

GUIDELINE: **FORTIFICATION OF WHEAT FLOUR WITH VITAMINS AND MINERALS AS A PUBLIC HEALTH STRATEGY**



**World Health
Organization**

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EXECUTIVE SUMMARY

Anaemia and iron, folate, zinc, vitamin A and iodine deficiencies are the most studied and more prevalent nutritional problems, constituting serious public health problems that particularly affect young children and women. The most common causes of micronutrient deficiencies are related to inadequate intakes, utilization or increased losses.

Fortification of industrially processed flour, when appropriately designed and implemented, is an efficient, simple and inexpensive strategy for supplying vitamins and minerals to the diets of large segments of the population. Wheat is cultivated and consumed in many parts of the world and its domestication contributed to the development of farming and human civilization. Industrial fortification of wheat flour with at least iron has been practised for many years in several countries where the flour is used in the preparation of different types of bread and national dishes.

Decisions about which nutrients to add to fortified wheat flour and how much of each nutrient to use should be based on the nutritional needs and intake gaps of the target populations; the usual level of consumption of wheat flour and products made from this staple; the sensory and physical effects of the fortificant on the flour and on flour products; the type of wheat and the extraction rate¹ of the flour; the availability and coverage of fortification of other staple food vehicles in addition to other commercially available fortified products; the population use of vitamin and mineral supplements; costs; feasibility; and acceptability of the fortified product by the consumers.

Wheat flour can be fortified with several micronutrients, such as iron, folic acid and other B-complex vitamins², vitamin A and zinc. Some micronutrients are incorporated for restitution of the original nutritional contents of unrefined wheat flour, and others are used for correcting inadequacies and associated deficiencies of public health significance. The bioavailability of the added micronutrients will partially depend on the grain type and the extraction rate of the flour.

PURPOSE OF THE GUIDELINE

The main objective of this guideline is to provide locally adaptable, clear, evidence-informed global recommendations on the fortification of wheat flour with vitamins and minerals as a public health strategy to improve the micronutrient status of populations, which are grounded in gender, equity and human rights approaches with the aim of leaving no one behind. The focus of this document is on the use of this intervention as a public health strategy and not on market-driven fortification of wheat flour or products³.

This guideline aims to help Member States and their partners to make informed decisions on the appropriate nutrition actions to achieve the 2030 [Sustainable Development Goals](#) and the global targets set in the World Health Organization (WHO) [Comprehensive implementation plan on maternal, infant and young child nutrition](#).

¹ The production of wheat flour is a multi-step process to isolate the endosperm and subsequent sifting into flour. The extraction rate of a flour is the extent to which it has been sifted to separate the fine-grain endosperm, with a higher extraction rate indicating higher retention of the bran and germ.

² The B-complex vitamins include B₁, thiamine; B₂, riboflavin; B₃, niacin; B₆, pyridoxine; B₉, folate; and B₁₂, cyanocobalamin. Thiamine, riboflavin, niacin and folic acid are commonly referred to by name, and their names are used throughout this document; the others are referred to by vitamin number.

³ Market-driven fortification refers to the situation where the food manufacturer takes the initiative to add one or more micronutrients to processed foods, usually within regulatory limits, to increase sales and profitability. Fortification as a public health strategy refers to the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals (including trace elements), in a food to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health.

The recommendations in this guideline are intended for a wide audience, including policy-makers, expert advisers, and technical and programme staff in ministries and organizations involved in the design, implementation and scaling-up of nutrition actions for public health. The recommendations are particularly relevant to the design and implementation of appropriate food-fortification programmes, as part of a comprehensive food-based strategy for combating micronutrient inadequacies and deficiencies.

These recommendations supersede the previous WHO recommendation on fortification of wheat flour¹. The guideline complements the WHO/FAO (Food and Agriculture Organization of the United Nations) *Guidelines on food fortification with micronutrients*² and the Pan American Health Organization (PAHO) *Iron compounds for food fortification: guidelines for Latin America and the Caribbean 2002*³. These two documents are not WHO standard guidelines but contain information still current that is not covered in this guideline. Because of the important aspects covered, the WHO Nutrition and Food Safety Department plans to update both documents.

GUIDELINE DEVELOPMENT METHODOLOGY

WHO developed the present evidence-informed recommendations using the procedures outlined in the *WHO handbook for guideline development*. The steps in this process included: (i) identification of the priority questions and outcomes; (ii) retrieval of the evidence; (iii) assessment and synthesis of the evidence; (iv) formulation of recommendations, including research priorities; and planning for (v) dissemination; (vi), equity, human rights, implementation, regulatory and ethical considerations; as well as (vii) impact evaluation and updating of the guideline. The Grading of Recommendations Assessment, Development and Evaluation (GRADE)⁴ methodology was followed to prepare evidence profiles related to preselected topics, based on up-to-date systematic reviews and other narrative syntheses of the evidence.

