

Fortification Basics

Maize Flour/Meal

Rationale

Maize or corn is a cereal with ears consisting of either white, yellow or rust coloured grains, rich in starch, which are attached to a cob protected by layers of fibrous leaves.

The way in which maize is processed and consumed varies greatly from country to country, maize flour and maize meal being two of the most popular products. For maize meal, the whole grain is ground into a granulated meal with a range of particle sizes from coarse to fine, while maize flour is obtained from milling the endosperm of the maize grain after the germ and outer layers are removed (see Figure 1). These products have replaced whole maize as important components in the diet in many parts of the world. As with all cereals, most micronutrients are concentrated in the outer layers of the grain; thus removing these layers in the milling process results in the loss of most vitamins and minerals. These losses, however, can be replaced through enrichment or fortification without affecting the quality or acceptability of foods made from maize flour or maize meal.

Maize flour or maize meal can be considered in fortification programs because they are staple foods in many parts of the world. For example, in Zambia, over two-thirds of the daily energy intake comes from maize; in Central America, almost one-half of the daily energy intake comes from maize flour; and in a number of other countries between 10 and 30 percent of daily energy intake is from maize flour or maize meal (Table 1).

Fortification Criteria

Whole maize is a good source of thiamin, pyridoxine and phosphorus, and a fair source of riboflavin, niacin, folate, biotin, iron and zinc. However, many of these nutrients are lost during milling (Table 2). Micronutrients not present in significant amounts include vitamins A and E and calcium. All of the above nutrients can be easily added to maize flour or maize meal during the milling process. The concentration of vitamins and minerals to be added must be calculated based on nutritional requirements and consumption patterns, after which losses during storage and cooking must also be considered. Venezuela, for example, fortifies maize flour with a vitamin-mineral premix containing vitamin A, thiamin, riboflavin, niacin, and iron. Also, certain producers in Zimbabwe and Namibia fortify maize meal with a vitamin-mineral premix containing vitamin A, thiamin, riboflavin, niacin, folate, pyridoxine and iron.

For a fortification program to be manageable, milling needs to be done in a few centralized mills rather than in hundreds or thousands of small local mills. This is because it would be extremely difficult to implement a quality control system where milling is not centralized. People who consume locally produced, unprocessed maize meal, are less likely to benefit from a fortification program. However, in Zambia and Zimbabwe programmes are under evaluation whereby hammermills may be able to fortify their maize meal using a modified mixing drum.

The growing centralization of maize milling, its world-wide consumption, and the simplicity of the fortification technology make this vehicle a good choice for nutritional intervention.

Figure 1
Cross Section of a Maize Kernel

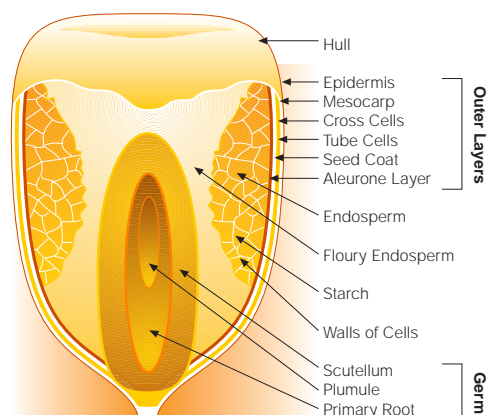


Table 1
Per Capita Maize Consumption and Percent Daily Energy Intake from Maize in Selected Countries

Country (1992-1994)	Consumption (g/day)	% daily energy intake
Bolivia	79	10
Brazil	59	7
Egypt	165	18
Guatemala	302	48
Honduras	249	36
India	23	3
Mexico	335	34
Nepal	135	22
Philippines	56	6
South Africa	293	32
Venezuela	175	18
Zambia	411	62

FAO 1996. Food Balance Sheets. 1992-1994. Rome

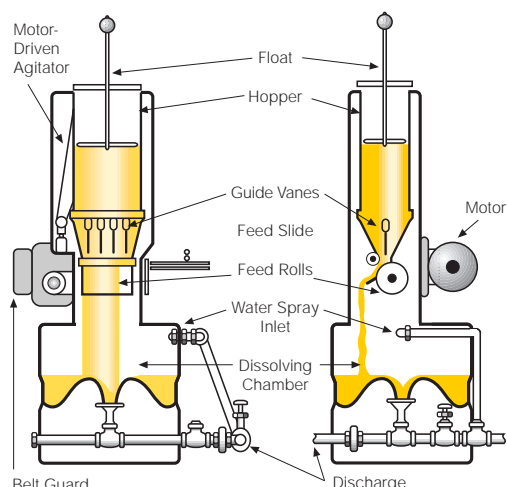
Table 2
Influence of Milling on the Vitamin and Mineral Content of Maize

