ABSTRACT In developed countries, food fortification has proven an effective and low-cost way to increase the micronutrient supply and reduce the consequences of micronutrient deficiencies. It has been rarely used in the developing world, but general conclusions can be drawn. The biological efficacy, but not the effectiveness, of fortifying oil and hydrogenated oil products as well as cereal flours and meals with vitamin A has been shown. Sugar has been fortified with vitamin A in Central American countries for years, and biological efficacy and program effectiveness are well established. Efficacy of fortifying monosodium glutamate with vitamin A was demonstrated but a program has not been established. Fortification with vitamin A in the developing world should satisfy certain elements for success. a) A potential food matrix (a food regularly consumed, produced by a few centralized factories, without sensorial changes compared with the nonfortified equivalent, and nutrient remains bioavailable and in a sufficient amount) is required. b) Fortified foods should provide at least 15% of the recommended daily intakes for the target group (e.g., individuals consuming the lowest amount of the fortified food). c) Voluntary fortification of processed foods should be regulated to prevent excessive consumption of vitamin A. d) Neighboring countries should harmonize technical standards, facilitate compliance and minimize conflicts over global trade laws. e) A practical monitoring system should be instituted. f) Social marketing activities should be permanent and aimed at industry, government and consumers. g) Food fortification should be combined with other strategies (e.g., supplementation) to reach those not adequately covered by fortification alone. Infants and small children, whose dietary habits differ from those of adults, require special attention. Fortification of food commodities is a very attractive and economic way to prevent and control vitamin A deficiency. Effective food fortification might make supplementation of postpartum women and older children unnecessary.

KEY WORDS: • food fortification • vitamin A • micronutrients • developing countries

Vitamin A deficiency (VAD) in the developing world is not restricted to preschool-aged children. It affects pregnant and lactating women and sometimes school-aged children and adolescents. Ideally, women of childbearing age should begin pregnancy with good vitamin A status, because it is difficult to entirely correct a deficiency with prenatal supplementation. The Food and Nutrition Board of the United States recommends avoiding supplementation with preformed vitamin A during the first trimester of pregnancy unless there is specific evidence of VAD. The World Health Organization advises that supplements during pregnancy not exceed 10,000 international units (IU) of vitamin A [3000 μg of retinol equivalents (RE)] per day or 25,000 IU (7500 RE) per week (2).

Alternative strategies that frequently supply small but effective amounts of vitamin A [e.g., one third of the recommended daily intake (RDI)] over a prolonged time would be helpful. A diverse diet, which includes foods of animal origin that are rich in preformed vitamin A (esters of retinol), might be sufficient to satisfy the daily requirements of vitamin A. However, in most developing countries, diets are monotonous and mainly based on cereals and legumes that are poor sources of vitamin A. Even carotenoid-rich vegetables have low vitamin A bioavailability and bioefficacy (3). Given these issues, food fortification with vitamin A can be an attractive and potentially effective and important intervention.
History

Food fortification has been used successfully in the developed world for >80 y. Reduction of goiter, rickets, ariboflavinosis and pellagra in the United States is attributed to the consumption of foods fortified with iodine, vitamin D, vitamin B-2 and niacin, respectively (3,4). Food fortification has proven sustainable because of a) the presence of large, centralized food industries, b) packing and labeling that facilitate monitoring and enforcement and c) well-educated consumers who are aware of the value of adequate nutrition and have sufficient income to purchase the products (4).

These conditions are less common in the developing world, where food fortification has been infrequent or has ended after successful pilot trials. The potential of food fortification to reduce micronutrient deficiencies in developing countries was recognized >30 y ago (5,6). Levinson (5) suggested considering unconventional carriers such as salt, sugar, seasonings and cooking oil, because the poorer segments of the population do not have access to other centrally processed foods, because they are sensitive to higher-priced fortified products, and because they have low purchasing power.

Experiences with vitamin A fortification

Fortifying a widely consumed centrally processed food or condiment capitalizes on the production and distribution system of the food market to deliver low doses of vitamin A daily to a large number of people. Food fortification has many advantages: it is generally socially acceptable, it requires minimal changes in food habits, it usually costs <2% of the cost of the unfortified food, its delivery system is already in place and it can become sustainable. Several publications have summarized these experiences with food fortification in the developing world (6–8).

