Fortification Basics

Sugar

Rationale

Sugar is an important source of energy for many people throughout the world. It is produced in over 100 countries and production of sugar is increasing, especially in South America (Table 1). Sugar processing and refining is carried out at only a few mills in sugar producing countries while sugar refining only is done in some sugar importing countries. For these reasons, fortifying sugar with micronutrients is both practical and feasible. In addition, sugar is eaten by the vast majority of people on a regular basis, although consumption levels do vary (Table 2); thus, fortification is an effective means to provide nutrients that are deficient in the population.

Among the micronutrient deficiencies, vitamin A deficiency is one of the most widespread, affecting more than 250 million children throughout the world (Fig. 1). One approach to eliminating this problem has been the fortification of sugar with vitamin A.

Fortification Criteria

The objective is to ensure that vitamin A needs are met for the groups at greatest risk of deficiency without resulting in excessive intakes for individuals having a high sugar intake.

The level of vitamin A to be added is determined by nutritional requirements and sugar consumption patterns; thus, nationally representative data disaggregated by socio-economic status and age groups are needed. Children under 5 years old are most vulnerable to vitamin A deficiency, and their recommended daily allowance is 400 µg RE (1,330 IU) per day. Pregnant women are also at high risk of deficiency, and their reccomended daily allowance is 600 µg RE (2,000 IU).

If, for example, the average sugar intake of children under five years old is 20 grams per day and that for adults in the highest consuming group is 150 grams per day, 15 µg of vitamin A per gram of sugar will both satisfy needs and remain below the maximum acceptable limit.

Technology

Because the quantity of vitamin A being added is so small, production of an homogeneously fortified product is facilitated by diluting the retinyl palmitate (the form of vitamin A used in fortification) in a small amount of sugar to form a premix.

Premix contains:

- Regular sugar.
- Cold water soluble vitamin A palmitate beadlets containing 75,000 µg /g (250,000 IU/g).
- A low peroxide, low in unsaturated fat vegetable oil (e.g. coconut or peanut), which adheres the vitamin A beadlet to the sugar crystal (Fig. 2). This prevents the separation of the vitamin A from the sugar crystal and results in an homogeneously fortified product, without noticeable changes in the sugar's organoleptic properties.

Table 1
Regional and World Sugar Production ('000MT) [1]

Region	1988	1994
Central America	15,000	11,500
S. America	13,000	17,000
Africa	8,000	7,000
Asia	26,500	33,300
Europe	31,500	27,300
N. America	6,500	7,000
Oceania	4,200	5,800
World Total	104,700	110,300

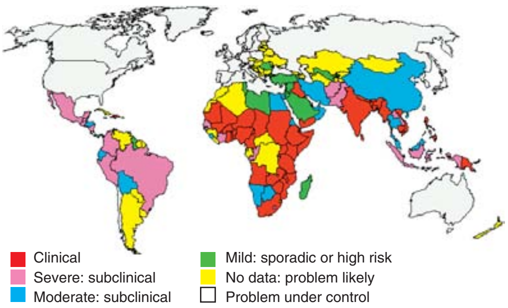
1. International Sugar Organization, 1995.

Table 2
Per Capita Sugar Consumption, and Percent of Daily Energy Intake in Selected Countries

Country (1994)	Consumption (g/person/day) [1]	% of daily energy intake [2]
Brazil	127	17
Peru	88	14
Guatemala	110	15
Honduras	85	12
India	42	5
Indonesia	42	5
Morocco	88	11
Mali	22	2
Egypt	80	10
Zambia	31	8
Cameroon	17	3
South Africa	100	15

1. International Sugar Association, 1995.
2. FAO Food Balance Sheets. 1984 - 1986 average.

Figure 1
Countries Categorized by Degree of Public Health Importance of Vitamin A Deficiency



WHO XVII IVACG Meeting, Guatemala,1996.

