In: Nutrient Addition to Foods. J.C. Bauernfeind and Paul Lachance (Eds.). Gainsville, Fl., Food and Nutrition Press, Inc., 1991, p. 251-264.

INCAP Publication I-1560

Foods Considered for Nutrient Addition: SUGARS

MARIO R. MOLINA, Ph.D.

INTRODUCTION

The most important food and nutrition problems around the world have been identified as protein-energy malnutrition, anemias associated with iron and folate deficiencies, hypovitaminosis A and iodine deficiency.[12,17,32,46,49,50] Of problems, protein-energy malnutrition can be recognized mainly as a food problem, while the other deficiencies (vitamin A, iodine and iron and folate) are micronutrient deficiencies. Micronutrient deficiencies can be corrected through several alternatives, such as: increasing consumption of the food items which contain them in the desirable concentrations and in a bioavailable form; or by supplying them periodically in a therapeutic dose; or by nutrifying suitable food carriers to assure an adequate intake of the micronutrients. Among the aforementioned alternatives, the public health nutrification of a suitable food carrier with the desired micronutrient has proved to be the most economical and practical alternative to ameliorate and/or prevent the principal micronutrient deficiencies cited. It is generally recognized that food nutrifying action is taken to fulfill a public health objective (to overcome micronutrient deficiency or insufficiency) and should be looked upon as a measure to be adopted in conjunction with other longer range interventions (agricultural production programs, food and nutrition education activities, and other effective social and economic approaches), which will assure adequate nutrition and optimal health for all vulnerable population groups.

In public health fortification programs the carrier or vehicle should have several desirable characteristics: first, it should be consumed regularly and in relatively constant amounts by the target population. The acceptability and/or quality of the carrier food or ingredient should not be affected by the micronutrient added, and, perhaps more importantly, the carrier should not affect the bioavailability of the added micronutrient. Also, the method of addition of the micronutrient should be technologically simple and should represent a low cost operation which, if possible, should be comparable with the production process of the carrier. The final product mixture obtained (micronutrient and carrier), should be stable and homogeneous and the

TABLE 8.2
STABILITY OF ADDED VITAMIN A IN NUTRIFIED SUGAR

			Percentage Retention of Vitamin A						
			45°C (Months)			23–25°C (Months)			
Product	Trial	Vitamin A Type	1	2	3	1	2	3	6
Premix[1]									
A	1	250-CWS	92	83	—	99	98	—	99
B	1	250-SD	87	79	—	97	95	—	96
C	2	250-CWS	—	—	86	—	—	92	94
D	2	250-SD	—	—	77	—	—	93	89
E	3	250-CWS	93	—	81	97	—	90	90
F	3	250-SD	92	—	74	100	—	95	93
Nutrified sugar[2]									
G	4	250-CWS	91	—	76	96	—	96	92
H	4	250-SD	90	—	73	100	—	88	85

Source: Bauernfeind and Arroyave.[12a]
[1]Vitamin A-sugar premix (50,000 IU/g).
[2]Vitamin-nutrified sugar (50–70 IU/g).

heavy paper bags and stored in a clean, dry and dark place. Special care should be taken to ensure proper storage conditions for the premix, as the bags are initially closed and then later reopened for use.[42]

As a practical example in the preparation of 100 kg of premix, 50 kg of sugar are mixed with 22 kg of retinyl palmitate 250-CWS until a uniform mix is obtained (approximately 10 minutes in a blender). Then, 26 kg more of sugar are added and the mixing is continued. Separately, 1.65 kg of the oil is placed in a stainless steel reservoir bubbling N_2 gas continuously. The oil is then heated to 60°C and 8.2 g of the stabilizer are added, mixing until the paste is dissolved (approximately 5 minutes). Nitrogen is bubbled continuously during this time to prevent any possible oxidation of the oil. It has been found that other vegetable oils (soybean, maize or cottonseed oil) could be substituted for the original peanut oil.[38] As a third step, the warmed oil containing the stabilizer (Ronoxan A) is slowly added to the vitamin A/sugar mixture. The mixing is continued for about 10 minutes after the addition of all the oil to assure uniformity. A uniform color is indicative of a good quality, well-prepared premix. A V-shaped, solid-liquid mixer is a good alternative apparatus for the mixing operation.