Oil

Oil is an ideal matrix for vitamin A, which is fat soluble. The methods for fortifying vegetable oil are well established, fairly simple and easy to implement at low cost. Furthermore, oil stabilizes retinol and delays oxidation of the vitamin. The vitamin A type is retinol acetate or retinol palmitate in oil base (9). It has been recommended that at least 18 mg of vitamin A be added per kilogram of vegetable oil from the U.S. Title II Food Aid Program (U.S.PL480), providing about 50% of the RDI with an average daily ration of 16 g per person (10). The cost of fortification is about $2.00 per metric ton (MT) of oil (9), 0.3–0.4% of the purchase cost, or US$0.012 per person/y.

In Brazil, vitamin A added to oil was well absorbed when given along with a rice-based diet, and it significantly increased plasma retinol and liver stores (11). Despite the potential advantages of fortifying oil with vitamin A, it has rarely been done for unknown reasons.

Margarine

After oil, margarine and other hydrogenated oil products are the most suitable vehicles for vitamin A. In fact, vitamin A is added to margarine in many countries to imitate the nutritional value of butter, which margarine has often replaced. Vitamin A fortification of margarine was initiated in Denmark in the 1920s, when cases of nutritional blindness appeared after butter was replaced with nonfortified margarine (12).

Several countries fortify margarine at levels ranging from 1 to 15 mg/kg as either a mandatory or a voluntary practice (9). This provides 2–40% of the RDI, assuming a daily consumption of 15 g. The cost is similar to that of oil fortification. In the Philippines, an intentional fortification program prompted by public health interest has proven to be very efficacious. Star margarine, a product that does not require refrigeration and is made from a blend of coconut oil and hardened palm oil, is fortified with vitamin A to a level of 25 mg/kg (plus 3.5 mg/kg from β-carotene). A field efficacy trial indicated that daily consumption of 24 g of this product, supplying 150% of the RDI for preschoolers and 100% for adolescents and adults, decreased the prevalence of low serum retinol (<0.70 μmol/L) in preschool-aged children from 23.7 to 10.1% after 6 mo of consumption. The product is now offered in the free market along with competing brands (13). In India, a fortified hydrogenated oil, Vanaspati, has been available since 1953. Vanaspati is replacing ghee, or clarified butter, as the traditional oil. It is fortified with vitamin A at a level of 7.5 mg/kg and supplies 0.4–21% of the RDI depending on consumption levels (0.3–17 g/d) (14).

Cereal flours and meals

Fortification of cereal flours and meals with vitamin A is technically feasible, and nutrient stability in the products is good. There is often no need for changes in flour manufacturing, because cereal flour production usually incorporates enzymes, oxidants and other substances. Venezuela has had a national program fortifying precooked corn flour since 1993. The flour is fortified with vitamin A at 2.7 mg/kg (15), which contributes ~30% of the vitamin A RDI assuming a consumption of 80 g/d and 15% losses of the vitamin A during handling and storage of the flour, as well as food preparation. Biological evidence of the impact has not been published. The vitamin A compound used in corn flour fortification is a spray dry product (Roche, SD-250) that is water dispersible. The current cost of fortification is about US$1.40/MT, which is about 0.35% of the purchase price of flour, or a total of US$0.040/y per person.

In the Philippines, wheat flour used in making the popular bread pandesal is fortified with vitamin A (4.5 mg/kg) to produce a pandesal fortified at 2.8 mg/kg (16). Daily consumption of 40 g of bread provides about 19% of the vitamin A RDI. Again, the vitamin A compound added is SD-250. Biological evidence of the impact was demonstrated by a significant increase in vitamin A liver stores of school children. The current cost of fortification is about US$2.75/MT, or US$0.040/y per person.

Other countries have carried out pilot studies to explore fortification of cereal flour or meal with vitamin A, but national programs are not in place. Wheat flour has been fortified with iron and B vitamins in the United States and other developed countries for >40 y (3,4). The U.S. Title II Food Aid Program (U.S.PL480) has been fortifying wheat flour with vitamin A (SD-250) since 1969 (17). The fortification level has been established at between 6.6 and 7.9 mg/kg to provide 80–100% of the RDI for consumption of 75 g/d and to ensure that the practice remains safe for people with higher consumption (17).

