

FAQ #2

What are the risks of toxicity from vitamin A fortification of foods?

Vitamin A fortification of foods is a safe and effective intervention that is practiced in both developed and developing countries. Foods fortified with vitamin A include cooking oils, margarine, sugar, milk and certain milk products, and, in developed countries, ready-to-eat breakfast cereals.

An intake of 10,000 IU/day has been set as the level safe for adults, including pregnant women. At the levels of fortification currently practiced around the world, enormously high and practically impossible amounts of an individual food or a combination of fortified foods would have to be consumed on a daily or regular basis to reach this toxicity threshold for humans. Therefore, vitamin A toxicity from fortified foods is highly unlikely. Indeed, even in developed countries where more than one food is fortified with vitamin A, there have been no reports of vitamin A toxicity attributed to the intake of fortified foods.

Careful planning and designing of a food fortification program, with special attention to the levels of vitamin A, supported by clear and effective policies and regulations will help minimize any potential risk for excessive intake of vitamin A through fortified foods.

For a more detailed and technical discussion see *A brief review of the safety of vitamin A fortification of foods*, on the following pages.

A BRIEF REVIEW OF THE SAFETY OF VITAMIN A FORTIFICATION OF FOODS

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I. Introduction

Vitamin A deficiency is a major public health concern throughout the developing world, contributing to morbidity and blindness in children under five years old. Vitamin A deficiency also increases the risk of mortality in infants and children by up to 23 percent (Beaton et al. 1993) and may increase the risk of pregnancy-related mortality (West et al. 1999).

Fortification of foods with vitamin A is a safe, effective, sustainable, and relatively inexpensive intervention to improve vitamin A status that is practiced in both developed and developing countries. There is some concern, however, among program planners and policy makers that fortifying widely consumed foods with vitamin A may cause adverse effects and potential toxicity from excessive intake of vitamin A. At the currently practiced levels of fortification, enormously high and practically impossible amounts of these foods would have to be consumed daily to reach the vitamin A toxicity threshold for humans. Indeed, even in developed countries where more than one food is fortified with vitamin A, there have been no reports of vitamin A toxicity attributed to the intake of fortified foods.

This paper provides a brief overview of the metabolism and toxicity of vitamin A; foods fortified with vitamin A worldwide; estimated toxicity thresholds of fortified foods at different levels of vitamin A fortification; successful vitamin A fortification interventions; and a history of vitamin A fortification of foods in the United States.

Physiology of vitamin A

Vitamin A is essential for vision and promotes growth and repair of body tissues, bone formation, and healthy skin and hair. It also plays an important role in the immune function and is thus crucial for child health and survival. Vitamin A is absorbed from the gut and transported through circulation bound to retinol-binding protein, transferred to cells for utilization, and stored in the liver as retinyl esters. The liver is the major storage site for vitamin A, although many other tissues also store some amounts of retinyl esters (Olson 1996).

Dietary sources of vitamin A

Vitamin A occurs naturally as preformed retinol in animal foods and as provitamin A carotenoids in plant foods. Animal foods containing vitamin A include liver, meats, eggs, and milk; carotene-rich plant foods include yellow fruit such as mango and papaya, dark green leafy vegetables, and yellow and orange vegetables such as sweet potatoes and squash. Preformed retinol from animal foods is absorbed more efficiently than carotenoids from plant foods whose bioavailability depends on several factors, including the type of carotenoid and other dietary ingredients. On average, one unit of retinol is considered nutritionally equivalent to 6 units of β -carotene and 12 units of other provitamin A carotenoids.

II. Toxicity of Vitamin A

The exact level of consumption at which individuals exhibit toxicity symptoms is difficult to determine as several factors influence the toxicity threshold. Among these are the size and age of the individual, the duration of consumption, and the quantity and form of vitamin A consumed (Greger 1987). However, average toxicity levels have been established. Vitamin A toxicity in humans is categorized as acute, chronic, or teratogenic. Acute toxicity occurs within hours or at most one or two days after a sufficiently

