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Fortification of Wheat Flour

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ELENA BEIZADEA
The Faculty of Tourism and Commercial Management, ''Dimitrie Cantemir'' Christian University, Constanta, Romania
E-mail: beizadea@yahoo.com

Abstract

Food fortification refers to the addition of essential micronutrients to food. Addition of vitamins, minerals and trace elements to staple foods has been practiced in numerous industrialized countries for many years with considerable success.
Food fortification is generally recognized as being the most efficient, as well as the most cost effective means to eliminate micronutrient deficiencies.
More than any other technology available today, food fortification offers an affordable and immediate opportunity to improve line and accelerate socioeconomic development.
Fortification of food has been responsible for eradicating most of the vitamin and mineral deficiencies in developed countries.

Keywords: flour fortification, vitamins, minerals, micronutrients projects

Introduction

Fortification of wheat flour has been practiced in the USA and in the European States for more than 50 years without any problems. The technology is also applicable in other countries where wheat is the main cereal staple.

Rice, corn wheat and their derivatives, such as flours and meals, are preferred vehicles for fortification because most staple foods consumed in developing countries fall into this category. Flour fortification is routinely performed in most developed countries.

Now, technical advances have made it possible to transfer the process to developed countries.

New developments in process technology lead to improvements in dosing, mixing and feeding systems, and better retention of the fortificants in the chosen vehicle.

Use of premixes, containing the necessary nutrients, cofactors and protective agents in appropriate quantities, simplify processing and quality control, reduces costs and wastage, and improve nutrient quality and stability of the finished product.

New micronutrient premixes offer the nutritional value, cost and stability to ensure that fortified flour will look feel, taste and smell like unfortified flour.

Micro-encapsulation and other novel formulation make fortificants more resistant to destructive elements in the environment, reduce the risk of interaction with other ingredients, and improve micronutrient retention in the finished product.

Research to improve fortification technology continues and is often directed at the specific needs of each individual situation. Recent advances have produced fortificants that are more robust and stable, new blending and bonding systems and ways to simplify processing and increase bioavailability.

Fortification: defining the concept

In its natural state, wheat is a good source of vitamins B1, B2, B6, niacin, E, as well as iron and zinc.

Most of these nutrients are concentrated in the outer layers of the wheat grain, and are lost during the milling process in a significant proportion. For lower extraction rates of flour, the loss of vitamins and minerals is greater.

In developed countries, wheat flour is generally fortified with vitamins B1, B2, niacin, and iron. In some countries calcium and folate are also added. The levels of vitamin B1, niacin and iron added to wheat flour is often equivalent to the amount lost in milling, these micronutrients are resorted and the flour is enriched.

For other micronutrients such as vitamin B2 the amount added is over and above that lost in milling when the flour is fortified.

Fortification rather than enrichment is done when the overall diet is deficient in particular micronutrients and restoring the micronutrients lost in milling will not make for this deficit.

Fortification of wheat flour

Wheat is the most widely produced cereal in the world, most of which is destined for human consumption; thus, its contribution to energy intake is significant, particularly in the Americas and the Middle East.

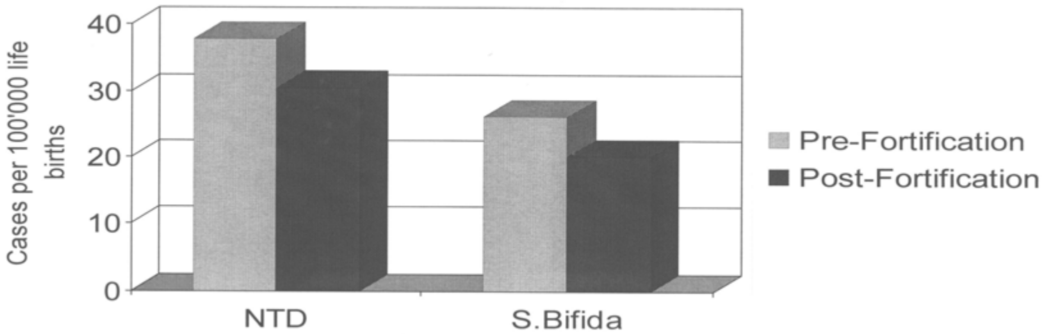

Figure 1. Flour fortification with folic acid reduces incidence of neural tube defect and spina bifida (USA)