However, vitamin A losses due to shipping and storage and during food preparation have not been considered. Losses have been estimated at 30–50%, which are within the normal range of stability for vitamin A in dry fortified products (18). This means that people who consume the products receive 40–70% of the RDA of vitamin A. In 1993 it was estimated that adding vitamin A at the indicated level in wheat flour would cost...
US$3.79/MT (17), that is US$0.104/y per person with an \( \sim 1\% \) increment in the purchase price.

Sugar

Sugar is a good vehicle for fortification in countries where it is centrally produced in a few plants and is widely consumed by most of the population. Some countries in Central America decided to fortify sugar in the 1970s because other options were inappropriate: salt was consumed in very small amounts and its quality was inadequate; oil/margarine and wheat flour were neither widely distributed nor consumed by the most needy individuals; dairy products were scarce; and corn flour, although widely consumed, was mostly produced at home (19).

The Institute of Nutrition of Central America and Panama developed appropriate technology, promoted legislation, and established national programs in three countries (Guatemala, Honduras and Costa Rica). The vitamin A compound that is being used is a gelatin-base beadlet (Roche, CWS-250; or BASF, CWD-250), which is bound to the sugar crystal through a layer of vegetable oil to avoid segregation (20). To avoid promoting higher sugar consumption because of its fortification, it was initially forbidden to declare that the product contained added vitamin A (19). A carefully designed evaluation in the mid-1970s in Guatemala conclusively demonstrated its effectiveness in reducing VAD (21,22). Nevertheless, the program was halted in 1979 because, although the fortification was mandatory, the industry was not sufficiently motivated and there were also limitations to obtain foreign currency to purchase the fortificant. The program was resurrected in the harvest season of 1987 and has been sustained by full industry commitment.

VAD prevalence rates have been dramatically reduced (23). Today, sugar in households in Guatemala and El Salvador contains an average of 9 mg of vitamin A per kilogram, which contributes 45–180% of the vitamin A RDI for people older than 3 y of age (per capita sugar consumption ranges from 30 to 120 g/d). Sugar is now the main source of vitamin A even for infants and young children; it supplies \( \sim 30\% \) of the RDI. Prophylactic supplementation with vitamin A to children younger than 3 y of age has been maintained to ensure adequate intake (data published in national reports). Sugar is fortified at the sugar mills at a theoretical level of 15 mg/kg, but the content is near 9 mg/kg after preconsumption losses at the household level. After 9 mo of shipping and storage, 40–70% of the vitamin A is estimated to remain in sugar, depending on the climatic conditions. The cost of fortification to the industry amounts to $9.18 per MT (24), which is about US$0.20/y per person and represents about 2% of the retail price of sugar. In the Central American countries, the actual cost per person is higher (US$0.32) because all sugar, regardless of its final use (domestic or industrial), is fortified to ensure that most of the population will receive the fortified product.

Monosodium glutamate

Technological experiments and field trials were carried out several years ago to make monosodium glutamate (MSG) a source of vitamin A. Despite successful biological impact (25,26), MSG fortification did not become a national program.

The efficacy of MSG fortified with vitamin A was demonstrated in the Philippines (25) and Indonesia (26). In the former, the fortification level was 2047 mg/kg to supply all the RDI required by MSG consumers. To avoid raising the purchasing price, the contents of the sachets were reduced from 2.4 to 2 g (reducing the amount of MSG by 17%). People recognized the lower than usual MSG amount and preferred the nonfortified product. The use of vitamin A as SD-250 caused discoloration (vitamin A is yellowish; MSG is white) and it separated from the MSG crystals. This was not a serious problem with small sachets, but it was unacceptable in large packs. In addition, the finely pulverized MSG intended to preserve the white color interfered with hermetic seals of the sachets.