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high dose (Hathcock et al. 1990). The toxicity threshold for acute toxicity is a single dose of >94,286 IU² for infants, >330,000 IU for children³, and >660,000 IU for adults (Olson 1996). Chronic toxicity, on the other hand, occurs after several weeks, months, or years of consumption of lesser amounts that are not acutely toxic (Hathcock et al. 1990). Chronic toxicity has been reported following the ingestion of vitamin A of at least ten times the USA RDA (recommended daily intake), i.e., 12,500 IU for an infant² and 33,300 IU for an adult, for a prolonged period of time (Olson 1996). Teratogenic toxicity of vitamin A is seen when large amounts of vitamin A are ingested during pregnancy, especially early pregnancy. Short-term exposure to high daily doses of 99,900 to 299,700 IU or long-term daily intakes of more than 25,000 IU have been associated with teratogenic toxicity in humans. The signs and symptoms of acute and chronic vitamin A toxicity, and the results of teratogenic vitamin A toxicity are presented in Table 1. Only chronic and teratogenic toxicities are relevant to the following discussion on toxicity through food fortification.

Table 1. Signs and symptoms of vitamin A toxicity

Acute toxicity		Chronic toxicity		Teratogenic toxicity
<i>Infants/ Children</i>	<i>Adults</i>	<i>Infants/ Children</i>	<i>Adults</i>	
Single dose of >94,286 IU (infants)/ >330,000 IU (children)	Single dose of >660,000 IU	Prolonged intake of \$12,500 IU/day (infants)	Prolonged intake of \$33,300 IU/day	Prolonged intake >25,000 IU/day
>7,543% RDA ^a / >18,013% RDA ^b	>19,820% RDA ^c	>1000% RDA ^a	>1000% RDA ^c	>938% RDA ^d
Loss of appetite Bulging fontanelles Drowsiness Increased intracranial pressure Irritability Vomiting	Abdominal pain Loss of appetite Blurred vision Drowsiness Headache Hypercalcemia Irritability Muscle weakness Nausea, vomiting Skin abnormalities	Loss of hair Loss of appetite Bone pain and tenderness Bulging fontanelles Hyperostosis Photophobia Skin abnormalities Hepatomegaly	Loss of hair Loss of appetite Anemia Bone abnormalities Hyperostosis Brittle nails Skin abnormalities Facial dermatitis Liver malfunction Neural abnormalities Muscle stiffness, pain Weight loss, fatigue Dryness of mucous membranes Nausea, vomiting Loss of sleep Diarrhea	Spontaneous abortions Birth defects: Microcephaly Microtia Harelip Congenital heart disease Kidney defects Neural defects Thymic defects

^a Based on USA RDA of 1,250 IU for infants

^b Based on an average USA RDA of 1,832 IU for children 1–10 years old

^c Based on USA RDA of 3,330 IU for male adults

^d Based on USA RDA of 2,664 IU for female adults, including pregnant women

Adapted from Hathcock et al. 1990 and Olson 1996

Reported cases of chronic, low-dose vitamin A toxicity

Most reports of vitamin A toxicity involve the consumption of supplements. The few reports of vitamin A toxicity through foods have occurred following the consumption of liver and liver products (Greger 1987) that contain a large concentration of vitamin A. Chronic vitamin A intoxication was reported in infants fed chicken liver homogenate containing 36,000 IU of vitamin A daily for four months (Mahoney et al. 1980). In children under five years old, most reports of toxicity involve very high intakes in the hundreds

² 1 µg retinol equivalent (RE) = 3.33 international units (IU)

³ The American Academy of Pediatrics established a single dose of 3,330–6,600 IU/Kg body weight as the threshold for acute toxicity and an intake of 19,980 IU/day for 1–2 months as the threshold for chronic toxicity in infants and children (Pediatric Nutrition Handbook 1998).

of thousands of IU/day, although some cases of chronic vitamin A toxicity have been reported in doses ranging from 1,700 to 6,300 IU/day of total vitamin A intake. Among adults, reported cases of chronic, low-dose vitamin A toxicity range from doses as low as 10,000 to 50,000 IU/day of total vitamin A intake. However, other conditions such as liver disease, wasting, protein-energy malnutrition, use of tetracycline (used in the treatment of acne), and alcohol abuse may have contributed to some of these cases. It should also be noted that most of these reports do not provide an estimate of supplemental versus dietary vitamin A intake (Hathcock et al. 1990).