Compulsory fortification of wheat flour and its products require addition of iron, vitamin B1, vitamin B2 and niacin in several countries such as Canada, United Kingdom, Venezuela, Chile, Nigeria, Saudi Arabia and most countries in Central America. Guatemala was the first country to include folic acid in the fortification of wheat flour. In the United States, as of January 1997, enriched wheat flour, fortified with iron, vitamin B1, B2 and niacin, will also be required to include folic acid in its fortification program. Ecuador legislated to have wheat flour enriched with vitamin B1, B2, niacin, folate and iron; India and Pakistan including wheat for vitamin A. Fortification of wheat flour with vitamin A is being evaluated in several countries.

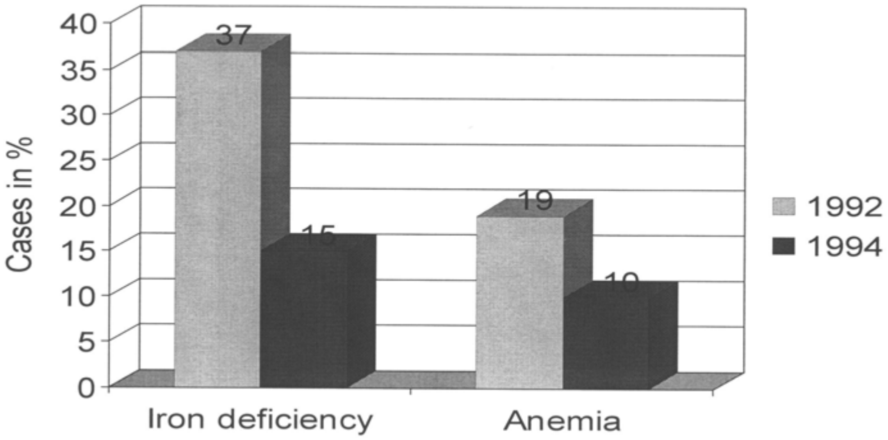

Figure 2. Fortification of wheat and corn flour reduces iron deficiency and anemia in children of lower socio-economic groups (Venezuela)

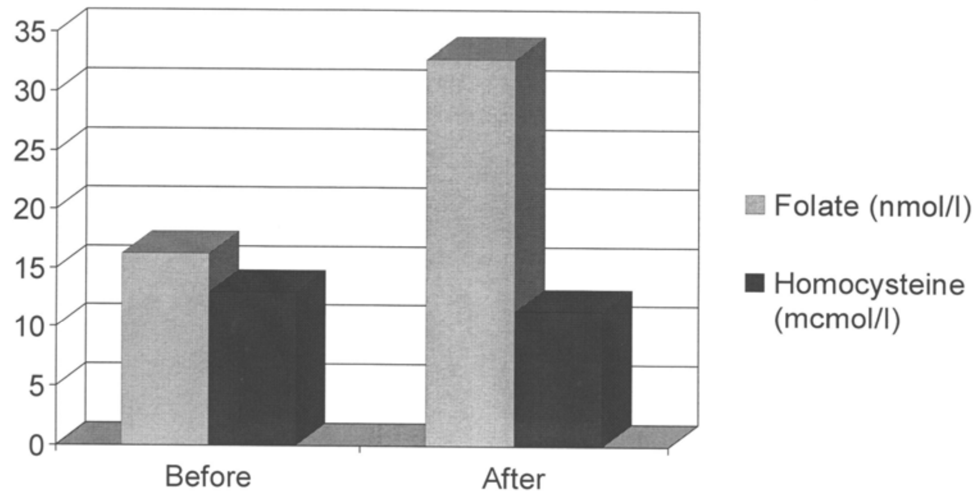

Figure 3. Serum folate and homocysteine levels before and after six months after fortification of wheat flour with folic acid (Chile)

Of the major foods categories in the United States, cereal-grain products meet many of the criteria for multiple nutrient fortification. Cereal- grain products are consumed by virtually 100% of the population every day and provide approximately 26% of the calories consumed. Cereals tend to be nutrified to provide a particular percentage of the United States Recommended Dietary Allowance (USRDA), often 25 percent. As evidence of the success of cereal fortification, people consuming breakfast cereal have been found to have higher vitamin and mineral intakes.