The guideline development group consisted of content experts, methodologists and representatives of potential beneficiaries. One guideline group participated in a meeting where the guideline was scoped, and a second WHO guideline development group – nutrition actions, was convened to discuss the evidence and finalize the recommendations. The members of the first guideline development group meeting identified five priority areas for guidelines on food fortification: wheat, maize, rice, sugar, and oil and condiments. For each item the group prioritized the nutrients based on the prevalence of deficiency and the feasibility of fortification based on nutrients to add and the characteristics of the food vehicle(s). For wheat flour the group prioritized iron, folic acid and zinc.

¹ Recommendations on wheat and maize flour fortification. Meeting report: interim consensus statement. Geneva: World Health Organization; 2009 (http://apps.who.int/iris/bitstream/10665/111837/1/WHO_NMH_NHD_MNM_09.1_eng.pdf, accessed 1 February 2022).

² Allen L, de Benoist B, Dary O, Hurrell R, editors. Guidelines on food fortification with micronutrients. Geneva: World Health Organization and Food and Agriculture Organization of the United Nations; 2006 (<https://apps.who.int/iris/handle/10665/43412>, accessed 1 February 2022).

³ Dary O, Freire W, Kim S. Iron compounds for food fortification: guidelines for Latin America and the Caribbean 2002. *Nutr Rev*. 2002; 60:S50–61. doi:10.1301/002966402320285218.

⁴ The GRADE approach defines the overall rating of confidence in the body of evidence from systematic reviews as the extent to which one can be confident of an estimate of effect across all outcomes considered critical to the recommendation. Each critical outcome had a confidence rating based on certainty of evidence – high, moderate, low or very low. High-certainty evidence indicates that we are very confident that the true effect lies close to that of the estimate of the effect. Moderate-certainty evidence indicates that we are moderately confident in the effect estimate and that the true estimate is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low-certainty evidence indicates that our confidence in the effect estimate is limited and the true effect may be substantially different from the estimate of the effect. Very low-certainty evidence indicates that we have very little confidence in the effect estimate and the true effect is likely to be substantially different from the estimate of effect.

Systematic reviews team members participated in the guideline development process as resource persons by presenting evidence and identifying research priorities. While developing recommendations, the guideline development group considered additional factors in the implementation of wheat flour fortification as a public health strategy, including equitable access and universal coverage. Four technical experts were invited to peer-review the draft guideline.

SUMMARY OF THE EVIDENCE

Several systematic reviews were included in the evidence to decision document presented to the guidelines development group to inform recommendations.

- For iron, seven systematic reviews were included that aimed to determine the benefits and harms of wheat flour fortification with iron on anaemia, iron status and health-related outcomes.
- For folic acid, one systematic review was commissioned to evaluate the effect of fortification of wheat and maize flour with folic acid on population health outcomes.
- For zinc, two systematic reviews evaluated the effects of the fortification of staple foods on health-related outcomes and biomarkers of zinc status in the general population.
- For vitamin A, one systematic review assessed the effects of fortifying staple foods on vitamin A deficiency and health-related outcomes in the general population.

IRON

A systematic review was commissioned to determine the benefits and harms of wheat flour fortification, with iron alone or with other vitamins and minerals, on anaemia, iron status and health-related outcomes. Ten trials, involving 3319 participants, were included in the review and assessment of different iron compounds, doses and duration of fortification. In comparison to unfortified flour, wheat flour fortified with iron alone or with other micronutrients may reduce anaemia and probably makes little or no difference in the risk of iron deficiency. The effect of wheat flour fortified with iron on haemoglobin concentrations is uncertain.

FOLIC ACID

A systematic review from 2019 concluded that fortification of wheat flour with folic acid alone or with other micronutrients may increase erythrocyte and serum/plasma folate concentrations and may reduce the risk of neural tube defects compared to unfortified flour.

ZINC

Two systematic reviews aimed to evaluate the beneficial and adverse effects of fortification of staple foods with zinc on health-related outcomes and biomarkers of zinc status in the general population. Both reviews show that zinc may improve the serum zinc status of populations, reducing the prevalence of zinc deficiency and may provide health and functional benefits, including a reduced incidence of diarrhoea.

VITAMIN A

A systematic review assessed the effects of fortifying staple foods with vitamin A for reducing vitamin A deficiency and improving health-related outcomes in the general population older than 2 years of age. Out of ten studies, two were on wheat flour and showed that vitamin A, with or without other micronutrients, made little or no difference to the serum retinol levels in children and adolescents after six months of intervention.