Given that most reports of adverse effects are associated with intakes above 25,000 IU/d and the lack of evidence of adverse effects with an intake of 21,600 IU or less, the Center for Responsible Nutrition, USA, set the lowest observed adverse effect level (LOAEL⁴) at 21,600 IU/day for adults. An intake of 10,000 IU/day is considered safe for adults, including pregnant women, and is set as the no observed adverse effect level (NOAEL⁵) (CRN 1997).

III. Food Fortification with Vitamin A

Foods fortified with vitamin A include milk (liquid or dried forms), cooking oils and fats, and sugar, and to a lesser extent, wheat and corn flours. In developed countries, several other foods, such as breakfast cereals and energy/nutrient bars, may also be fortified with micronutrients, including vitamin A. Table 2 lists various foods and the levels of fortification with vitamin A, either alone or in combination with other micronutrients, in both developed and developing countries.

Table 2. Vitamin A fortified staple foods and fortification levels around the world^a

Country	Food vehicle	Level of vitamin A fortification (IU ^b /kg)	Other nutrients added
AFRICA			
Kenya	Maize meal product	2,165	Iron
	Oil and margarine	XX ^c	None
Malawi	Oil	XX	None
Namibia	Maize meal	4,718	Thiamin, riboflavin, iron, niacin, pyridoxine, folate
South Africa	Maize meal	4,246	Thiamin, riboflavin, niacin
	Margarine	20,000–40,000	Vitamin D
	Margarine	33,000	Riboflavin, pyridoxine, folate, and niacin
	Bread	3,130	Thiamin, riboflavin, iron, niacin, pyridoxine, folate
Zambia	Sugar	≥33,300	None
	Maize meal (proposed legislation for voluntary)	7,076	Thiamin, riboflavin, iron, niacin, pyridoxine, folate
Zimbabwe	Maize meal	7,076	Thiamin, riboflavin, iron, niacin, pyridoxine, folate
	Bread	3,596	Thiamin, riboflavin, iron, niacin, pyridoxine, folate
	Margarine	27,000–33,000	Vitamin D
ASIA AND THE NEAR EAST			
India	Vanaspati spread	≥25,000	None
	Margarine	≥30,000	None
Indonesia	Margarine	25,000–30,000	Vitamin D

⁴ The LOAEL is the lowest intake at which some adverse effects have occurred under certain circumstances (CRN 1997).

⁵ The NOAEL is the intake level at which there are no credibly substantiated adverse reactions observed in humans (CRN 1997).

Malaysia	Table margarine	25,000–30,000	Vitamin D
	Condensed, filled, or evaporated milks	≥6,700	None
Pakistan	Ghee (butter oil)	33,000	None
Philippines	Margarine	117,000	Vitamin D
	Orange drink	62,500	Riboflavin, folate
	Wheat flour	16,170	Thiamin, riboflavin, niacin, iron
	Edible oil	XX	None
	Filled, evaporated, or condensed milks	4,866	Vitamin D
Saudi Arabia	Enriched wheat flour	551.2	Thiamin, riboflavin, niacin, vitamin D, magnesium
Singapore	Margarine and table margarine	≥28,300	Vitamin D
Taiwan	Table margarine	≥45,000	None
Thailand	Noodle seasoning	889 IU/serving	Iron, iodine
Turkey	Margarine	20,000	Vitamin D
LATIN AMERICA AND CARIBBEAN			
Argentina	Liquid & dried milks (whole and skim)	2,500 IU/L	Vitamin D
Barbados	Wheat flour	2,340	Thiamin, riboflavin, niacin, iron
Brazil	Dry skim milk for complementary feeding	15,000–25,000	Vitamin D
	Margarine	15,000–50,000	Vitamin D
Chile	Margarine	30,000	Vitamin D
Colombia	Margarine	3,180–7,950	Vitamin D
Costa Rica	Sugar	50,000	None
Ecuador	Margarine	20,000–30,000	Vitamin D
El Salvador	Margarine	15,000	None
	Sugar	50,000 ^d	None
Guatemala	Skim and whole milks	2,000–3,000 IU/L	Vitamin D
	Margarine	15,000–50,000	None
	Sugar	50,000 ^d	None
Honduras	Milk	2,000 IU/L	Vitamin D
	Margarine	35,000	Vitamin D
	Sugar	50,000 ^d	None
Mexico	Low fat milks	4,000 IU/L	Vitamin D
	Evaporated whole milk	4,000 IU/L	Vitamin D
	Margarine/spreads	20,000	Vitamin D
Nicaragua	Milk	XX	None
	Sugar	50,000 ^d	None
Panama	Margarine	20,000	Vitamin D
	Sugar	50,000	None
Peru	Margarine	30,000	Vitamin D
Venezuela	Dry milk powder	4,000 IU/L	Vitamin D
	Precooked corn flour	9,500	Thiamin, riboflavin, niacin, iron