The process summarized above and presently used for the preparation of the premix[42] differs somewhat from the original work carried out at INCAP.[3,4] The differences are found primarily in the fact that originally vitamin A palmitate 250-SD was used to attain a final concentration of 0.021 mg of retinol per gram of sugar, rather than the presently used 0.015 mg/g concentration. The former, original concentration (0.021 mg/g) was based on the calculation of an amount of sugar which

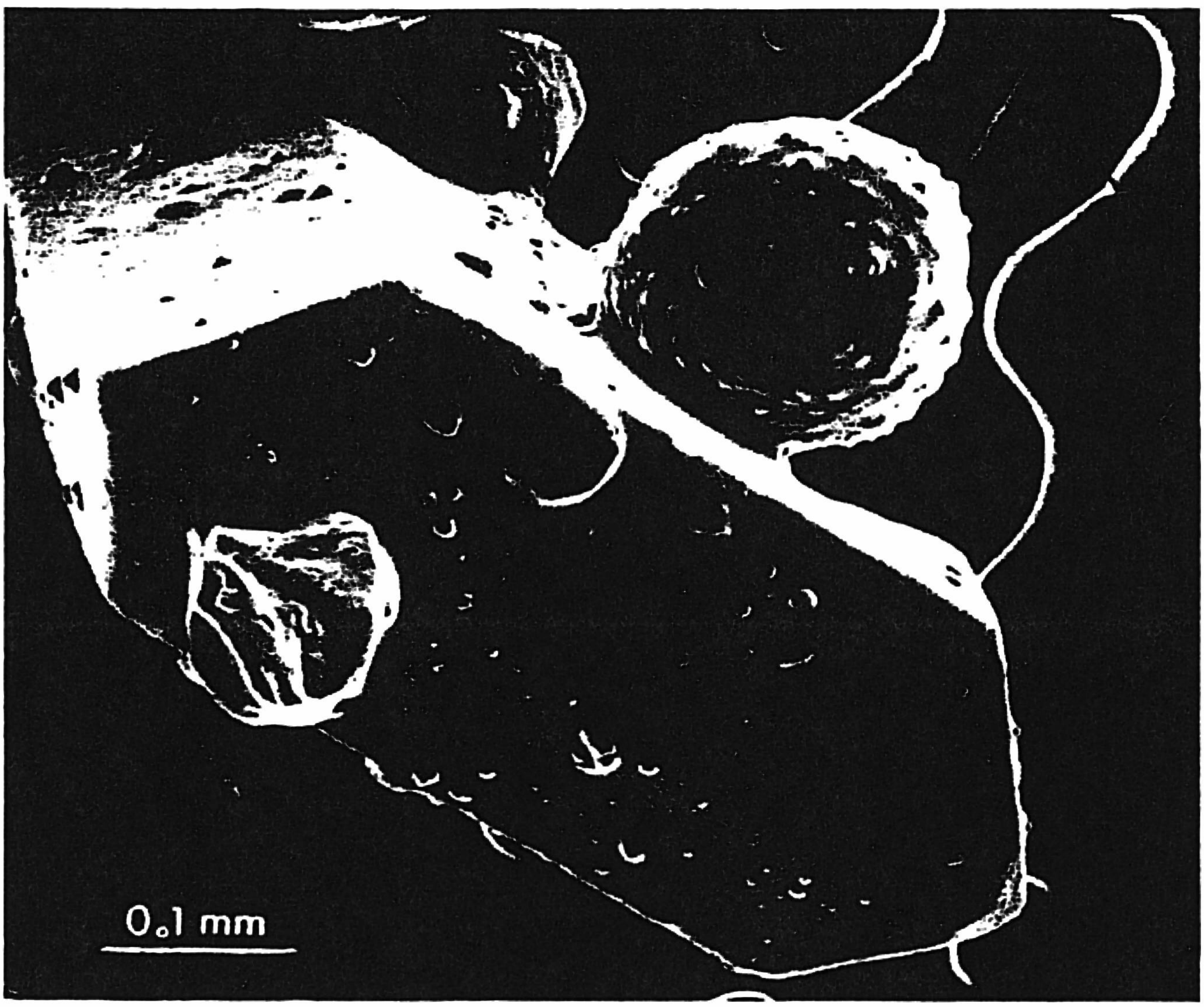
TABLE 8.3
FORMULATION OF THE VITAMIN A FORTIFIED PREMIX
(Per metric ton, with 10% excess)

Ingredient	Concentration (kg)
Retinyl palmitate 250-CWS	220.00
Peanut oil (peroxide free)[1]	16.50
Stabilizing mixture[2]	0.08
Sugar	763.42

Source: Data from Pineda.[42]

[1]Other vegetable oils as those of soybean, maize, cottonseed or african palm may be used according to availability (Mejía and Pineda.[38]).

