific fortification did not become possible 73 until the late 1930s, as more and more vitamins were produced synthetically. In the USA it became permissible as early as 1938 to fortify flour with the micronutrients vitamin B_1, niacin and iron to prevent diseases such as *beriberi, pellagra* and iron deficiency anaemia. The next step followed in 1943, when the Food and Drug Administration (FDA) implemented mandatory guide-lines for the level of fortification for the micro-nutrients already used and the additional use of vitamin B_2. During the Second World War, flour enrichment was introduced in the United Kingdom too. There are now numerous countries in which flour producers

are obliged by law to fortify their products with certain vitamins and minerals. Many other countries practise specific flour fortification on a voluntary basis.

Experience in these countries has shown that the amounts of vitamins required for vitaminization do not have negative effects on the technical properties of fortified flours and the products made from them. However, the vitamin preparations used must be carefully chosen for the particular purpose.

Homogeneous distribution of the components and correct dosing is ensured optimally by the continuous addition of micro-quantities to the stream of flour at the mill.

Only five years ago, the main purpose of fortifying the staple food flour was to prevent deficiency symptoms. But it has since become known that certain vitamins also have the effect of helping to prevent degenerative diseases. It was therefore a logical step for the FDA to adjust its regulations on flour fortification again in 1998 by raising the levels of the vitamins B_1, B_2 and niacin and making the addition of folic acid obligatory also (chapter 17.2.5, Tab. 84).

17.1.5 Final Remarks

The history of the discovery of vitamins is a good example of how technological developments can inspire scientific progress. Vitamins are present in all plants and animals, which means that deficiency symptoms do not occur if we have a balanced diet. But it was known from experience at sea and in wartime that under extreme conditions diseases such as scurvy may occur. When diseases like beriberi and pellagra occurred at the end of the 19th century, it took a long time to realize that these were caused by severe vitamin deficiencies. Only gradually did people become aware that the cause of these diseases might have something to do with the introduction of modern processing methods for rice and wheat. In 1834 the Swiss engineer Sulzberger invented the forerunner of today's roller mill, thus triggering a technical revolution in milling. "White flour", once a luxury confined to the upper classes, suddenly became available for the entire population. The advantages of the new flour such as a long shelf life, excellent baking properties, easy digestibility and – not least – its prestige value ensured its success. But the fact that besides its more obvious properties also the composition of the flour had changed went unnoticed until the above diseases occurred on a massive scale. In the light of our present knowledge it is easy to understand that an unbalanced diet consisting of products baked from vitamin depleted flours was bound to result in the diseases that were then observed. Therefore over 150 years ago the implementation of new technologies in milling also made a great contribution to the discovery of the vitamins. With today's knowledge, modern high-quality flours make an important contribution to the basic provision of vitamins in many countries and are even used in the context of nutritional measures to prevent disease.