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RETINOL STABILITY IN FORTIFIED SUGAR IN GUATEMALA

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BACKGROUND AND SIGNIFICANCE

Retinol, the active form of vitamin A, is sensitive to light, oxidizing agents, UV light and low pH values. To reduce the negative effect of these factors, the food industry has developed special compounds into which retinol is incorporated within gelatine beadlets together with antioxidating and emulsifying substances. One of the prototypes is the product called 250-CWS, the fortifying compound used in sugar and other solid foods.

In Central America, sugar is fortified at 15 micrograms of retinol per gram, that is 50 IU/g. This concentration was selected to provide at least 50-75% of the RDA, to small children of poor communities, estimating that the average sugar consumption of this group is around 20 g per day. Older persons receive a higher proportion of their vitamin A RDA values but always within safe levels.

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PRODUCTION-COMMERCIALIZATION CHAIN OF FORTIFIED SUGAR

The process of sugar fortification consists of the production of a premix made by the combination of sugar, the compound 250-CWS, an antioxidant and vegetable oil. This last ingredient serves as an adhesive between sugar crystals and vitamin A beadlets. The amount of retinol in the premix is around 1000 times higher than that in sugar.

The premix is diluted 1 to 1000 in white sugar to obtain a final retinol concentration of 15 ± 5 µg/g. Fortified sugar is packed in bulk amounts of 50 kg and is stored in warehouses. Finally, sugar is packed in smaller containers, from 1 to 10 pounds, inside transparent polyethylene bags and offered to the public in retail stores.

When the fortification program was implemented, it was determined that sugar in bulk presentations maintained 85-90% of its initial retinol level after 9 months of storage under moderate climatologic conditions.

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However, in 1991 when we compared data of the retinol content of samples from sugar mills with those obtained at the household level, we discovered a great discrepancy. For example, 94% percent of sugar samples contained retinol in the sugar mill against a mere 57% in homes. The explanation of this phenomenon may be smuggling of non-fortified sugar from neighboring countries, and/or a retinol stability lower than that previously estimated. Therefore, we decided to review the issue of retinol stability in sugar in bag sizes used for delivering it to consumers.

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OBJECTIVES

The objectives of our work were:

1. To determine the retinol stability in fortified sugar in consumer-size packages and stored under the different climatologic conditions of Guatemala.

2. To assess the effect of the container type (transparent or not) and position inside the package (surface or interior) over the retinol stability of sugar.

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METHODOLOGY

In the food pilot plant of INCAP, we prepared fortified sugar using a rotative stainless steel mixer. In difference with the industrially produced sugar, we fortified at a level of 30 µg/g with the purpose of increasing the sensitivity of the possible changes. Half of the sugar was packed inside transparent polyethylene bags. The other half was placed in plastic bags which were introduced inside paper bags to protect the samples from exposure to light. In each case, two sizes of bags were used: 1 pound and 12.5 pounds. Some of the larger bags were destined for sampling from the surface and others for sampling the sugar located in their interior. Each month, the retinol concentrations of two samples of each treatment were determined in duplicate or triplicate, using an spectrophotometric assay after retinol extraction in a ~~diethyl ether and petroleum ether mixture~~ [organic solvent phase]. For some samples, the humidity percentage was also determined.

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Replicates of each treatment were stored in four different locations of Guatemala, typical of four distinct weather conditions of the country. Thus:

Quetzaltenango, a city in the highlands, with a cold-humid climate.

Sanarate, in our semi-dry area, a hot-dry place.

Guatemala City, as an example of cool-humid climate.

And, Tiquisate, in the Pacific low lands, representative of subtropical hot and humid weather.

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RESULTS

We found that sugar samples in 1-pound packages from the hot and humid climate became wet after the 8th month of the study. To correct for the weight increase because of humidity, we determined the percentage of sucrose in the samples. From the 9th. month onward, the sugar from the hot and humid place was unacceptable for consumption, but it still contained measurable amounts of retinol.