Vitamins (mcg/g)	Whole Maize	Dehulled	Degermed
Vitamin A	0	-	-
Thiamin (B1)	4.7	4.4	1.3
Riboflavin (B2)	0.9	0.7	0.4
Niacin	16.2	13.9	9.8
Pyridoxine (B6)	5.4	5.4	1.9
Vitamin E	0	-	-
Folate	0.3	0.2	0.1
Biotin	0.073	0.055	0.014
Minerals			
Calcium	30.8	26.7	14.5
Phosphorus	3,100	2,500	800
Zinc	21.0	17.1	4.4
Iron	23.3	19.7	10.8

Bauernfeind, J.C. and E. DeRitter. 1991. Cereal Grain products. In Nutrient Addition to Foods. Bauernfeind, J.C. and P.A. Lachance (Eds). Food and Nutrition Press, Trumbull, CT.

Figure 2

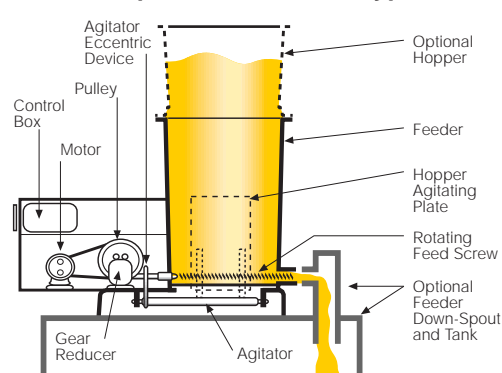
Roll-Type Volumetric Feeder with Slide Bar Feed-Rate Adjustment



Lund, D. 1991. Engineering aspects of nutrifying foods. In Nutrient addition to foods. Bauernfeind, J.C. and P.A. Lachance (Eds). Food and Nutrition Press. Trumbull, CT

Figure 3

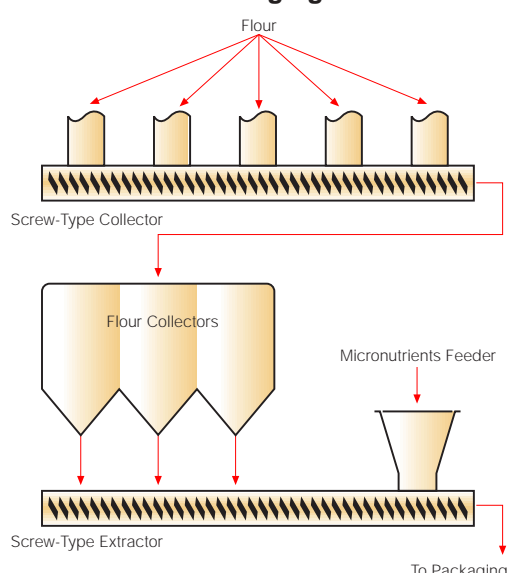
Variable Speed-Drive Screw-Type Feeder



Lund, D. 1991. Engineering aspects of nutrifying foods. In Nutrient addition to foods. Bauernfeind, J.C. and P.A. Lachance (Eds). Food and Nutrition Press. Trumbull, CT

Figure 4

Addition of Micronutrients Before Packaging



Technology

The process of adding micronutrients to maize flour or maize meal and the selection of the dosifiers or feeders must be carefully considered. The dosification process should ensure uniform distribution of the nutrients in the product at the mill, during storage, and in foods after they are prepared. Losses during processing, storage and cooking should be calculated and taken into account when determining the level of micronutrient(s) to be added.

Micronutrients can be added singly or as a premix combined in specified proportions. The premix is added at a rate compatible with the flow of flour or meal along the conveyor belt (usually 10–60g/100 kg flour or meal) using adjustable feeders. Volumetric (Figure 2) or screw-type (Figure 3) automatic feeders are used. It is important for flour to be mixed well after the micronutrients are added.