[2]Ronoxan A from Hoffmann-LaRoche, Switzerland.



Courtesy of John Gmünder

FIG. 8.1. MAGNIFIED PHOTOGRAPH OF VITAMIN A BEADLETS ADHERING TO SUCROSE CRYSTAL

would supply the daily recommended intake of vitamin A (0.75 mg of retinol) for adults as stated by FAO/WHO.[20] The rationale for modifying the vitamin A fortification level was the recognition that the primary goal of the program should be adequate vitamin A intakes of preschool children, not adults, since the latter derive part of their vitamin A requirements from dietary sources other than fortified sugar.[42]

In the preparation of the premix the work of Lacera[31] *et al.* should be mentioned. These researchers investigated the possibility of substituting part of the added vegetable oil with shark's liver oil (rich in natural vitamin A) and increasing the oil content of the premix. Lacera *et al.*[31] reported that an acceptable, good quality premix could be prepared by adding 6.4 ml of shark's liver oil per 100 g of premix, rather than the standard 1.65 ml of vegetable oil. The added shark's liver oil supplied between 10–12% of the vitamin A activity desired in the final premix. Considering that sharks are a marine resource found off the coasts of various Central American countries with people suffering from vitamin A deficiency, this modification seems worthy in the quest to lower the need for imported pure vitamin A (such as retinyl palmitate). If adopted, the stability of the fish oil vitamin A addition in the sugar mixture would need to be examined.

Fortification Process. The process involves blending the premix with regular white sugar to produce vitamin A nutrified sugar. The operation can presently be affected either (1) in the centrifuge at the end of the sugar washing cycle or (2) during the transportation of the sugar (on transporting belts), either before or after drying and prior to final packaging.[42]

When fortification of the crystallized sugar is carried out on the transporting belts, an adjustable precision feeder mechanism is synchronized with the propulsion system rate of the belt; thus, the flow of the premix is synchronized with the flow of the sugar stream. A thorough mixing is accomplished during the drying process.

When the fortification process is conducted in the centrifuge at the end of the sugar washing cycle, the weight of the centrifuge charge must be first obtained. The weight of the charge is calculated from the physical constants of the centrifuge (height and large and small radius) corrected by the pi value and the density of the product being centrifuged, according to the following general expression:

$$p = \pi d (R^2 - r^2) h$$

Where: p = weight of the charge of the centrifuge (kg)

Pi = 3.1415 = π

d = density of product being centrifuged (kg/m^3)

R and r = large and small radius of the centrifuge, respectively (m)

h = height of the centrifuge (m)

In Guatemala the average density of the product being centrifuged is 880 kg/m^3 (Pineda[42]).

Once the weight of the charge of the centrifuge is known, the amount of premix needed per lot being centrifuged is relatively easy to establish and to program in repeated cycles. Here again, the mixing of the premix and the sugar is accomplished during the drying and packing operations.

The vitamin A nutrified sugar is generally packed in cloth bags and stored for marketing. During the fortification process and storage of the nutrified sugar, moisture exposure should be kept at a minimum for maximum stability of the incorporated vitamin A.

Quality Control

Homogeneity. One of the first concerns of the entire fortification operation of table sugar with vitamin A is the attainment of an even distribution of the micronutrient in the sugar.

In the studies carried out using vitamin A palmitate 250-SD, even distribution of vitamin A has been reported in the nutrified sugar.[2,4,19,30] This work has also resulted in a rapid, quantitative method for determining the vitamin A in the nutrified sugar,[1,6,9] based on the Carr-Price procedure.[45] Two easy-to-read publications were prepared by INCAP[1,8] with the intent of educating sugar manufacturers and thus assuring satisfactory quality control procedures for the program. These goals are reflected in the latest easy-to-read publication.[42] One colorimetric test is illustrated as Table 8.4.