NORTH AMERICA			
Canada	Margarine	≥33,000	Vitamin D; addition of vitamin E is optional
	Food aid canola oil	22.5 mg/g	
USA	Margarine	33,000	Vitamin D
	Fortified nonfat dry milk	2,115	Vitamin D
	Evaporated skim milk	4,225	Vitamin D
	Evaporated milk	4225/L	Vitamin D at 845 IU/L is mandatory
	Whole milk	2,115	Vitamin D
	Dry whole milk	2,115	Vitamin D
	Breakfast cereals	800–2,660 IU/serving (30–100% USRDA)	Several other micronutrients
	Title II wheat flour	22,000–26,400	Thiamin, riboflavin, niacin, iron, calcium
EUROPE			
Belgium	Margarine	22,500–27,000	Vitamin D
Denmark	Margarine	25,200	None
Netherlands	Margarine	≥20,000	Vitamin D
Portugal	Margarine	18,000	None
Sweden	Margarine	≥30,000	Vitamin D
	Low-fat milk	1,500	
	Food aid canola oil	15 mg/g	
UK	Margarine	24,000–30,000	Vitamin D

^a Products in bold are fortified under mandatory fortification laws; all other products are fortified on a voluntary basis

^b 3.33 IU are equal to 1 µg retinol or 1 retinol equivalent (RE)

^c XX denotes that the level of fortification is not known

^d Level of vitamin A required to be present in sugar at the production plant

IV. Contribution of Fortified Foods to Vitamin A Requirements

The levels of vitamin A fortification in staple foods should be based on the consumption patterns of the food, the deficit in micronutrient requirements, and the expected contribution of the fortified food to the micronutrient needs of different segments of the at-risk population. The recommended intakes of vitamin A set by different organizations are presented in Table 3. The contribution of fortified foods to vitamin A requirements of the population group that is most at risk for vitamin A deficiency, i.e., preschool children, may be estimated as follows. At the levels of fortification currently practiced across the world (Table 2),

- a daily consumption of 20 g of oil or margarine will provide 30–75 percent of the USA RDA for children 1–3 years old (400 RE or 1,332 IU/day) and 24–60 percent of the USA RDA for children 4–6 years old (500 RE or 1,665 IU/day);
- a daily consumption of 20 g of sugar will provide 50–75 percent and 40–60 percent of the USA RDA for children 1–3 and 4–6 years old, respectively;
- a daily consumption of 200 mL of milk will provide 30–60 percent and 24–48 percent of the USA RDA for children 1–3 and 4–6 years old, respectively; and
- a daily consumption of 150 g of cereal flour will provide 79–101 percent and 63–81 percent of the USA RDA for children 1–3 and 4–6 years old, respectively.

Table 3. Recommended intakes for vitamin A for different age groups (RE/day)

Age group	FAO/WHO		European Community			USA RDA
	Basal	Safe	Lowest Threshold	Average Requirement	Population Reference	
Infants 0–0.5 y old	180	350				375
Infants 0.5–1.0 y old	180	350			350	375
Children 1–10 y old	200–250	400			400–500	400–700
Males 10–14/15 y old	300–350	500–600			600	1,000
Males 14/15–70+ y old	300–400	600	300	500	700	1,000
Females 10–14/15 y old	270–330	500			600	800
Females 14/15–70+ y old	270	500	250	400	600	800
Pregnancy	+100	+100			+100	+0
Lactation 0–0.5 y	+180	+350			+350	+500
Lactation >0.5 y	+180	+350			+350	+400