The two most common sites for adding micronutrients are:

- before packaging on a screw-type conveyor (good mixing) (Figure 4).
- where flours or meal from different batches converge (excellent mixing) (Figure 5).

To minimize errors in feed rates, the micronutrients must be free flowing and, to avoid separation of the added micronutrients from the flour or meal, the particle size must be similar to that of the end product. Monitoring and adjusting the feeder is important for supplying the correct amount of micronutrients to the flour or meal.

Stability of Micronutrients

Factors that influence the stability of added vitamins and minerals during storage and preparation of maize flour or maize meal are:

Storage	Preparation
temperature	temperature
moisture content	type of preparation
presence/absence of light	length of cooking process
pH of the system	
presence of oxygen	
length of storage packaging	

Vitamin A, D, and folic acid are unstable when exposed to air, light, and heat. Vitamin B1 is sensitive to heat and alkalis. Vitamin B2 is sensitive to light and alkaline pH. Vitamin B6 and biotin are pH sensitive. Niacin is the most stable vitamin being essentially unaffected by light, heat, or pH.

The stability of micronutrients in fortified maize flour stored at room temperature is good (Table 3). One study showed that yellow maize flour retained all its vitamin B6, over 95 percent of vitamins A, B1, and B2, and about 85 percent of folic acid activity after six months storage at room temperature. In another study that involved storing fortified maize flour for 12 weeks at 45°C, over 95 percent of the original vitamin B6 and folate and 67 percent of the vitamin A were retained. Warm and humid storage conditions adversely affect the stability of some micronutrients, such as vitamin A. This must be considered in humid environments where warehouses are not climatically controlled.

Despite the gradual loss of vitamin A during storage, its bioavailability (absorption in the intestine) from maize flour stored for three months at room temperature, 40°C, and 45°C, is above 95 percent, which is excellent.

The stability of vitamins and minerals in cooked foods made with fortified maize flour is also good. Only vitamin A showed a loss of between 10 and 15 percent after boiling maize flour for 5 minutes.

According to analyses done in South Africa, the losses of vitamin A during the traditional cooking of maize meal is somewhat higher

than for maize flour, probably due to the different time-temperature conditions. These losses can be overcome by adding an additional amount or "overage" of this vitamin to the maize flour or maize meal.

Because riboflavin has a bright yellow colour, consumers may reject foods that contain it, which can limit the amount used in fortification. For example, Venezuela had to reduce the riboflavin level in fortified maize flour from 4 mg/kg to 2.5 mg/kg of flour for this reason. The colour of maize meal fortified with 2.5 mg/kg is not affected and is well accepted by consumers. The degradation of niacin in high pH bakery products, such as tortillas, may cause off-odours.

Calcium, iron, magnesium, and zinc compounds that have acceptable sensory and physical properties can be added to maize flour and maize meal. Colour problems often result when ferrous sulphate or ferrous fumarate are the sources of iron. Elemental iron has its disadvantages too. The fine particle size of elemental iron can result in it being lost from the flour or meal in purifiers that use air separation. It can also get trapped by magnetic bars, if they are located close to the packaging site. Nevertheless, Venezuela is using a mixture of ferrous fumarate and reduced iron with good results.

Quality Control

A vitamin and mineral fortification program requires periodic testing to ensure that the desired amount of micronutrients are in the final product prior to consumption. Facilities, procedures, and properly trained staff are, therefore, needed. A precise quality control plan must be outlined to determine the level of fortificant in fortified flour or meal, especially for the more labile nutrients, like vitamin A.

Determination of vitamins A, B₁, B₂, B₆, niacin, and folic acid is done using a quantitative method. Quantitative methods include the use of HPLC or spectrophotometric methods. The HPLC method is based on the separation of a specific vitamin from other substances that absorb radiant energy at an equal or similar wavelength to that of the specific vitamin. The method is accurate but the equipment is expensive and highly trained personnel are required. Vitamin A (retinol) can also be determined spectrophotometrically, whereby the absorbance of retinol is measured after its selective destruction through exposure to UV light. The spectrophotometric method is less expensive and easier than the HPLC method and the results can be obtained in a much shorter time period, but it is less sensitive than the HPLC method. Niacin too can be measured spectrophotometrically after mixing the food with sulfanilic acid to yield a yellow colour, whose intensity is proportional to the concentration of niacin in the food.