Even distribution of the vitamin A in the final fortified product is assured by preparing a good quality premix. The even distribution of retinyl palmitate in the premix is verified by chemical assay, although an empirical judgment can be obtained by visually observing for uniform color and a granular, homogeneously "lightly greasy" texture.[42]

Acceptability. Welfare institutions and the INCAP dining facilities were used to test the acceptability of the vitamin A fortified sugar over a four-month period.[29] Results of this "blind test" showed that consumers could detect no difference between regular sugar and the vitamin A nutrified sugar. In a second study, vitamin A fortified sugar was distributed through regular channels to a rural community.[3] Again, the results showed that the acceptability of the nutrified sugar was not appreciably different from that of the regular sugar.

In addition, triangle tests were performed on drinks prepared with vitamin A fortified sugar. The samples tested included coffee, Incaparina, pineapple refreshment, tea, orangeade, lemonade and horchata (a rice flour cold drink). The panelists were able to detect the fortified sugar in coffee, pineapple refreshment and orangeade, but they considered the flavor imparted by the vitamin A containing sugar to be acceptable.

Bioavailability. Studies of the bioavailability of vitamin A in the enriched sugar carried out on rats demonstrated that the product contained 100% of the expected biological activity.[29]

TABLE 8.4
RAPID COLORIMETRIC METHOD FOR THE CONTROL OF THE FORTIFICATION OF SUGAR WITH VITAMIN A

A. *Description of the method*

1) Reagents

a) Chromogen reagent. To prepare this reagent weigh in a beaker 60 g of trichloroacetic acid and 40 g of methylene dichloride ($CH_2\ Cl_2$) or ethylene dichloride ($CH_2Cl{\cdot}CH_2Cl$). To dissolve completely, warm mixture in a water bath at 60-70°C with constant stirring. Store the reagent in an amber glass container with glass stopper.

b) Distilled water.

B. *Materials*

1) Test tubes 13 x 100 mm.
2) A measuring scoop (plastic or glass) which, when leveled, should contain approximately 500 mg (1/2 g) of sugar.
3) A small glass funnel to introduce the sugar into the test tube.
4) A dropper.
5) A 10 ml graduated syringe (glass or polyethylene) to measure the chromogen reagent. It is convenient to attach a length of polyethylene tubing to the tip of the syringe to facilitate delivery of the reagent into the test tube.
6) Color scale. In 13 x 100 mm test tubes place 4 ml of the following concentrations of copper sulfate water solution ($CuSO_4$, $5H_2O$) per 100 ml: 0.0, 1.0, 2.5, 5.0, 7.5, 10.0, 12.5, 20.0, and 25.0. Cover tubes with a rubber stopper sealing them airtight to prevent any evaporation. Label tubes from 1 to 9.

C. *Procedure*

With the measuring scoop place 500 mg of the sugar into a 13 x 100 mm test tube. Add 3 drops of distilled water and warm in a water bath at a temperature of 60-70°C for 1 minute; shake occasionally. Cool at room temperature in a cold water bath (±20°C). Add with the measuring syringe 3 ml of the chromogen reagent and mix immediately. Compare against the color scale the blue color developed, which reaches its peak between 5-10 seconds. After 10 seconds the color begins to fade.

In our experience, using white sugar fortified within the limits recommended by the fortification program in Guatemala (43 to 57 IU per gram), the readings fall between tubes 6 and 9.

When the sugar being fortified is not completely white, but is instead yellow due to impurities, the color reaction tends to give a greenish color.

The colorimetric method permits rapid determination of whether a sample of sugar is or is not fortified with vitamin A, as well as the approximate level of fortification. For this reason it can be employed as a field method. For this purpose, the necessary reagents and materials can be placed in a portable box and transported directly to the places where one would wish to check the presence of vitamin A in the sugar.

Source: Arroyave *et al.*[10]

In a study of lactating mothers supplied with fortified sugar, Arroyave *et al.*[11] reported that their blood serum retinol level increased significantly over the course of the study. Thus, the results indicated that the vitamin A was biologically available to the mothers. Furthermore, the authors found that after the fourth month of lactation the babies from mothers consuming nutrified sugar showed a higher serum retinol level than the babies of the control mothers. A similar relationship was noted in studies of the maternal milk retinol content. Since mother's milk was the sole dietary source of vitamin A for the babies, the finding on their serum values again confirm the bioavailability of vitamin A from the ingestion of nutrified sugar.