Figure 2
Vitamin A Beadlet Adhered to Sugar Crystal

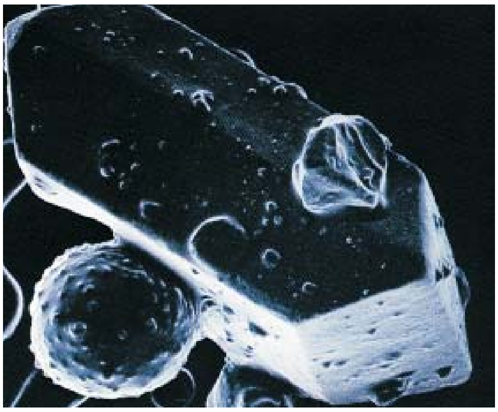


Figure 3
V-type Mixer and Oil Deposit

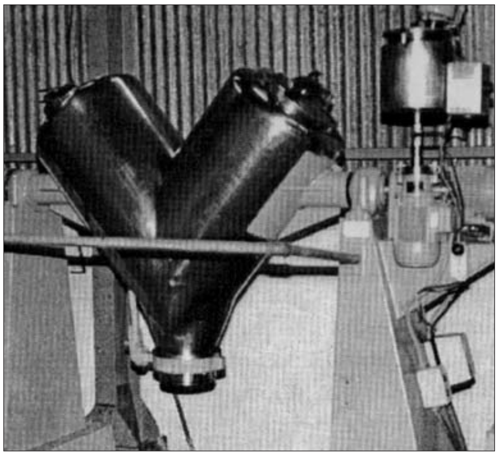
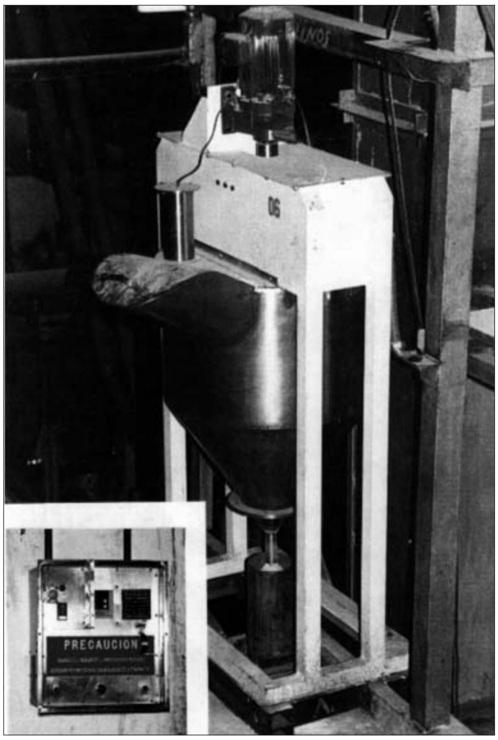


Figure 4
Automatic Dosifier and Control Panel



- An antioxidant blended from natural antioxidants (ascorbyl palmitate, DL-alpha tocopherol, and lecithin) to prevent the oil from going rancid. Rancid oil destabilizes vitamin A and has adverse effects on the sensory characteristics of sugar. Blending the oil and antioxidant in an inert, oxygen-free atmosphere, i.e., in the presence of nitrogen gas, prevents oxidation of the oil.

Premix Composition

Ingredients	Amount	Units
Sugar	76.35	Kg
Vitamin A 250 CWS	22.03	Kg
Peanut oil	2	L
Antioxidant	0.008	Kg
TOTAL	100	Kg

Premix is made by mixing the sugar and vitamin A in a blender (generally a V-type, Fig. 3), with a spraying device attached to it that allows the oil-antioxidant mixture to be added during the mixing operation.
After 10 to 20 minutes of mixing, the premix is packaged in 25 Kg black polyethylene bags covered with polypropylene bags. This minimizes exposure to light, thereby preventing the destruction of retinol. This premix is added to sugar in a ratio of 1:1000.
The addition of premix to sugar can be done manually or automatically. In manual operations, the premix is added into the centrifuges. This method is not ideal because the accuracy of the amount of premix added is dependent on the operator. In automatic operations (Fig. 4), feeders can be placed in different sites along the production line (Fig. 5). The best site is where the humidity and temperature are lowest, which would be just before packaging. This is not always possible because of limitations in the amount of space available. Fortified sugar is packaged in polyethylene bags.