RECOMMENDATIONS

Overarching principle for recommendations – Fortification of cereal flours, in this case industrially processed/produced wheat flour fortification, should be considered when wheat flour is regularly consumed by large population groups in a country. The fortification scheme in terms of which nutrients to add and in what amounts should be based on the nutritional needs of the population, usual consumption of fortifiable flour, sensory and physical effects of the added nutrients on flour and flour products, type of wheat and the extraction rate of flour, other fortified food items or ongoing micronutrient programmes, and fortification costs, feasibility and acceptance.

Based on available evidence, the recommendations to fortify wheat flour are as follows.

- Fortification of wheat flour with highly bioavailable iron is recommended as a public health strategy to improve haemoglobin concentrations and iron status, and to prevent anaemia and iron deficiency in populations, particularly for vulnerable groups such as children and women (*strong recommendation, low certainty of evidence*).
- Fortification of wheat flour with folic acid is recommended as a public health strategy to reduce the risk of occurrence of pregnancies affected by neural tube defects among women of reproductive age and to improve folate status in populations (*strong recommendation, low and very low certainty of evidence*).
- Fortification of wheat flour with zinc may be used as a public health strategy to improve serum/plasma zinc status of populations (*conditional recommendation, low certainty of evidence*).

KEY REMARKS

The remarks in this section are suggestions intended to give some considerations for implementation of the recommendations, based on the discussions of the guideline development group.

- When vitamin A deficiency constitutes a public health problem and no other/insufficient strategies to address it are in place, fortification of wheat flour with vitamin A could be considered as a public health strategy to improve vitamin A status or to reduce the risk of subclinical vitamin A deficiency.
- In countries with a high prevalence of vitamin B₁₂ depletion and deficiency, the inclusion of vitamin B₁₂ could be considered when staples are fortified with folic acid, to prevent unintended consequences of imbalances caused by the addition of folic acid alone.
- Since some of the B-complex vitamins naturally present in the wheat kernel are removed during milling, especially with low-extraction (i.e. refined) wheat flour, the restoration of thiamine, riboflavin, niacin and pyridoxine in wheat flour could be considered as a regular practice in fortification.

- The choice of iron compound is a compromise between cost, bioavailability, micronutrient interactions and the acceptance of texture, taste, smell and/or colour.
- The removal of phytates in wheat flour could increase the bioavailability of iron and zinc.
- Addition of vitamins and minerals to wheat flour should be based on evidence about inadequacy of micronutrient intakes and/or the prevalence of deficiency. This pre-fortification data will also serve for measuring impact of the fortification programme.
- Countries that fortify wheat flour may also fortify other food items. A combined fortification strategy using multiple vehicles appears to be a suitably effective option for reaching all segments of the population. Fortification of wheat flour should be integrated and monitored as part of their national programmes for prevention and control of micronutrient deficiencies and insufficiencies.
- Food fortification should be guided by national standards, with quality-assurance and quality-control systems to ensure quality fortification. Continuous programme monitoring should be in place as part of a process to ensure high-quality implementation. Monitoring consumption patterns and evaluation of micronutrient status in the population can inform adjustment of fortification levels over time.
- Populations should be encouraged to receive adequate nutrition, which is best achieved through consumption of a healthy balanced diet. Fortified foods only complement the diet when feasible and required.
- Although evidence is limited, fortification of wheat flour could potentially decrease inequity in population access to and consumption of micronutrient required to achieve good health and to prevent adverse health outcomes.
- The following table contains a list of nutrients and levels that could be added to wheat flour for fortification and/or restitution of contents based on extraction rate, chemical form and estimated per capita flour consumption.

TABLE 1. Average level of nutrients to consider adding to fortified wheat flour based on extraction rate, fortificant compound, and estimated per capita flour availability

Nutrient ^a	Flour extraction rate ^b	Chemical form of the compound	Amount of nutrient to be added in (mg/kg wheat flour) based on estimated average per capita wheat flour consumption			
			<75 g/day ^c	75–149 g/day	150–300 g/day	>300 g/day
Iron ^d	Low	NaFeEDTA	40	40	20	15
		Ferrous sulfate	40	40	30	20
		Ferrous fumarate	60	60	30	20
		Electrolytic iron	NR	NR	60	40
	High	NaFeEDTA	40	40	20	15
Folate	Low or high	Folic acid	5.0	2.6	1.3	1.0
Zinc ^e	Low	Zinc oxide				
		Zinc sulfate	95	55	40	30
		Zinc acetate				
	High	Zinc oxide				
		Zinc sulfate	100	100	80	70
		Zinc acetate				