Taken from Olson 1996

V. Toxicity Thresholds of Fortified Foods

An estimate of toxicity thresholds for foods fortified at different levels of vitamin A is presented in Table 4 using the NOAEL figure of 10,000 IU/day and the LOAEL figure of 21,600 IU/day and the levels of fortification currently practiced (Table 2). For example, one would have to consume daily 200 g (40 teaspoons) or 432 g (86 teaspoons) of sugar fortified with 50,000 IU/kg of vitamin A to reach the NOAEL or LOAEL levels, respectively. Similarly, the consumption of 286 g (57 teaspoons) or 617 g (123 teaspoons) of margarine fortified with 35,000 IU/kg of vitamin A will reach the NOAEL or LOAEL levels, respectively. It is difficult, if not practically impossible, to reach these consumption levels from single foods fortified at the current levels.

At currently practiced levels of vitamin A fortification, enormously high and practically impossible amounts of fortified foods would have to be consumed daily to reach the toxicity threshold for humans. Therefore, vitamin A toxicity from fortified foods is highly unlikely.

Table 4. Levels of consumption of individual fortified foods needed to reach the NOAEL and LOAEL levels for vitamin A

Food vehicle	Fortification level (IU/kg)	Daily consumption (in grams) needed to reach	
		NOAEL (10,000 IU/d)	LOAEL (21,600 IU/d)
Sugar	33,000	303	655
	40,000	250	540
	50,000	200	432
Oil/Margarine	20,000	500	1,080
	35,000	286	617
	50,000	200	432
Milk	2,000 IU/L	5,000 mL	10,800 mL
	3,000 IU/L	3,333 mL	7,199 mL
	4,000 IU/L	2,500 mL	5,400 mL
Wheat/maize flours	7,000	1,429	3,087
	8,000	1,250	2,700
	9,000	1,111	2,400

Multiple foods fortified with vitamin A

It should be noted, however, that when more than one food is fortified in the country, the levels of daily consumption needed to reach the toxicity thresholds are lower than those presented in Table 4. For example, if both sugar fortified at 40,000 IU/kg and margarine fortified at 35,000 IU/kg are available in a country, the total consumption of both products together at 133 g will reach the NOAEL level and at 288 g will reach the LOAEL level—levels that are unlikely to be consumed on a daily or regular basis for a prolonged period of time. The following scenarios may be also used to show the safety of vitamin A fortified foods:

Scenario 1. Two fortified foods—margarine at 35,000 IU/kg and milk at 3,000 IU/L—are available in a country:

- A daily consumption of 20 g of margarine and 200 mL of milk will provide a total of 1,300 IU of vitamin A.
- To reach the NOAEL level of 10,000 IU/d, a daily consumption of 200 g of margarine plus 1,000 mL of milk, 115 g of margarine plus 2,000 mL of milk, or other such combinations of high intakes are needed. Even higher intakes will be needed to reach the LOAEL level of 21,600 IU/d.

Scenario 2. Three fortified foods—sugar at 40,000 IU/kg, margarine at 35,000 IU/kg, and milk at 3,000 IU/L:

- A daily consumption of 30 g of sugar, 20 g of margarine, and 200 mL of milk will provide a total of 2,500 IU of vitamin A.
- To reach the NOAEL level of 10,000 IU/d, a daily consumption of 100 g of sugar, plus 100 g of margarine plus 830 mL of milk, 75 g of sugar plus 72 g of margarine plus 1,500 mL of milk, or other such combinations of high intakes are needed. Even higher intakes will be needed to reach the LOAEL level of 21,600 IU/d.

Vitamin A losses during storage and distribution vary from about 5 percent up to 50 percent depending the food item, time of storage, and exposure to light, temperature, and humidity conditions. When these losses are taken into account, the amounts of fortified foods that will have to be consumed to reach the NOAEL or LOAEL levels will be higher than those presented above or estimated in Table 4.

However, in theory, the potential risk of toxicity may rise as an increasing number of foods are fortified with vitamin A. This may be especially true when the food vehicles are staples and the levels of fortification are high enough to cumulatively provide, at average levels of consumption, more than 100 percent of the vitamin A requirement in pregnant women, the population group most likely to have disastrous effects from vitamin A toxicity.