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This table exemplifies the data that were obtained in each one of the locations. The hot and humid place was the only one that showed differences between large and small bags. Retinol stability was lower in the latter bags due to gain in humidity. In the rest of places, there were no differences in retinol stability among all treatments. Thus, we concluded that the package size and types analyzed in this work do not influence the retinol degradation rate. In other words, stability is similar in transparent or in opaque bags as well as for sugar located at the surface or in the interior. We speculate that retinol stability is better in bulky packages, because sugar is better protected against humidity and air exposure. However, we have not confirmed this detail yet.

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This figure shows the kinetic profile of retinol degradation in 1-pound samples of fortified sugar in the hot and humid place. Green squares depict transparent bags, and red squares the light-protected bags. This example illustrates that retinol degradation is a first order kinetic reaction, that is an exponential decay. In the other sites, this behavior was not as clear as the one shown here, because environmental conditions are not as homogeneous during the year as it is the case in the subtropical hot and humid location. The figure also shows that there were no differences between transparent and light-protected bags.

This table shows a summary of the results. As it was expected, retinol stability is better in cold or dry weather, and worse in hot and humid places. After 6 months of storage, the remaining amount of retinol was between 62 and 77% of its initial level. These amounts are similar to those reported for fortified beverages protected against oxygen exposure. Reports from developed countries claim that in dry foods fortified with vitamin A beadlets -as it is the case with sugar- retinol stability is 75 to 100% after 6 months of storage. The discrepancy of those results with ours could be explained by the type of packaging. Developed countries generally apply air-tight bags that are frequently aluminum laminated. We consider that with sugar, air-tight containers would improve retinol stability; however, for developing countries, at the moment, the cost increment of a better packaging is higher than the expected benefit. Higher quality packaging will come with economical and industrial development of the developing countries, but for the moment the amount of remaining retinol in sugar, under the actual conditions, is sufficient to generate biological impact in human populations.

Using this data, we estimate a retinol half-life time in small containers in Guatemala between 8 and 18 months. Similar studies in Panama with refined sugar and in very hot and humid conditions have also revealed a half-life time of 8 months.

Using the retinol degradation rate for each location, and assuming that the initial retinol value was 15 µg/g, we estimated the annual average of level retinol in sugar. In all the cases, the annual average should be from 10.5 to 11.4, high enough to produce biological response in an efficient, and inexpensive way. Considering that sugar consumption of small infants is around 20 g per day, these retinol levels would provide more than 50% of RDA values, and 100% of the Basal Requirements -amount that prevents clinical signs of deficiency, but does not lead to increments of vitamin A reserves-. Children older than 3 years and adults should be receiving even a higher proportion of their RDA values.

CONCLUSIONS

1. Apparently, container size and type currently used to sell sugar do not influence retinol stability in sugar. We consider that retinol stability in bulk presentations is better. Air-tight containers probably would improve retinol stability, but in developing countries their introduction is an issue of cost-effectiveness.

2. Combination of high environmental temperature and humidity is the main factor to cause retinol loss in sugar. Under Guatemalan weather conditions, it means a retinol half-life time in sugar of 8-18 months.

3. Under ideal production and sugar consumption practices, the most at-risk groups of the Guatemalan population should receive at least 50% of the RDA for vitamin A through sugar. However, to reach this goal, it is necessary to assure compliance with the recommended level of fortification (15 ± 5 µg/g) at the moment of sugar production.

RETINOL STABILITY OF FORTIFIED SUGAR IN GUATEMALA

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BACKGROUND AND SIGNIFICANCE

- RETINOL is sensitive to light, oxidizing agents
  UV light and low pH values

- Fortifying compounds of retinol: DRY-GELATINE BEADLETS
  (250-CWS) - Retinol plus antioxidant and emulsifying substances

- FORTIFIED SUGAR: 15 μg/g (50 IU/g)
  Small children: 20 g/day X 15 μg/g = 300 μg/day
  $\rightarrow$ 75% RDA

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PRODUCTION-COMMERCIALIZATION CHAIN OF FORTIFIED SUGAR

1. PREMIX PREPARATION: (X 1000)	sugar/250-CWS/ vegetable oil
2. FORTIFICATION OF SUGAR:	1/1000 = $15 \pm 5\ \mu g/g$
3. WAREHOUSES:	100 - pound bags (~ 45 kg bags)
4. RETAIL STORES:	5 - 10 pounds (2.3 - 4.5 kg) polyethylene and transparent bags

OD-96-03-03

SUGAR FORTIFICATION PROGRAM IN 1991
Cummulative Percentage

[Vit. A] (μg/g)	Sugar mills	Households
≥ 18	14	1
12.0 - 17.9	44	4
6.0 - 11.9	77	18
1.5 - 5.9	94	57
< 1.5	100	100
n	77	70

- smuggling?
- low retinol stability?