Stability of Retinyl Palmitate

An industrially produced encapsulated vitamin A compound that is dry, solid, and miscible in water, facilitated the development of fortification technology. Despite its excellent stability, 250-CWS is still sensitive to air, light, moisture, heat, and acids; thus, appropriate handling and storage conditions of the premix and fortified sugar are important.

In the premix and, during the fortification process

Experimental data report retinol losses of between 10 and 20 percent during the processing of fortified sugar, and between 20 and 40 percent during storage after one year. These losses need to be compensated for by adding the appropriate overage of premix to sugar during the fortification process.
Retinyl palmitate is susceptible to oxidation in the presence of sun or artificial light. Packaging premix in bags covered with black polyethylene bags reduces exposure to light and degradation of vitamin A.
Retinyl palmitate beadlets resist temperatures of 105 °C for 10 minutes. This is important because the premix is added to sugar before it passes through the drying turbines, where temperatures are between 65 and 70 °C.

In fortified sugar
Stability tests show that fortified sugar packaged for retail sale in polyethylene bags retains between 50 and 70 percent of the initial vitamin A level after 3 months of storage (Fig. 6 and 7). Heat and moisture together are believed to be more detrimental to retinyl palmitate than either alone (Table 3).

Fortified sugar in foods
Vitamin A in fortified sugar remains stable in foods prepared at home, although moisture, heat, and acidity do reduce its activity.
When fortified sugar is added to beverages such as lemonade and orangeade, 60 to 80 percent of the vitamin A remains after two days.
Vitamin A is sensitive to acids and losses can be expected. Most of the vitamin A in fortified sugar, however, can be lost in the manufacturing of soft drinks as a result of using activated charcoal and diatomaceous earth to eliminate color and impurities; thus, when non refined sugar is used in manufacturing soft drinks there is complete destruction of the vitamin. If, however, refined sugar is used two-thirds of the original retinol level remains.
The stability of vitamin A in baked foods is also good. The retention of the micronutrient after baking is in the order of 80 to 90 percent.
Micronutrient interactions with vitamin A in sugar are unlikely because sugar is a pure product with minute quantities of other compounds.

Quality Control
The vitamin A content of the premix is determined using quantitative methods, while that for fortified sugar is carried out using both semiquantitative and quantitative methods.
Quantitative methods include the use of HPLC or spectrophotometric methods. The HPLC method is based on the separation of vitamin A (retinol) from other substances that absorb radiant energy at an equal or similar wavelength to retinol. Detection of retinol in the HPLC column can be done using UV light or fluorescence. This method is accurate, does not destroy retinol, and requires a small amount of sample. However, the equipment is expensive, highly trained personnel are required, and few samples can be run at a time, making the analysis expensive. The spectrophotometric method involves measuring the absorbance of retinol in sugar after its selective destruction through exposure to UV light. This method is easy to use, less expensive than the HPLC method, and results can be obtained in a much shorter period of time.
The semiquantitative colorimetric method involves adding a chromogenic reagent to a volume of solubilized sugar to produce a blue color. The intensity of this blue color is proportional to the amount of retinol in the sample, measured against a set of standards. Semiquantitative assays at 1 to 2 hours intervals during production verify that the fortified sugar contains the amount of vitamin A that falls within the range stipulated in the norms. Results are immediate and permit adjustments to the amount of premix added to sugar.