When using vitamin mineral premixes in foods, only one micronutrient may be analyzed as a reference level in the final product.

Costs

The cost of maize flour or maize meal fortification includes the cost of micronutrients, equipment (feeders), equipment maintenance, quality control, and additional personnel. When considering fortification with multiple micronutrients, it is important to consider interactions between micronutrients and perhaps separate the more reactive ones using two different premixes.

In Venezuela, a premix containing five vitamins and minerals (A, B₁, B₂, niacin, and iron at levels shown in Table 4) costs between US\$12 and US\$15/kg. At an addition rate of 0.20 kg per ton of flour, the impact in cost ranges from US\$ 2.4 to US\$ 3.0 per metric ton of maize flour which in turn represents around 0.3 percent of the retail price of the product. In Zimbabwe, a premix containing vitamins A, B₁, B₂, B₆, niacin, folate (25% RDA/200g after cooking) and iron (20% RDA/200g after cooking) costs between US\$ 2.5 to US\$ 3.0 per metric ton of maize meal.

Table 3
Stability of Vitamin-Iron Premix in Yellow Maize Flour (6.5% Moisture Level) During Storage at Room Temperature

Nutrient	Units	Initial	3 mo.	6 mo.
		Units per lb		
Vitamin A (250 SD)	IU	6000	5820	5880
Thiamin (vitamin B ₁)	mg	3.2	3.2	3.1
Riboflavin (vitamin B ₂)	mg	2.0	1.8	1.9
Niacin	mg	26.0	25.7	Na
Pyridoxine (vitamin B ₆)	mg	4.5	4.0	4.5
Folic acid	mg	0.6	0.5	0.5
Iron	mg	41.0	39.0	40.0

na = not available
Rubin, S.H., A. Emodi, and L. Scalpi. 1977. Micronutrient addition to cereal grain products. Cereal Chem. 54: 4. 895-903.

Figure 5
Addition of Micronutrients Where Different Batches of Flour Converge

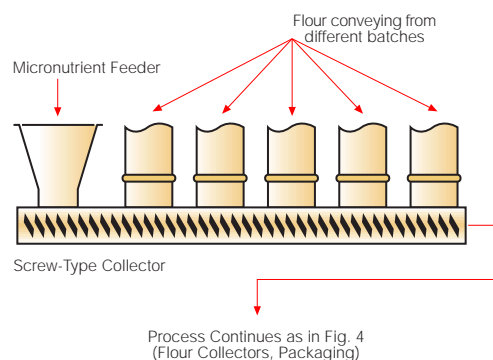


Table 4
Level of Fortification of Precooked Maize Flour in Venezuela

Nutrient	Level / 89 g*	% RDI
Vitamin A (IU)	801	30
Thiamine (vitamin B ₁) mg	0.28	32
Riboflavin (vitamin B ₂) mg	0.22	17
Niacin (mg)	4.54	30
Iron (mg)	4.45	40

Instituto Nacional de Nutrición, Enriquecimiento de la harina de maíz precocida y de la harina de trigo en Venezuela: Una gestión con éxito. 1995. Serie cuadernos azules. N° 51. Caracas, Venezuela.
* Mean consumption level.

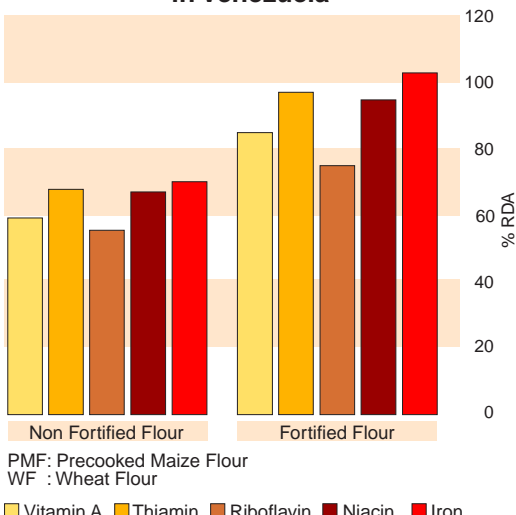
Table 5

Fortification Level for Enriched Corn Meal in the U.S.A.