In Indonesia, some of the technological difficulties were overcome (26). Part of the solution was to reduce the vitamin A level to 810 mg/kg with the aim to provide \( \sim 50\% \) of the RDI. Children consumed 0.24 g/d of MSG and adults consumed 0.4 g/d. At the time of consumption, 57% of the vitamin remained in the product, so the MSG provided only \( \sim 30\% \) of the RDA for vitamin A. MSG was selected because it was centrally processed, it reached the target population and the consumption varied little. Assuming a cost similar to that of sugar, it is estimated that the cost of fortification would be US$575/MT. If the retail price of MSG is US$5/kg, then the increment in the price due to fortification should be 11.5%, which is relatively high to compete against the nonfortified product in the free market. Nevertheless, the current annual cost per person remains relatively low at about US$0.050.

Other foods

Fortification with vitamin A has also been tried with whole-wheat grain, tea, instant noodles, fish sauce, yogurt and salt. Technological and logistical/feasibility issues have prevented large-scale implementation of these efforts. Fortification of rice deserves special attention, considering that it is widely consumed in many developing countries where VAD is highly prevalent. Fortification has been tried by coating (27) or introducing the nutrients into artificial kernels, a technology known as Ultra-Rice (28). Despite extensive trials, unacceptable losses of vitamin A have been reported in the coating system (29), and the Ultra-Rice technology, although biologically efficacious (30), is still too expensive. In practice, the logistical feasibility of safely and effectively fortifying rice produced by thousands of local millers represents a major barrier to fortification programs. Other approaches include fortifying sauces provided with instant noodles, which is gaining widespread support.

Other types of fortified products are complementary foods aimed at infants or school feeding programs. Biscuits and beverages fortified with multiple micronutrients, including vitamin A, are used in school feeding programs in Mexico, Central America, Indonesia and Peru.

A successful product need not be one consumed in large measure by the youngest children. If it is consumed by women, improving their vitamin A status and therefore the vitamin A content of their breast milk, it will play a major role in ensuring improved vitamin A status of young, breast-fed children during the critical first 2 yr of life (31).

Critical elements of successful programs

Mora et al. (24) summarized the lessons learned from sugar fortification programs in Central America. A few critical elements for success in food fortification programs in the developing world have been identified.

Identification of potential vehicles

In addition to the need to document the existence of significant VAD, the challenge is to identify an indigenous
TABLE 1

Estimated fortification levels of vitamin A (mg/kg) at different levels of consumption of fortified food

<table>
<thead>
<tr>
<th>Daily dietary goal</th>
<th>Consumption level of fortified food (g/d)</th>
<th>μg RE</th>
<th>% RDI1</th>
</tr>
</thead>
<tbody>
<tr>
<td>μg vitamin A/kg food</td>
<td>5</td>
<td>15</td>
<td>40</td>
</tr>
</tbody>
</table>
| Level of fortification:  
| 90 | 15 | 18 | 6 | 2.2 |
| | 180 | 30 | 36 | 12 | 4.5 |
| | 360 | 60 | 72 | 24 | 9.0 |

1 RDI for family: 600 μg/d (RDI for 1–10 y old = 400 μg/d). RE, retinol equivalent.

The commodity that is widely consumed in constant amounts, especially by the target population (fertile women and young children); the food must also be produced in a few centralized sites. These conditions explain why staples, salt, sugar and seasonings have been the vehicles of choice in developing countries.

The quantity of food consumed is very important; otherwise the vitamin A concentration may be too high, causing technical and cost problems. In practice, oils, hydrogenated oils, cereal flours and sugar should be fortified at no more than 20 mg/kg. Vitamin A losses during production, storage and handling increase program expense. In addition, a high concentration of vitamin A increases the potential for individuals who consume large amounts of the product to consume too much vitamin A. Table 1 shows the estimated vitamin A levels at different consumption patterns, to meet distinct portions of the RDI. Consumption of 5 g of any food fortified with vitamin A (at a level of 18 mg/kg at the consumer table) would provide 15% of the RDI; 10 g would provide 30%. Therefore, any food consumed in amounts <5 g a day is difficult to be considered as suitable for food fortification.

Vitamin A compounds needed for fortification of dry matrices (e.g., flour and sugar) are at least four times more expensive than the oily forms, and their stability is inferior. Hence, dry foods tend to be fortified with less vitamin A, which requires higher consumption. In summary, vitamin A fortification is reasonable in countries where oil or margarine is consumed in quantities >5 g/d (1.8 kg/y) and flour or sugar is consumed in amounts >15 g/d (6 kg/y).