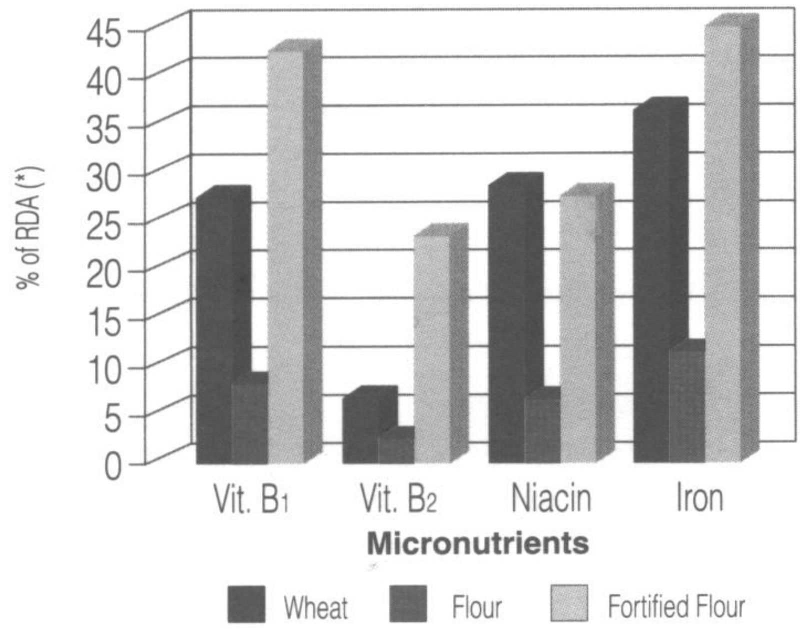

Figure 4. Nutrient allowance per 100g of different wheat products

Figure 4 shows the contribution that flour fortified with vitamins B1, B2 and niacin, as well as iron, makes toward meeting the Recommended Dietary Allowances (RDA) for adult men in the USA.

Table 1. Per capita wheat Consumption in selected countries

Country	Consumption g/person/day	% Dally Energy Intake
Pakistan	318	45
Turkey	484	44
Syria	490	44
Chile	372	42
Egypt	397	35
Greece	371	28
Argentina	344	28
Uruguay	269	26
Romania	250	25
Bolivia	159	20
South Africa	191	18
Peru	136	17

Source: FAO, Food Supply, 2002

The technology for fortifying flour is simple. First, a premix of the micronutrients to be added is needed.

Table 2. Example of premix composition

Nutrient	Level (mg/kg Flour)	Product Form	grams/Kg Premix
Vitamin B1	4.45	Thiamine Mononitrate	61.80
Vitamin B2	2.65	Riboflavin	36.90
Niacin	35.62	Nicotinamide	494.70
Iron	30.20	Reduced Iron	406.60

Dosage: 72g/ton of flour
Source: DSM Nutritional Products, 2007

The advantage of using a premix over that of adding micronutrients singly is that there is a greater likelihood of ensuring:

- the correct concentration of micronutrients
- an even distribution of micronutrients