Toro *et al.*[45] working with sugar fortified with retinyl acetate 325L (Hoffman-LaRoche) in Chile failed to decrease the clinical signs of vitamin A deficiency in 160 school children and 60 adults in a 3-month period. The authors attributed this finding to the short period of ingestion of the enriched sugar. Assays of fortified sugar taken at consumption locations at time intervals would have revealed the presence or absence of the expected vitamin A content.

Economic Aspects

Since the original studies, it has been determined that the cost of the vitamin A added to the sugar is relatively low. In fact, Arroyave[3] stated that such a cost was equivalent to US$0.03 per person per year. This relatively low cost (around US$2.25 per metric ton of sugar) was a major factor in the decision by the Central American sugar manufacturers to absorb the cost of the nutrification program. For these types of intervention programs to proceed successfully, the operational costs should be kept at a minimum, as accomplished in the present Central American case.

Legal and Political Aspects

The legal and political aspects are an important part in any fortification program, such as the vitamin A addition to table sugar. Each must be considered and regulations should support their public health value and thus assure that the program will be implemented properly and monitored adequately. The responsibilities of all concerned should be clearly defined, indicating who will carry out each component in the program, as well as to delineate what sanctions are to be imposed if the program is not operated properly. In Central America the fortification of sugar with vitamin A has been legislated in Costa Rica, Guatemala, Honduras and Panama. The regulation applies to refined white table sugar rather than to sugar for industrial purposes.[2,7,19]

POTENTIAL FOR THE NUTRIFICATION OF SUGARS WITH OTHER NUTRIENTS

Iron

Sugar has also been evaluated as a carrier of iron. At INCAP Viteri and García-Ibáñez[47] reported the possible fortification of sugar with ferric-sodium-EDTA. The operation could be effected in a similar fashion to that for vitamin A, as previously described, or both nutrients could be added in the same mixture. When the iron fortified sugar (13 mg of iron as ferric-sodium-EDTA/100 g sugar) was consumed by 31 normal subjects mixed in a corn-bean-bread and coffee diet, a mean iron absorption value of 6.4% was observed. The absorption value compared well with the 2.8% value obtained when ferric sulfate was used in a similar trial.

Disler *et al.*[18] added iron in a variety of compounds to a commercial white cane sugar at two levels (100 and 200 mg/kg). In several cases, ascorbic acid was also added to the sugar at a concentration of either 1 or 2 g/kg. The authors reported two methods of fortification; (1) dissolving the iron and ascorbic acid in water and spraying the solution onto the sugar; (2) dampening the sugar in water (1 g/kg) before mixing the sugar with each of the finely ground dry supplements. The latter method was preferred, since when the former was used a discoloration (purple/brown color) of the sugar resulted. After fortification, the sugar was air dried and could be stored between 22–27 °C in a mean relative humidity of 55% without problems. The same authors (Disler *et al.*[18]) reported that when ferric orthophosphate was used with ascorbic acid in the fortification of sugar the absorption value was much better when the fortified sugar was added to a maize porridge before cooking (12.7%) than when it was added after cooking (1.8%). This finding suggests that an absorbable iron complex may be formed between the insoluble ferric orthophosphate and ascorbic acid during cooking. Jams prepared with sugar fortified with ferric orthophosphate and ascorbic acid provided a relatively high iron absorption value (13.8%). But this was not the case when the sugar was fortified only with ferric orthophosphate (absorption value 2.3%), indicating the benefit of added ascorbic acid. In biscuits prepared with ferric orthophosphate and ascorbic acid, the relatively high absorption value mentioned in the other products was not obtained and can be attributed to destruction of ascorbic acid by the high baking temperture.[18]

Layrisse[33] and Layrisse *et al.*[35] indicate that a benefit of using sugar as a carrier for iron is that the sugar acts as a reducer and maintains the iron salts in a ferrous form. At a concentration of 1 mg of iron per gram of sugar, the fortification does not affect the color nor the taste of sugar.