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OBJECTIVES

- To determine the stability of retinol in fortified sugar packaged in consumer-size bags and stored under the different climatologic conditions of Guatemala.

- To assess the effect of the container type (transparent or not) and the position of the sugar inside the package (surface or interior) over the stability of retinol in sugar.

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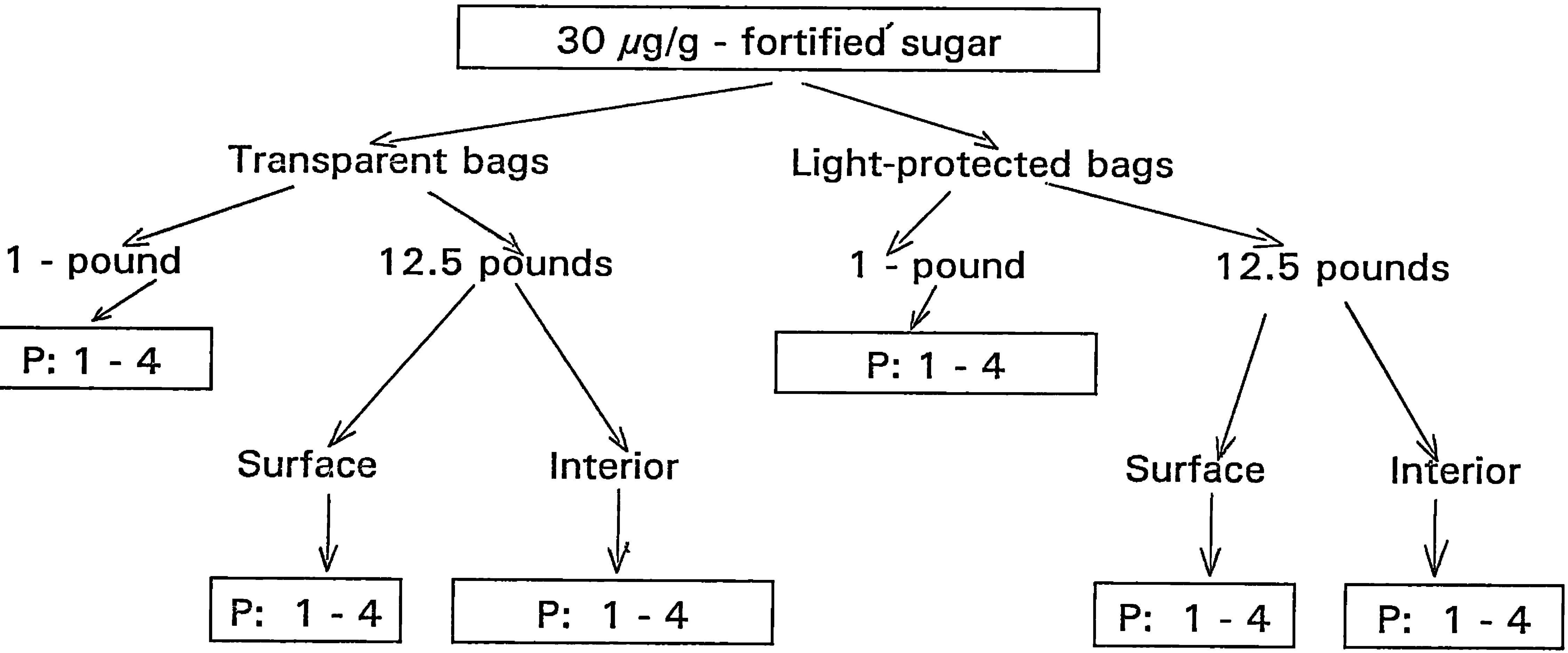
METHODOLOGY