The fortification process itself is accomplished by adding the micronutrients through a volumetric feeder located towards the end of the milling process. The most commonly used feeder consists of a rotating feed screw that is driven by a variable speed motor. The screw rotates inside a chamber containing the premix and pushes the premix through an outlet spout. The amount of premix added to the flour can be modified by changing the motor speed. The concentration of premix added to the flour can be calculated by weighing the amount of premix deposited by the feeder in one minute divided by the volume of flow passing underneath in the same period of time. The premix can be either fed directly into the flour by gravity ex by air convection using a pneumatic system. The homogeneity of micronutrients in fortified flour is largely dependent on the location of the feeder and it is very important that the mixing of the micronutrients with the flour is good. In a gravity driven system, experience has shown that the best site for adding micronutrients is before the mid point along the screw conveyor that collects flour from ail the mill passages, just before bulk storage or sacking. If the feeder is placed towards the beginning of the screw conveyor, the amount of flour in the conveyor will be too little. If on the other hand, the feeder is located toward the end of the screw conveyor, the required homogenization will not be achieved in a pneumatic system feeders can be placed in a remote centralized location.

Vitamin and mineral stability during processing

Usually, in foods, the stability of vitamins is more precarious than that of minerals because vitamins are sensitive to heat, oxidizing and reducing agents, light, and other kinds of physical and chemical stress. The sensitivity of vitamins to various physical and chemical factors is shown in Table 3.

Table 3. Sensitivity of Vitamins

	Heat	Humidity	Light	Acids	Alkalis	Oxidizing Agents	Reducing Agents
Vitamin B1	+++	++	++	+	+++	+	+
Vitamin B2	+	+	+++	+	+++	+	++
Vitamin B6	+	+	++	++	++	+	+
Niacin	+	+	+	+	+	+	++
Folic Acid	+	+	++	++	++	+++	+++
Biotin	+	+	+	++	++	+	+
Pantothenic Acid	+	++	+	+++	+++	+	+++
Vitamin A	++	+	+++	++	+	+++	+
Vitamin E	++	+	++	+	++	++	+
Vitamin C	++	++	+	++	+++	+++	+

+ Hardly or not sensitive; ++ Sensitive; +++ Highly sensitive
Source: DSM Nutritional Products, Switzerland

Vitamin B1 (*Thiamin*) is one of the most unstable B vitamins. Baking, pasteurization, or boiling of foods fortified with thiamin can reduce its content by up to 50 percent. The stability of thiamin during storage depends greatly on the moisture content of the food. Flours with a 12 percent moisture content retain 88 percent of the added thiamin after five months.

If the moisture level is reduced to 6 percent, no losses occur. Thiamin is stable during bread baking; between 15 to 25 percent of the vitamin is lost.

Vitamin B2 (*Riboflavin*) is very stable during thermal processing, storage, and food preparation. Riboflavin, however, is susceptible to degradation on exposure to light. The use of light-proof packaging material prevents its deterioration

Vitamin B6 (*Pyridoxine*) losses depend on the type of thermal processing. For example, high losses of B6 occur during sterilization of liquid infant formula; in contrast, B6 in enriched flour and corn meal is resistant to baking temperatures. B6 is susceptible to light induced degradation and exposure to water can cause leaching and consequent losses. However, vitamin B6 is stable during storage; wheat flour stored at either room temperature or 45°C retained about 90 percent of the vitamin.

Niacin is one of the most stable vitamins and the main loss occurs from leaching into cooking water. Thiamin, riboflavin, and niacin fortified spaghetti, retained 96, 78, and 94 percent of their initial levels, respectively, after three months of storage in the dark, followed by boiling for 14 minutes.

Folic acid is unstable and loses its activity in the presence of light, oxidizing or reducing agents, and acidic and alkaline environments. However, it is relatively stable to heat and humidity (Table 3); thus, premixes, baked products, and cereal flours, retain almost 100 percent of the added folic acid after six months of storage.

Biotin is sensitive to both acids and bases. Good stability of various micronutrients during storage of fortified corn flour has been demonstrated.

Pantothenic acid is stable to heat in slightly acid to neutral conditions, but its stability decreases in alkaline environments.

The stability of vitamin A in fortified wheat and corn flour is excellent. Studies show that wheat flour and yellow corn flour, stored under normal conditions, retain over 95 percent of their vitamin A after six months at room temperature. However, the stability of vitamin A under high storage temperatures is not as good. Wheat flour stored for three months at 45°C retained only 72 percent of vitamin A.