Despite urbanization trends and the concomitant increase in consumption of commercially processed foods, finding suitable vehicles for fortification in the less-developed countries where VAD is endemic has been difficult.

KEEPING TRACK OF ECONOMIC, MARKET AND TRADE ISSUES

Advocacy for fortification should not be limited to nutrition and public health issues. Proper appreciation needs to address production, market, trade and economic issues that are critical to industry’s commitment to fortification. A large part of industry’s motivation is increased profit and protection from competition. Cooperation between the public sector and industry should be secured through an effective public/private partnership by reconciling the business interests of the industry and the public health concerns of the government.

Table 2 shows that all described programs (oil, margarine, cereal flours, sugar and MSG) are very cost effective. The cost per person per year (supplying at least 30% RDI) ranges from US$0.008 for oils and margarine to US$0.121 in the case of sugar. These data show that food fortification is a cost-effective way to provide vitamin A to the people who need it. Furthermore, the data also suggest that oils are the most suitable candidates for carrying vitamin A, because marginal costs are increased the least. The annual cost to supply the same amount of vitamin A through MSG is similar to that for cereal flours and sugar, but the margin of increase in the product price is very different: 0.26% for flours, 1.39% for sugar and 25.3% for MSG. Therefore, fortification of MSG is very unappealing to producers, because the fortified product cannot compete with the nonfortified one, unless the government mandates fortification by all producers or prices are maintained by subsidies.

Even though the total cost of vitamin A fortification programs might seem low to public health workers, it remains a matter of concern for producers, whose profits will decrease unless they are able to transfer the cost to consumers. In the past, price control policies were an important limitation to introducing food fortification programs in the developing world. Now the main constraint is the possibility of importing and selling nonfortified products at lower prices. Because food fortification may be viewed as a technical non-tariff barrier to trade, developing countries need to enforce their own nutritional standards for commercially processed foods, wherever they come from, based on public health and nutrition needs, just as they do for sanitary standards. To facilitate acceptance of food fortification regulations under the

| TABLE 2 |

Comparative cost of different examples of food fortification with vitamin A to supply 180 μg of retinol equivalent (RE), i.e., 30% recommended daily intake (RDI)

<table>
<thead>
<tr>
<th>Food matrix</th>
<th>Typical consumption g/d</th>
<th>Level at households1 mg/kg</th>
<th>Level at stores2 mg/kg</th>
<th>Overage for production3 %</th>
<th>Cost (US$/MT)</th>
<th>% of Purchasing price</th>
<th>Annual cost per person (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil/margarine</td>
<td>200</td>
<td>12.0</td>
<td>15.0</td>
<td>20</td>
<td>1.87</td>
<td>0.37</td>
<td>0.008</td>
</tr>
<tr>
<td>Cereal flours</td>
<td>50</td>
<td>1.0</td>
<td>1.25</td>
<td>40</td>
<td>1.25</td>
<td>0.26</td>
<td>0.091</td>
</tr>
<tr>
<td>Sugar</td>
<td>200</td>
<td>3.5</td>
<td>4.5</td>
<td>100</td>
<td>6.65</td>
<td>1.39</td>
<td>0.121</td>
</tr>
<tr>
<td>Monosodium glutamate (MSG)</td>
<td>0.25</td>
<td>720.0</td>
<td>900.0</td>
<td>100</td>
<td>1266.00</td>
<td>25.324</td>
<td>0.116</td>
</tr>
</tbody>
</table>

1 Level = dietary goal (μg of RE)/consumption pattern (g/d).
2 Assuming 25% additional amount to compensate for any losses.
3 Theoretical estimate based on reported stability information and length of product marketing life.
4 Assuming that MSG costs US$5/kg.
new conditions of world trade, it is advantageous if neighboring countries agree on the same technical standards.

**Establishing and enforcing regulatory instruments**

The strongest expression of government political commitment is legislative action to make fortification an official program. Legislation is necessary but not sufficient. Often general legislation exists that empowers some government unit to identify foods to be fortified and establish technical specifications (regulations). Standards of identity are required for both mandatory and voluntary fortification. Regulations should define minimum nutrient content at the retail store level and, to the extent possible, require universal coverage. Some countries prefer to establish higher levels of fortification at factories than at retail stores, taking into consideration the expected losses of the nutrient during transportation and storage. However, it is preferable to set levels at retail stores, thus encouraging industry to improve the technology and the handling of the fortified product to meet the requirement at a lower cost. The retail store fortification level would also be used to judge the quality of an imported product.