Several countries fortify multiple foods with the same nutrient because a single food vehicle may neither reach all of the at-risk population groups nor provide sufficient vitamin A to meet the vitamin A requirements of the at-risk population groups. Thus, more than one food has been fortified with vitamin A in both developed and developing countries. However, given the potential risk of chronic toxicity of vitamin A at low doses taken over a long period of time, it is important to have clear regulations and standards and strict monitoring and quality assurance/control measures in place.

Vitamin A fortification levels in currently fortified foods may need to be adjusted as more foods are fortified with vitamin A. Where there is only one food to be fortified, nutrient levels tend to be set at high enough levels to meet the consumption gap; as more foods are fortified, these levels should be revised.

In most developed countries, food regulations and standards specify foods to be fortified (mandatory or optional), levels of fortification, guidelines for labeling, monitoring mechanisms, and actions and penalties for noncompliance. These standards are strictly adhered to by manufacturers and enforced by the government. However, in developing countries, a lack of resources, infrastructure, responsible government agency, and other constraints may prevent the development and implementation of such a strong and effective monitoring system. In such cases, it becomes critical to objectively evaluate any national fortification program to determine its need and expected benefits and to minimize risks of toxicity from the point of inception itself.

VI. Successful Vitamin A Interventions

Additional information on the history and successful vitamin A fortification interventions is presented in the Roche/USAID publication series, *Fortification Basics*, available through the MOST Web site at www.mostproject.org.

Oils and margarine

A successful intervention with vitamin A fortified margarine (45 IU vitamin A/g margarine) initiated in Newfoundland in 1944–45 led to a marked improvement in vitamin A status, as indicated by serum retinol levels in a sample of the population (Aykroyd et al. 1949). Observations on the curative effects of milk fat, but not of margarine (Bloch 1931), eventually led to the enrichment of margarine with vitamin A in Denmark.

Sugar

In the 1970s, Guatemala, one of the first countries to implement a national sugar fortification program, reported the effectiveness of the program in decreasing low serum retinol levels indicative of vitamin A deficiency in children and in human milk (Arroyave et al. 1979). Fortified foods continue to make an important contribution to vitamin A intake among poor urban Guatemalan toddlers; about 55 percent of their total vitamin A intake from non-breast milk food sources was derived from three fortified foods: sugar, Incaparina (a fortified cereal flour product), and margarine (Krause et al. 1998). An evaluation of the national sugar fortification program initiated in 1987 in Honduras revealed that 14 percent of children had serum retinol levels $<20 \mu\text{g/dL}$ in 1996 compared with 18 percent in 1987 and 40 percent in 1965. At the household level, 82 percent of sugar that was tested contained vitamin A compared to 23 percent in 1995 and 12 percent in 1994 (Chinchilla et al. 1997; Mora et al. 2000). In Costa Rica, fortification of sugar was practiced from 1977 to 1981. The prevalence of vitamin A deficiency in children dropped from 33 percent in 1965 to 2 percent in 1980 and rose to 9 percent in 1996, leading to a renewed interest to resume sugar fortification in the country (Mora et al. 2000).

Cereal flours

Precooked maize flour, in which flour is steamed and then dried, is used to make *arepa*, a staple food in the Venezuelan diet. Vitamin A fortification of this flour, consumed at 89 g/day, increased its contribution to vitamin A requirements from 0 percent to 33 percent of the RDA (Chavez 1998).

Other foods

A Swedish multicenter study, 1980–81, on food habits and nutrient intake in children 1–15 years old revealed that enrichment of low-fat milk and margarine, along with the relatively frequent consumption of liver and liver pâté, contributed to a mean vitamin A intake of 3,000 to 6,000 IU/day among this population (Hagman et al. 1986).

VII. Case Study of Vitamin A Fortification in the United States

A case study of vitamin A fortification in the United States, a country with a long history of vitamin A fortification, is discussed below to highlight the contribution of food fortification to the vitamin A requirements of the population as well as the importance of a sound fortification policy.

History and current practices

Fortification in the US began in the early 1900s. The first public health measure using fortification appears to have been the inauguration of iodized salt in Michigan in 1922 (Mertz 1997; Subar and Bowering 1988). Fortification of milk with vitamin D started in 1932, immediately after the structure of vitamin D₂ was determined, while the fortification of flour with B-vitamins and iron was initiated in November 1940 (Mertz 1997; Subar and Bowering 1988).