Costs
The costs of sugar fortification include the capital investments, i.e. building and equipment costs, and recurrent costs, i.e. personnel costs, premix and fortified sugar production costs, as well as monitoring and evaluation costs. In Guatemala, the cost of fortifying 1 metric ton of sugar is US$9.51, and the cost

Figure 5
Possible Points for Premix Addition During Sugar Production

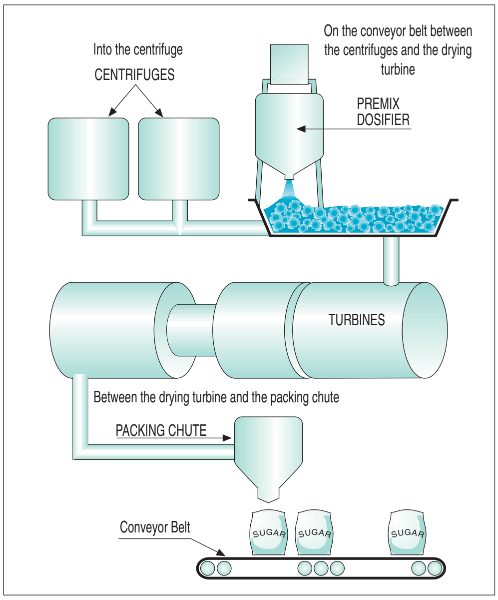
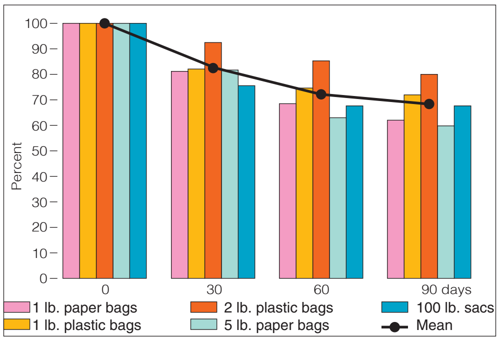
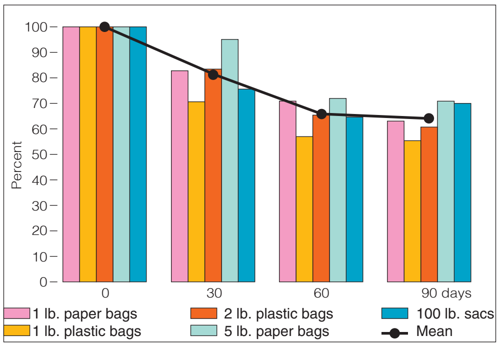


Figure 6
Stability of Vitamin A in Sugar, Cia. Azucarera La Estrella S.A.



De Gracia, M.S., F.E. Murillo. 1993. Estabilidad de Vitamina A en azúcar fortificada resúmen ejecutivo. INCAP/U de P.

Figure 7
Stability of Vitamin A in Sugar, Cia. Azucarera Nacional S.A.



De Gracia, M.S., F.E. Murillo. 1993. Estabilidad de Vitamina A en azúcar fortificada resúmen ejecutivo. INCAP/U de P.

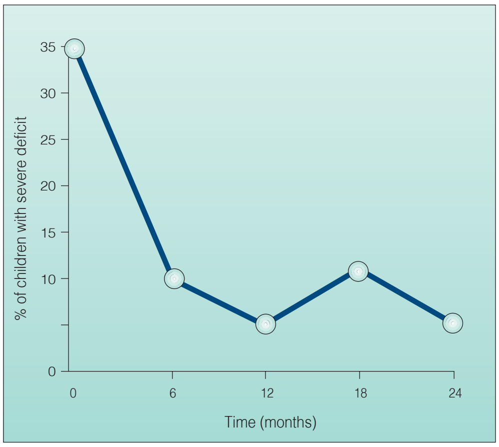
Table 3
Stability of Retinol in Fortified Sugar (% retention in 125 lb. sacs)

Location Type	Months of Storage 3	6	9
Cold - Humid	90	77	66
Hot - Dry	92	71	63
Temperate - Humid	83	69	43
Hot - Humid	80	62	40

Dary, O., De león, L. Conference on XVII IVACG Meeting, Guatemala, 1996.