**QA/QC and monitoring systems**

A functional quality assurance/quality control (QA/QC) and monitoring system, with a clear definition of responsibilities for the industry and the government, is critical for maintaining the quality and coverage of the program. Failure of some fortification programs to become sustainable can be attributed in part to weak industry motivation and government political commitment and law enforcement capacity, which is reflected in inefficient or nonexistent QA/QC and monitoring systems. Although quality assurance of the fortified product is clearly the responsibility of industry, a regular government monitoring system at production plants, retail stores and households is indispensable.

**Documenting program effectiveness for sustained commitment**

Documenting impact and effectiveness is important for maintaining industry’s motivation and government’s political commitment. Programs of demonstrated effectiveness are more likely to get the political support they need.

**Voluntary and consumer-driven fortification**

Consumer-driven fortification, as seen in developed countries, is far from being achieved in many developing countries. Urbanization is leading to increased production and consumption of commercially processed foods, but they are not yet regularly consumed in significant amounts by low-income households at risk of VAD. In the absence of educated consumers, mandatory fortification of one or more processed staple foods to meet at least 15% the RDIs for the target group (e.g., individuals consuming the lowest amount of the fortified food) is needed. An encouraging policy environment for voluntary fortification should be created in developing countries, especially if fortified foods can be made affordable to low-income consumers.

The American Dietetic Association points out that exceeding intake recommendations provides no demonstrated benefit for healthy people (32). In the case of fortification with vitamin A, it would be adequate to recommend voluntary fortification to provide 15–30% of the RDI, ~90–180 μg of REs per serving. In the special case of complementary foods for infants and small children, who have the greatest need to improve their vitamin A intake, the level of acceptance might be set up to 30–60% of the specific RDI (i.e., 120–240 μg RE per serving).

Even with mandatory fortification, campaigns are important to strengthen the commitment of government and industry, to maintain or increase the demand and consumption of the fortified food and to remove any fears about vitamin A toxicity. An educated consumer is needed to achieve the long-term goal of consumer-driven fortification, and systematic education and social marketing will play an important role to this end. The health messages for iodized salt in the United States provide a good example. The fortified product is labeled, “This salt supplies iodide, a necessary nutrient,” and the nonfortified product says, “This salt does not supply iodide, a necessary nutrient.” The challenge is more critical in the developing world, where vast sectors of the population are illiterate and food selection is based on price rather than quality.

**Fortification as part of an integrated approach to VAD**

A positive effect of a food fortification program is limited to the population that consumes the food in adequate amounts. Ideally, the benefit should be received by those who need it most. However, sometimes it is difficult to design a fortification strategy focused only on that group. That is the case of sugar fortified with vitamin A in Central America (33). The product provides 45–180% of the vitamin A RDI for individuals older than 3 y of age and 30–50% of the RDI for younger children because of the different patterns of sugar consumption. Raising the vitamin A level would provide little additional benefit to small children, but it could make the program more expensive and supply large and unnecessary amounts to other age groups. Therefore, food fortification should be visualized as part of an integrated approach to reduce VAD. Targeted supplementation and fortified complementary foods, as well as other food-based approaches, are needed to reach those groups not likely to adequately benefit from fortification.

**CONCLUSION**

**Selecting a food vehicle for public health programs**

The traditional elements of a potential food matrix for fortification are a) regularly consumed by the target population, b) produced by a few factories in a centralized fashion, c) without sensorial changes compared with the nonfortified equivalent and d) retain adequate stability and bioavailability at the point of consumption. In the case of vitamin A, it is important that the typical amount consumed by the target population be large enough. For oil and hydrogenated oils, the consumption should be at least 5 g/d (1.8 kg/y), and for cereal flours and sugar it should be at least 15 g/d (5.5 kg/y). The purpose is to keep the increase in cost due to fortification within an acceptable range and to avoid supplying unnecessary amounts of vitamin A to high-consumption individuals.