Nutrient ^a	Flour extraction rate ^b	Chemical form of the compound	Amount of nutrient to be added in (mg/kg wheat flour) based on estimated average per capita wheat flour consumption			
			<75 g/day ^c	75–149 g/day	150–300 g/day	>300 g/day
Vitamin A ^f	Low or high	Vitamin A palmitate Vitamin A acetate	5.9	3.0	1.5	1.0
Vitamin B ₁₂ ^g	Low or high	Cyanocobalamin	0.04	0.02	0.01	0.008
For restitution of content lost during milling of refined flours^h						
Vitamin B ₁ (thiamine)	Low or high	Thiamine Thiamine mononitrate Thiamine hydrochloride	3.0	3.0	3.0	3.0
Vitamin B ₂ (riboflavin)	Low or high	Riboflavin Riboflavin 5' phosphate	2.0	2.0	2.0	2.0
Vitamin B ₃ (niacin)	Low or high	Niacin Niacinamide	40.0	40.0	40.0	40.0
Vitamin B ₆ (pyridoxine)	Low or high	Pyridoxine Pyridoxine hydrochloride	2.0	2.0	2.0	2.0
Other nutrientsⁱ						
Vitamin D ^j	Low or high	D ₃ cholecalciferol	0.02	0.02	0.02	0.02
Calcium	Low or high	Calcium carbonate Calcium phosphate	3125	2112	1250	1250

NaFeEDTA: sodium iron ethylenediaminetetraacetate; NR: not recommended.

Note: This table is for general guidance and is partially based on the 2009 [Recommendations on wheat and maize flour fortification](#). The number and amounts of nutrients should be adapted according to the needs of the country. These estimated target levels consider only wheat flour as the main fortification vehicle in a public health programme. If other large-scale food fortification programmes are implemented effectively, these suggested fortification levels may need to be adjusted downwards as needed.

^a Nutrient levels were adapted from the 2009 [Recommendations on wheat and maize flour fortification](#) and the evidence presented and discussed at the guideline development group meeting.

^b High-extraction flour (>80%) is also known as whole flour. It retains high levels of natural phytates, which inhibit the body's ability to absorb iron and zinc. High-extraction flours contain a naturally higher content of vitamins and minerals than low-extraction flours.

^c Estimated per capita consumption of <75 g/day does not allow for the addition of sufficient amounts of fortificant to cover the needs of some micronutrients for women of reproductive age. Fortification of additional food vehicles and other interventions may need to be considered.

^d The amounts of micronutrients such as iron, zinc and calcium presented here are in mg of the elemental micronutrient. The amount of a micronutrient compound to add should be calculated depending on the molecular weight of the compound.

^e These amounts of zinc fortification assume 5 mg zinc intake and no additional phytate intake from other dietary sources. As with iron, the phytate concentration of high-extraction flour will affect the bioavailability of zinc.

^f Consider fortifying wheat flour with vitamin A when deficiency constitutes a public health problem and no other strategies to address it are in place.

^g Inclusion of vitamin B₁₂ is recommended when its deficiency is a public health problem or when wheat flour is fortified with folic acid.

^h Restitution of some B-complex vitamins should be achieved as a regular practice in all settings. The B-vitamins contents vary between types of whole wheat flours.

ⁱ Compounds and amounts indicated in this section are seldom used and constitute only rough estimates. Including them will depend on country needs, wheat type and other ongoing nutrition programmes.

^j Level used in Jordan and Mongolia, with consumptions above 300 g/day. For lower levels of wheat flour consumption, consider increasing the amount of vitamin D.

EVIDENCE GAPS

The WHO guideline development groups and the systematic reviews teams highlighted the limited evidence available in some areas. Further research on wheat flour fortification is merited, particularly in:

- the bioavailability of different iron compounds for use in wheat flour fortification, including mixtures of different compounds;
- the bioavailability and stability of added folic acid, vitamin A and vitamin D in wheat flour;
- fortification of wheat flour with zinc only in comparison with fortification with a mix of micronutrients;
- the effects of different phytate contents on the absorption of iron and zinc from the premix formulation;
- biomarkers of individual micronutrient status under different conditions of infection and inflammation;
- stability of different micronutrients and compounds in different cooking processes that are context specific;
- relative bioavailability among different chemical forms of various micronutrients that can be used in wheat flour fortification, including nutrient–nutrient interactions;
- the most appropriate delivery platforms of the fortified flour/fortified flour products for reaching the intended target population;
- the impact of wheat flour fortification on micronutrient status and health outcomes to prevent excessive supplies of micronutrients to certain groups and identify situations where complementary interventions are needed to reduce inequity in populations.

PLANS FOR UPDATING THE GUIDELINE

The WHO Secretariat will continue to follow research developments in wheat flour fortification, particularly for questions in which the certainty of evidence was found to be low or very low. If the guideline merits an update, or if there are concerns about the validity of the guideline, the Department of Nutrition and Food Safety, in collaboration with other WHO departments or programmes, will coordinate the guideline update, following the formal procedures of the [WHO handbook for guideline development](#).