Figure 8

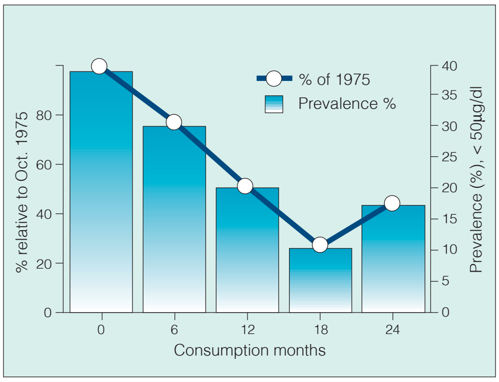
Decrease in % Children with Serum Retinol Level Below 10 mcg/dL After Consumption of Fortified Sugar



Arroyave G, Aguilar Jr, Flores M, Guzmán Ma. Evaluation of Sugar Fortification with Vitamin A at the National Level Pan American Health Organization. Scientific Publication 384 Washington, DC., 1979.

Figure 9

Effect of Fortified Sugar Consumption on the Prevalence of Low Retinol Levels in Human Milk



Arroyave G, Aguilar Jr, Flores M, Guzmán Ma. Evaluation of Sugar Fortification with Vitamin A at the National Level Pan American Health Organization. Scientific Publication 384 Washington, DC., 1979.

Table 4

Status of Legislation for Sugar Fortification in Latin America

Countries Enforcing Legislation	Countries in Process of Legislating	Countries with Interest (Private or Official)
Guatemala	Nicaragua	Brazil
Honduras	Ecuador	Dominican Rep
El Salvador		Colombia
		Bolivia

per person is US$0.36/year. Given that a kilogram of sugar costs US$0.45 before fortification, adding vitamin A increases the price to US$0.459, that is, 2 percent above the original price.

The economic analysis of a program can be presented in different ways, for example, cost per metric ton, cost per person, cost per person covered, cost per possible beneficiary, and in terms of cost-effectiveness. The cost of a sugar fortification program is inexpensive, especially when compared with the costs of vitamin A deficiency, and the cost of other interventions.

Legislation

To be successful, a fortification program requires the collaborative participation between various government sectors, food producers, private organizations, and international agencies. The strongest expression of political commitment to eliminate vitamin A deficiency is legislative action to make a vitamin A fortification program official. Such legislation shall define the norms for implementing fortification, including the responsibilities of each sector involved. The regulations for vitamin A fortification must specify the type of vitamin A fortificant and the permitted range of retinyl palmitate in fortified sugar both at the refinery and at the point of sale when appropriate. The regulations must define the precautions and food safety conditions to be observed during production, transportation, storage, and sale of the fortified sugar.

Labeling the bags of fortified sugar at the refinery should be enforced, especially when unfortified sugar is also produced for industrial use. Sugar packaged for retail sale should be labeled in a way that is true and accurate, and provides essential information specified by the health authorities.

The official creation of a specific committee, for example, a Food Fortification Committee, with representatives from different sectors is recommended. The role of this committee would be to monitor program implementation and analyze the information coming from the different operating units, and to ensure that the operating units and those responsible at the points of sale comply with their responsibilities.

History and Successful Interventions

Guatemala was one of the first countries to implement a sugar fortification program to ensure an adequate intake by the population with satisfactory results (Fig. 8 and 9).

Other countries in Latin America are now implementing vitamin A fortification programs (Table 4). Asian countries are also considering sugar fortification.

Vitamin A is an essential nutrient and deficiency is associated with adverse health effects. Sugar fortification presents an important intervention for improving the vitamin A status of at-risk populations.

Although the current technology is adequate enough, it can still be improved in order to increase the efficiency of the fortification program. In existing refineries, space where the dosifiers can be installed is often limited. Future plant layouts should make provisions for this limitation.