In terms of cost-effectiveness, attention should first focus on oils and hydrogenated oils (e.g., margarine), then on cereal flours and finally on sugar and similar products. Cereal flours have the additional advantage that they permit addition of

---

* It is unnecessary to check vitamin A (retinol) bioavailability in each case, because there is sufficient evidence that its absorption and bioefficacy is very high.
other micronutrients at the same time, reducing the overall cost of the fortification process.

**Fortification level**

The concentration of vitamin A in the food vehicle depends on the biological goal and the typical amount of the food vehicle consumed. In general, it is advised that the amount of vitamin A supplied through fortification meets at least 15% of the RDIs for the target group (e.g., individuals consuming the lowest amount of the fortified food). This amount divided by the daily ration determines the minimum level of fortification estimated at the household level. The minimum level of fortification at retail stores should include an average of 10–20%. Industries must estimate an adequate overage to add during production to account for anticipated losses during handling, shipping and storage. For example, if the intention is to provide 180 μg of vitamin A to a population whose sugar consumption is 50 g a day, the sugar marketing time is 6 mo and 50% of the added vitamin A remains in the product during that period, then

- Dietary goal: 180 μg/d.
- Household minimum: 180 μg/50 g = 3.6 μg/g or 3.5 mg/kg.
- Retail store minimum: 3.5 mg/kg × 1.2 = 4.2 = 4.5 mg/kg.
- Minimum amount of vitamin A to be added in the factory: 4.5 mg/kg/0.5 = 9 mg/kg.

Note that all these values are minimum criteria, because it is easier to examine discrete cut-off points than averages.

**Vitamin A level for voluntary fortification**

Urbanization and economic globalization are encouraging some industries to improve the perceived value of their products through fortification, which could lead to many more persons achieving the RDI of vitamin A. Infants and small children, whose nutritional needs of micronutrients might remain unmet through fortification of food staples, could get additional benefits from consuming fortified complementary foods. It is necessary to regulate that practice. It is recommended that voluntarily fortified foods provide 15–30% of the vitamin A RDI per serving (90–180 μg RE). In the case of complementary foods for small children, the limits might be higher; 30–60% of the specific RDI seems adequate (i.e., 120–240 μg RE per serving).

**Regional accords**

The increasing attention to market globalization and free-trade agreements requires that neighboring countries with similar conditions adopt the same technical standards for food fortification. This strategy would reduce conflicts between the health and the industrial/trade sectors. Because of insufficient resources in developing countries to ensure enforcement of the fortification requirements, and because the population with the greatest need tends to select foods based on price rather than quality, fortification of commodities should follow a mandatory and universal system.

**Monitoring and evaluation systems**

One of the weak points of ongoing food fortification programs is the lack of data about quality, coverage and impact. A practical and effective system of monitoring should be required from conception of the program. It is important to establish an annual household surveillance system to obtain process indicators such as coverage, quality and consumption of fortified foods by consumers. This system would serve as the main means to confirm that the program is reaching the expected outputs. It is also important to periodically evaluate the biological impact of the programs (effectiveness). As a strategy to keep the interest of industry, government and consumers focused on maintenance and improvement of the fortification programs, the information should be systematized and published. Strengthening government capacity in these fields is an urgent need. Establishing an external monitoring system through consumer protection societies, where possible, might serve as an additional force to ensure quality and coverage.

**Systematic advocacy and sensitization to industry, government and consumers**

Social marketing activities regarding the benefits of the food fortification programs should receive special consideration, especially in countries where free trade policies are pursued aggressively. These activities should reach all players: industry, government and consumers. A successful food fortification program is the product of a concerted action among all these players.

**Targeted supplementation and other strategies**

Food fortification is an efficient and cost-effective strategy to improve the vitamin A status of populations. Nevertheless, some groups, because of age or geographical isolation, escape coverage. Therefore, other focal interventions are often needed. For example, periodic supplementation aimed at children younger than 36 mo of age could complement universal fortification of staples. In turn, fortification of staples might make it less necessary to supplement postpartum women.

**LITERATURE CITED**

10. Bagriansky, J. & Ranum, P. Vitamin A fortification of PL480 vegetable oil. SUSTAIN (undated manuscript), Washington, DC.