When iron fortified sugar is ingested with a diet of wheat and black beans the addition of ascorbic acid increases the absorption of both the extrinsic and the intrinsic iron in the diet, thus lowering the negative effect of the absorption-inhibiting substances in the vegetable product.[18,33,35,36]

One major problem reported with iron fortified sugar is the marked discoloration developed when coffee or tea are prepared with it. The discoloration develops almost immediately as the sugar is added.[18] Layrisse *et al.*,[36] however, noted that when Fe-(III)-EDTA was used as the fortifying compound the discoloration in tea was produced very slowly for the first 2 h and the iron itself resisted precipitation for at least 24 h. Although the discoloration problem may be reduced using Fe-(III)-EDTA, the question remains whether or not such a compound can prevent the formation of nonabsorbable tannin-iron complexes. The addition of Fe-(III)-EDTA to maize appears to favor the absorption of both extrinsic and intrinsic iron.[34]

Other Micronutrients

The nutrification of sugar with phosphates and calcium has been examined primarily to minimize the possible negative effect of sugar on dental decay.[21,40] The fortification of sugar with fluorides has also been examined with a similar purpose.[39] A comprehensive review on the subject was published by Navia.[41]

Patents have been obtained for the production and marketing of multinutrient fortified sugar.[14] Industrial efforts[41] have been made to produce a sugar fortified with both vitamins and minerals, but the producers mention problems of odor, taste and discoloration with the fortified product. However, considering the advantages of sugars as a universal carrier and emerging technological advances, there is hope that the sensory limitations of marketed multinutrient sucrose products will be overcome.

SUMMARY

The Central American experiences with vitamin A nutrification of crystalline sugar as a successful intervention strategy in the alleviation of vitamin A deficiency in the Central American population is an outstanding achievement in the history of public health, brought about by the creative efforts of organic chemists, nutritionists, food technologists and food engineers, as well as the support of the food industry, government and the general public. Hopefully, through this accomplishment, sugar may become more universally recognized as a potentially practical carrier of other micronutrients where merit exists for its consideration.

REFERENCES

1. AGUILAR, J. R., ARROYAVE, G. and GALLARDO, I. C. 1977. Manual de Supervisión y control de programas de fortificatión de Azúcar con vitamina "A." Instituto de Nutrición de Centro América y Panamá (INCAP). Publicación INCAP E-913. Guatemala Centro América.

2. AGUILAR, J. R., ARROYAVE, G. and PORTELA, E. 1975. Rapid method for adding vitamin A to sugar at an industrial level. 10th Int. Congr. Nutr., Kyoto, Japan.
3. ARROYAVE, G. 1971. Distribution of vitamin A to population groups. Proc. West. Hemisphere Nutr. Congr. *III*, 68–77.
4. ARROYAVE, G. 1977. Control of vitamin A deficiency fortification of sugar with vitamin A. Part II. Sugar Azúcar *72*, 36–40.
5. ARROYAVE, G. and BRENES, E. A. 1972. Control de la deficiencia de vitamina A en Guatemala. Rev. Col. Médico (Guatemala) *23*, 66–80.
6. ARROYAVE, G. and DE FUNES, C. 1974. Enriquecimiento de azúcar con vitamina A. Método para la determinación cuantitativa de retinol en azúcar blanca de mesa. Arch. Latinoam. Nutr. *24*, 147–153.
7. ARROYAVE, G., AGUILAR, J. R. and FLORES, L. M. 1978. Evaluation of programs to control vitamin A deficiency. Proc. West. Hemisphere Nutr. Congr. *V*, 46–56.
8. ARROYAVE, G. AGUILAR, J. R. and PORTELA, E. 1975. Manual de Operaciones Para la Fortification de Azúcar Con Vitamina "A." Instituto de Nutrición de Centro América y Panamá (INCAP), Publicación INCAP E-853. Guatemala, Centro América.
9. ARROYAVE, G., PINEDA, O. and DE FUNES, C. 1974a. Enriquecimiento de Azúcar con vitamina A. Método rápido para la fácil inspección del proceso. Arch. Latinoam. Nutr. *24*, 155–159.
10. ARROYAVE, G., AGUILAR, J. R., FLORES, M. and GUZMÁN, M. A. 1979. Evaluation of sugar fortification with vitamin A at the national level. Scientific Publ. No. 384. Pan Am Health Organization, Washington, DC.
11. ARROYAVE, G., BEGHIN, I., FLORES, M., SOTO DE GUÍDO, C. and TICAS, J. M. 1974b. Efectos del consumo de azúcar fortificada con retinol, por la madre embarazada y lactante cuya dieta habitual es baja en vitamina "A." Estudio de la madre y del niño. Arch. Latinoam. Nutr. *24*, 485–512.
11a. ARROYAVE, G. 1986. Vitamin A deficiency control in Central America. *In* Vitamin A Deficiency and Its Control, J. C. Bauernfeind (ed.). Academic Press, Orlando.
12. AYKROYD, W. R. 1970. Eliminación de las enfermedades carenciales. Resultados y perspectivas. World Health Organization (WHO), Geneva, Switzerland. Estudio Básico No. 24.
12a. BAUERNFEIND, J. C. and ARROYAVE, G. 1986. Control of vitamin A deficiency by the nutrification of food approach. *In* Vitamin A Deficiency and Its Control, J. C. Bauernfeind (ed.). Academic Press, Orlando.
13. BIERMAN, E. L. and NELSON, R. 1975. Carbohydrates diabetes, and blood lipids. World Rev. Nutr. Diet. *22*, 280–287.
14. CARTER, J. F. 1971. Production of fortified sugar. U.S. Patent No. 3,607,310. Sept. 21.
15. DANOWSKI, T. S., NOLAN, S. and STEPHAN, T. 1975. Obesity. World Rev. Nutr. Diet. *22*, 270–279.
16. DEMAEYER, E. M., LOWENSTEIN, F. W. and THILLY, C. H. 1979. The control of endemic goitre. World Health Organization (WHO), Geneva, Switzerland.
17. DIEZ-EWALD, M. and MOLINA, R. A. 1972. Iron and folic acid deficiency during pregnancy in Western Venezuela. Am. J. Trop. Med. Hyg. *21*, 587–591.
18. DISLER, P. B., LYNCH, S. R., CHARLETON, R. W., BOTHWELL, T. H., WALTER, R. B. and MAYET, F. 1975. Studies on the fortification of cane sugar with iron and ascorbic acid. Br. J. Nutr. *34*, 141–152.