Vitamin A fortification of margarine, using concentrated fish oils, was reported to be practiced before the structure of vitamin A was determined (Williams 1956). The Food and Drug Administration (FDA) of the US Department of Health and Human Services is the agency that regulates the food supply in the country. The FDA set forth standards of identity for foods, including certain milk products, salt, margarine, and certain cereal products, stating that these foods must have nutrients added in accordance with the standards. The standards of identity for margarine call for mandatory fortification with 15,000 IU/lb (33,000 IU/kg) of vitamin A, and about two-thirds of this amount is reportedly added as β -carotene to impart a butter-like color to the product (Mertz 1997). Certain milk forms, including fortified nonfat dry milk and evaporated milks, also have standards of identity mandating the addition of a minimum level of 2,115 IU/L of vitamin A in fortified nonfat dry milk and 4,225 IU/L of vitamin A in evaporated skim milk.

Several other foods, including breakfast cereals, juices, drinks, certain frozen cereal products, and meal replacement beverages, do not have standards of identity and are fortified without specific regulation (Subar and Bowering 1988), other than to meet food labeling and any health claim requirements. Of these, breakfast cereals are of particular relevance to this discussion because they make a significant contribution to the overall micronutrient intake among children and adults due to the high levels of fortification and frequency of consumption. Breakfast cereals are fortified with several micronutrients, including vitamin A at levels ranging from 30 to 100 percent of the USRDA, i.e., 800 to 2,660 IU/serving size of one cup (30–59g).

Contribution of fortified foods to vitamin A intake

National surveys, the 1976–80 National Health and Nutrition Examination Surveys II and the 1977–78 National Household Food Consumption Survey, showed that the average vitamin A intake through dietary sources reached approximately 90 percent of the RDA among adults (DHHS 1983; Pao and Mickle 1981). The NHANES III, Phase 1, 1988–91 survey showed that 24-hour dietary intake of vitamin A was 922 RE (246 percent of the USA RDA) among infants 2–11 months old, 687–878 RE (125–172 percent RDA) among children 1–11 years old, 959–1,322 RE (96–132 percent RDA) among adult males, and 786–1,155 RE (98–144 percent RDA) among adult females of the US population (Alaimo et al. 1994).

The Continuing Surveys of Food Intakes by Individuals (CSFII) of 1989–91, the most recent data available on dietary sources of vitamin A among different age groups, showed that ready-to-eat cereal is the top contributor, providing 22 percent of total vitamin A intake in children 2–18 years old, followed by milk (20 percent), carrots (16 percent), and margarine (8 percent) (Subar et al. 1998a). The study, however, did not report the total amount of vitamin A consumed by children. The same survey also showed similar trends in the contribution of different dietary sources to vitamin A intake in adults; ready-to-eat cereals, primarily because of fortification, were among the top food sources of several micronutrients, including vitamin A (Subar et al. 1998b).

Another study among affluent, suburban women, 25–49 years old, in New York reported that mean vitamin A intakes exceeded 120 percent of the RDA. However, fortified foods were not the top contributors to vitamin A intake in this population. Fortified dairy products and margarine provided 6 percent and fortified breakfast cereals provided 6 percent, while non-fortified food sources provided the bulk (88 percent) of the vitamin A consumed (Subar and Bowering 1988).

Thus, fortified foods, particularly breakfast cereals, appear to be important sources of vitamin A in the US diet. Similar findings have been reported in other developed countries. Fortified breakfast cereals were associated with higher intakes of β -carotene and higher serum retinol levels among schoolchildren in Spain (Ortega et al. 1995) and with higher daily intake of vitamin A among schoolchildren in Northern Ireland (McNulty et al. 1996).

Enriched grains and grain products, including enriched cereal flours, are required by law in the US to be fortified with 94.6 to 308 $\mu\text{g}/100\text{g}$ of folic acid to improve the intake of folate among women of reproductive age and, consequently, decrease the risk of fetal neural tube defects. To avoid the risk of teratogenic vitamin A toxicity through the consumption of these foods, the FDA has also mandated that products carrying a folate health claim must not contain more than 8,000 IU/serving of vitamin A, a daily consumption level considered safe among all adult women, including pregnant women (US Code of Federal Regulations, 21 CFR 101.79). Such a careful examination of a fortification program is needed to realize the benefits of the program without potentially harmful public health effects.