Nutrient	Level (mg/100 g)
Thiamin	0.44-0.66
Riboflavin	0.26-0.40
Niacin	3.5-5.3
Folate	0.15-0.22
Iron	2.9-5.7
Vitamin D (optional)	55-220 IU
Calcium (Optional)	110-165.

Code of Federal Regulations: 197.260, 1998.

Figure 6
Contribution of 80 g PMF+30 g WF to Micronutrient Requirements in Venezuela

PMF: Precooked Maize Flour
WF : Wheat Flour

■ Vitamin A ■ Thiamin ■ Riboflavin ■ Niacin ■ Iron

J.F. Chávez, Food fortification to end micronutrient malnutrition - Symposium report, Micronutrient Initiative, 1998.

Table 6

Proposed Level of Fortification of Maize Meal in Zambia (To Be Legislated)

Nutrient	Level per 200 g before cooking	% RDA after cooking
Vitamin A	425 RE*	25
Vitamin B ₁	0.61 mg	25
Vitamin B ₂	0.52 mg	25
Vitamin B ₆	0.63 mg	25
Niacin	5.85 mg	25
Folate	0.11 mg	50
Iron	2.80 mg	20
Zinc	3.00 mg	20

F. Hoffman - La Roche, South Africa, 1998.

* 1 RE = 3.33 IU

Legislation

Government legislation is needed but it is not enough to guarantee that a fortification program will work. To ensure its success, an interdisciplinary fortification task force with experts from the relevant sectors should be set up. It would be ideal to include the maize industry, trade organizations, universities, Ministry of Health, nutrition institutions, regulatory institutions, consumers, and donors.

A fortification plan should specify the micronutrients and the levels of each micronutrient to be added per serving size, as well as state precautions and food safety conditions to be observed during production, transportation, storage, and sale.

Producers may face some constraints, e.g. the price of flour or meal may be controlled and the added cost of fortification may not be passed on to consumers. Taxes may be levied on all imported vitamins. Additionally, legislation may require the use of certain forms of fortificants which may increase the price of the premix.

History and Successful Interventions

Dependence on unfortified corn (as maize is referred to in the U.S.) as a major source of energy can result in pellagra, as occurred in the southern United States early in this century. In 1943, the US National Research Council recommended enrichment standards for food products, which was first enacted in South Carolina, including the addition of vitamins B₁, B₂, niacin, and iron to corn products.

In 1974, the Food and Nutrition Board of the National Academy of Sciences proposed a revised fortification policy for all cereal-grain products, including corn flour. The revised guidelines required the addition of vitamins B₁, B₂, and niacin and an increased amount of iron, as well as provided for the optional addition of calcium and vitamin D. In 1998, fortification with folate also became mandatory (Table 5).

Restoration of the micronutrients lost in maize milling is required by law in Canada and Denmark.

In 1979, South African millers started a maize meal fortification program, triggered by surveys showing inadequate intakes of riboflavin and niacin. However, it is estimated that 90 percent of the product is not fortified at the desired level, or as declared on the packaging. Lack of support from the industry and health authorities, and the absence of adequate regulatory control contributed to the failure of the program.

Precooked maize flour, in which the flour is steamed and then dried, is used to make "arepa", a staple food in the Venezuelan diet. This process greatly reduces cooking time, making it more convenient and appealing to consumers. This maize flour was selected as a vehicle for a fortification program designed to reach the majority of the population. Precooked maize flour is fortified with vitamins A, B₁, B₂, niacin, and iron, making the maize flour an important source of these micronutrients. The contribution of fortified precooked maize flour and fortified wheat flour to micronutrient requirements in Venezuela is illustrated in Figure 6.

In Zimbabwe and Namibia a few of the commercial maize millers have fortified maize meal with vitamins A, B₁, B₂, B₆, niacin, and folate (25% RDA after cooking), and iron and zinc (20% RDA after cooking) per 200 g. These programmes have been actively supported by governments.

In Zambia, current studies show that enrichment of maize meal at the hammermill level is feasible. Serious consideration has also been given to the legislation of all commercially produced maize meal in Zambia with vitamins A, B₁, B₂, B₆, niacin, and folate, iron and zinc (Table 6).

Fortification of regular maize flour with vitamins B₁, B₂, niacin and folate, iron, and zinc is being contemplated in Mexico. Fortification of "nixtamalized" (lime-treated) flour is also being considered; however, some technological issues need to be resolved first.