19. DORIÓN, R. C. 1977. Control of vitamin A deficiency. Fortification of sugar with vitamin A. Part I. Sugar Azúcar, *72*, 33–36.
20. FAO/WHO Joint Expert Group. 1967. Requirements of vitamin A, thiamine, riboflavine and niacin. WHO Tech. Rep. Ser. No. 362. Geneva, Switzerland.
21. FINN, S. B. and GLASS, R. B. 1975. Sugar and dental decay. World Rev. Nutr. Diet. *22*, 304–326.
22. GRANDE, F. 1975. Sugar and cardiovascular disease. World Rev. Nutr. Diet. *22*, 248–269.
23. Instituto de Nutrición de Centro América y Panamá. 1969a. Evaluación nutricional de la poblacion de Centroamérica y Panamá. INCAP, Guatemala.
24. Instituto de Nutrición de Centro América y Panamá. 1969b. Evaluación nutricional de la poblacion de Centroamérica y Panamá. INCAP, El Salvador.
25. Instituto de Nutrición de Centro América y Panamá. 1969c. Evaluación nutricional de la poblacion de Centroamérica y Panamá. INCAP, Honduras.
26. Instituto de Nutrición de Centro América y Panamá. 1969d. Evaluación nutricional de la poblacion de Centroamérica y Panamá. INCAP, Nicaragua.
27. Instituto de Nutrición de Centro América y Panamá. 1969e. Evaluación nutricional de la poblacion de Centroamérica y Panamá. INCAP, Costa Rica.
28. Instituto de Nutrición de Centro América y Panamá. 1969f. Evaluación nutricional de la poblacion de Centroamérica y Panamá. INCAP, Panamá.
29. Instituto de Nutrición de Centro América y Panamá. 1974. Fortification of sugar with vitamin A in Central America and Panama. INCAP.
30. Instituto de Nutrición de Centro América y Panamá (INCAP). 1975. Evaluation of sugar fortification with vitamin A at the national level. Proposal submitted to U.S.A.I.D. in Nov. 1975. INCAP.
31. LACERA, A., MEJÍA, L. A., MOLINA, M. R. and BRESSANI, R. 1983. Fortificatión de azúcar con aceite de hígado de tiburón, para alimentación humana. *In* Proc. Int. Conf. "Marine Resources of the Pacific." P. M. Arana, (ed.). Viña del Mar, Chile.
32. LAYRISSE, M. 1966. The aetiology and geographic incidence of iron deficiency. Plenary Sessions. XI Congr. Int. Soc. Haematol.
33. LAYRISSE, M. 1975. Iron nutriture. Proc. West. Hemisphere Congr. *IV*, 148–154.
34. LAYRISSE, M. and MARTÍNEZ-TORRES, C. 1977. Fe-(III)-EDTA complex as iron fortification. Am. J. Clin. Nutr. *30*, 1166–1174.
35. LAYRISSE, M., MARTÍNEZ-TORRES, C., RENZÍ, M., VÉLEZ, F. and GONZÁLEZ, M. 1976a. Sugar as a vehicle for iron fortification. Am. J. Clin. Nutr. *29*, 8–18.
36. LAYRISSE, M., MARTÍNEZ-TORRES, C. and RENZI, M. 1976b. Sugar as a vehicle for iron fortification: further studies. Am. J. Clin. Nutr. *29*, 274–279.
37. LEE, J. E. and RUÍZ, C. 1982. La canasta mínima de alimentos dentro de la economía familiar. Resumen de la Semana Técnico-Científica sobre Alimentación y Nutrición. INCAP.
38. MEJÍA, L. A. and PINEDA, O. 1986. Substitución del aceite de maní usado para la fortificacion de azucar con vitamina "A" por otros aceites vegetales de azúcar con vitamina "A" por otros aceites vegetales disponibles en Centroamérica. Arch. Latinoam. Nutr. *36*, 127–134.
39. MERNAKER, L., NAVIA, J. M. and TAYLOR, R. E. 1978. Rat molar incorporation and cariostatic effect of fluoride consumed together with sucrose. Proc. Int. Assoc. Dentr. Res. *146*, A-111. (Abstr.)