Vitamin E added in the form of α-tocopheryl acetate shows excellent retention in wheat flour. Losses of vitamin E occur only during prolonged heating such as in boiling and frying.

Vitamin C (*Ascorbic acid*) is easily destroyed during processing and storage through the action of metals such as copper and iron. Both exposure to oxygen and prolonged heating in the presence of oxygen destroy ascorbic acid; thus, the stability of vitamin C in fortified foods depends on the product, processing method, and type of packaging used. Vitamin C retention in fortified foods and beverages stored for 12 months at room temperature ranges from 75 to 97 percent.

Baking fortified bread causes losses as shown in Table 4. Thiamin, riboflavin and niacin are stable during bread baking; between 5 to 25 percent of the vitamins are lost. Over 70 percent of folic acid added to wheat flour is retained during bread baking. Baking fortified bread causes only limited losses of vitamin A.

Table 4. Vitamin Losses During Typical Bread Baking

Nutrient	**% Loss during baking**
Vitamin A	10 – 20
Thiamin	15 – 25
Riboflavin	5 – 10
Niacin	0 – 5
Folic Acid	20 – 30

Source: F Hoffman – La Roche. Basel

The use of stabilized, encapsulated forms of vitamins has greatly improved the resistance of vitamins to severe processing and storage conditions.

Minerals are more resistant to manufacturing processes than vitamins; copper, iron and zinc are also affected by moisture, and may react with other food components such as proteins and carbohydrates. Various forms of iron are used in fortification, among the most popular ones being ferrous sulphate and elemental iron powders because of their relatively high bioavailability. Other potential iron sources include ferric orthophosphate, sodium iron phosphate, ferrous fumarate, and iron-EDTA. The stability of different forms of iron depends on various factors including the nature of the food it is added to, particle size, and exposure to heat and air. Elemental iron, as reduced iron or electrolytic iron, is used to fortify ready – to – eat breakfast cereals and has been found to have excellent stability during processing and storage.

Impact of flour fortification on public health

Food fortification programs have been key elements in this fight against micronutrient malnutrition, with flours (Table 5), breads, and other cereal products serving as the primary vehicles for micronutrient enrichment.

Table 5. Flour Enrichment Worldwide

Country	Vitamin B1 (Mg/Kg)	Vitamin B2 (Mg/Kg)	Niacin (Mg/Kg)	Acid Folic (Mg/Kg)	Iron (Mg/Kg)
Canada	4.4 – 7.7	2.7 – 4.8	35 – 46	(0.4 – 0.5)	29 – 43
Chile	6.30	1.30	13.00		30.00
Costa Rica	4.4 – 5.5	2.6 – 3.3	35.2 – 44.0		28.7 – 36.4
Dominican Rep	4.45	2.65	35.62		29.29
Ecuador	4.45	7.48	83.58	0.59	58.65
El Salvador	4.41	2.65	35.30		28.70
Guatemala	4.0 – 6.0	2.5 – 3.5	35 – 40	0.35 – 0.45	55.65
Honduras	4.40	2.60	35.20		28.70
Nigeria	4.5 – 5.5	2.7 – 3.3	35.5 – 44.4		28.9 – 36.7
Panama	4.40	2.60	35.20		28.70
Saudi Arabia	≥ 6.38	≥ 3.96	≥ 52.91		≥ 36.30
UK	≥ 2.4		≥ 16.0		≥ 16.5
USA	6.40	4.00	52.90		44.10
Venezuela	1.50	2.00	20.00		20.00

Source: Raunhardt, O. and A Bowley. 1996. Nutriview 1

In developing countries, enrichment and fortification of cereal products are the most effective ways to upgrade the nutritional status of the population. When widely practiced, enrichment improves nutrient consumption, individual work performance, and general public health. Micronutrient fortification programs applied to cereal products are among the most cost-effective public health interventions that can be employed.

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