To avoid the risk of teratogenic vitamin A toxicity, the FDA mandated that foods carrying a folate health claim must not contain more than 8,000 IU/serving of vitamin A, a total daily consumption level considered safe among pregnant women.

Nevertheless, current fortification practices in the US food supply have been criticized and fortification policies questioned (Mertz 1997). The need for the vast number of fortified foods in the US market has been questioned given the abundant supply of natural dietary sources of vitamin A as well as the wide consumption and growing popularity of micronutrient supplements. The NHANES III revealed that about 40 percent of the US population consumes dietary supplements (Ervin et al. 1999). Other surveys have shown that 35–50 percent of adults in the US regularly consume micronutrient supplements (McDonald 1986; Moss et al. 1989) and the median vitamin A intake from supplements is greater than the RDA (Gray et al. 1983; Shank and Wilkening 1986). The dependence on fortified foods and supplements is not consistent with the dietary guidelines set by the Food and Nutrition Board, and educational efforts should emphasize the importance of meeting daily nutrient requirements through natural dietary sources (Hathcock et al. 1990; Subar et al. 1998). A thorough examination of the present fortification policy was recommended because current fortification practices seem to have deviated from the criteria⁶ for fortification set forth by the Food and Nutrition Board in 1974 (Mertz 1997). An excessive intake of some nutrients is unnecessary, although harmless, while an excessive intake of other nutrients, such as vitamin A, can be potentially toxic. However, it should be noted that to date there are no reports of vitamin A toxicity through fortified foods.

VIII. Conclusions

Vitamin A is essential for child health and survival and performs important functions throughout the life cycle. Vitamin A deficiency is a significant public health problem that afflicts millions of children in the developing world. Vitamin A consumed in excessive amounts is toxic; the effects of vitamin A toxicity are adverse and, in severe cases, irreversible. Fortification of foods with vitamin A is a safe, effective, and relatively inexpensive intervention that is practiced in both developed and developing countries. Foods fortified with vitamin A include cooking oils, margarine, sugar, milk and certain milk products, and, in developed countries, ready-to-eat breakfast cereals. At the currently practiced levels of fortification,

⁶ The six general criteria mentioned in the 1974 Proposed Fortification Policy for Cereal Grain Products as conditions to be met for the Food and Nutrition Board to endorse fortification include 1. The intake of the nutrient is below the desirable level in the diets of a significant number of people; 2. The food used to supply the nutrient is likely to be consumed in quantities that will make a significant contribution to the diet of the population in need; 3. The addition of the nutrient is not likely to create an imbalance of essential nutrients; 4. The nutrient added is stable under proper conditions of storage and use; 5. The nutrient is physiologically available from the food; and 6. There is reasonable insurance against excessive intake to a level of toxicity (Mertz 1997).

enormously high and practically impossible amounts of these foods would have to be consumed daily to reach the vitamin A toxicity threshold for humans. Indeed, even in developed countries where more than one food is fortified with vitamin A, there have been no reports of vitamin A toxicity attributed to the intake of fortified foods. Several factors that need to be considered to minimize the risk for excessive intake of vitamin A through fortified foods include the following:

- Careful planning and designing of a food fortification program, with special attention to the levels of vitamin A to be added to a particular food vehicle and the need for legislation and regulations;
- Effective implementation of a fortification program with proper training and regular monitoring to ensure that the specified levels of vitamin A are added;
- Fortification of multiple staple foods with vitamin A should be undertaken only when the need for such a program is clearly established. The levels of vitamin A added to each of the staple foods must be determined based on the geographic reach and consumption of each potential food vehicle among different age groups, the extent and severity of vitamin A deficiency, the gaps in vitamin A requirements, and the estimated contribution of the food vehicles to vitamin A intake among these populations; and
- Due consideration should be given to other interventions, including supplementation, to establish a fortification program that is complementary to ongoing public health measures.

Food fortification with vitamin A based on sound principles and supported by clear policies and regulations is a safe and effective tool to deal with vitamin A deficiency.

IX. References

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