40. NAVIA, J. M. 1968. Enrichment of sugar and sugar products. J. Agr. Food Chem. *16*, 172–176.
41. NAVIA, J. M. 1983. Fortification of sugar. *In* Handbook of Nutritional Supplements, Vol. I: Human Use, M. Rechcigl, Jr. (ed.). CRC Series in Nutrition and Food. CRC Press, Boca Raton, Fla.
42. PINEDA, O. 1989. Fortificación de Azúcar con vitamina A. Manual de Operaciones. Instituto de Nutrición de Centro América y Panamá (INCAP), Guatemala.
43. SAYERS, M. H., LYNCH, S. R., CHARLTON, R. W., ROTHWELL, H., WALKER, R. B. and MAYER, F. 1974. The fortification of common salt with ascorbic acid and iron. Br. J. Haematol. *28*, 483–495.
44. STARE, F. J. 1975. Role of sugar in modern nutrition. World Rev. Nutr. Diet. *22*, 239–247.
45. TORO, O. DE PABLO, S., AGUAYO, M., GATTAN, V., CONTRERAS, I. and MONCKEBERG, F. 1976. Prevention of vitamin A deficiency by fortification of sugar: A field study. Arch. Lationoam. Nutr. *26*, 169–179.
46. VALVERDE, V., DELGADO, H., NOGUERA, A. and FLORES, R. 1984. Malnutrition in tropical America. *In* Malnutrition: Determinants and Consequences, P. L. White and N. Selvey (eds.). Alan R. Liss, New York; 1983. Proc. West. Hemisphere Nutr. Congr. *VII*, Aug. 7–11.
47. VITERI, F. E. and GARCÍA-IBÁÑEZ, R. 1977. Prevention of iron deficiency in Central America by means of sugar fortification with Na-Fe-EDTA. West. Hemisphere Nutr. Congr. *V*, 419. (Abstr.)
48. VITERI, F. E., GARCÍA-IBÁÑEZ, R. and TORÚN, B. 1978. Sodium iron Na-Fe-EDTA as an iron fortification compound in Central America. Absorption studies. Am. J. Clin. Nutr. *31*, 961–971.
49. VITERI, F. E., GUZMÁN, M. A. and MATA, L. 1973. Anemias nutricionales en Centro América, influencia de infección por uncinaria. Arch. Latinoam. Nutr. *23*, 33–53.
50. World Health Organization (WHO). Vitamin A Deficiency and Xerophthalmia. Report of a Joint WHO/USAID meeting. WHO Tech. Rep. Ser. *590*. Geneva, Switzerland.