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WEATHER CONDITIONS OF STUDIED LOCATIONS

LOCATION (altitude)	TYPE	TEMPERATURE (^{o}C)	R.HUMIDITY (%)	DAYS RAIN/ppt
QUETZALTENANGO (2380 m)	COLD-HUMID	13.5	75.1	120/797 mm
SANARATE (370 m)	HOT-DRY	27.7	62.5	114/920 mm
GUATEMALA (1500 m)	COOL-HUMID	18.8	78.5	124/1112 mm
TIQUISATE (70 m)	HOT-HUMID	25.8	74.8	134/2051 mm

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CHANGES OF SUGAR HUMIDITY DURING THE STUDY
(1 pound packages)

LOCATION TYPE	MONTH	% SUCROSE
COLD-HUMID	9	99.6
	10	99.1
COOL-HUMID	9	99.3
	10	99.6
HOT-HUMID	9	87.7
	10	89.0
	11	83.4

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RETINOL STABILITY IN SUGAR
(TIQUISATE, HOT-HUMID PLACE)
(% Initial Value)

MONTH	1 Pound		12.5 Pounds			
	Transp.	Dark	Transp. S.	Transp. I.	Dark S.	Dark I.
1	90	80	89	74	90	94
2	92	85	99	85	74	74
3	67	76	96	78	71	78
4	68	79	72	72	67	66
6	58	60	57	67	64	61
7	48	42	48	52	45	51
9	38	33	42	46	34	39
10	27	31	39	45	49	42
11	20	23	43	47	46	43

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RETINOL STABILITY AND ESTIMATION OF THE ANNUAL AVERAGE LEVEL AND INTAKE

LOCATION TYPE	Months storage (12.5 lbs) % Initial Value			ANNUAL AVERAGE (μg/g)*	Infant Retinol Intake**	
	3	6	9		% RDA	% B.R.
COLD-HUMID	90 ± 14	77 ± 7	66 ± 4	11.4	57	114
HOT-DRY	92 ± 8	71 ± 14	63 ± 10	11.0	55	110
COOL-HUMID	83 ± 16	69 ± 8	43 ± 6	10.9	54	108
HOT-HUMID	80 ± 11	62 ± 4	40 ± 5	10.5	52	104

* Assuming and initial value of 15 μg/g
** Assuming 20 g sugar daily consumption

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CONCLUSIONS

1. Apparently, container size and type currently used to sell sugar do not influence retinol stability in sugar. Air-tight containers probably would improve retinol stability, but their introduction is an issue of cost-effectiveness.

2. Combination of high environmental temperature and humidity is the main factor to cause retinol loss in sugar. Under Guatemalan weather conditions, it means a retinol half-life time in sugar of 8 - 18 months.

3. Under ideal production and sugar consumption practices, the most at-risk groups of the Guatemalan population should receive at least 50% RDA of vitamin A through sugar. However, to reach this goal, it is necessary to assure compliance with the recommended levels of fortification (15 ± 5 $\mu g/g$) at the moment of sugar production.

SUGAR CONSUMPTION AND VITAMIN A INTAKE FROM SUGAR BY INFANTS OF GUATEMALAN CHILL CARE CENTERS

Age (Months)	Sugar Consumption (g/day)	Vit. A - Intake* (% RDA)	Vit. A Deficiency** (% < 20 μg/dL)
6 - 11	14.4	20.6	---
12 - 23	16.1	20.1	19.9
24 - 35	25.8	32.2	17.7
36 - 47	37.7	47.1	13.1
48 - 59	44.0	55.0	11.9

* Assuming a retinol sugar level = 5 μg/g

** Guatemalan National Survey, 1995

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VITAMIN A DEFICIENCY IN INFANTS OF GUATEMALA, ECUADOR, NICARAGUA, AND DOMINICAN REPUBLIC (% below 20 μg/dL)

Age (Months)	GUATEMALA (1995)	ECUADOR (1993)	NICARAGUA (1993)	DOMINICAN REPUBLIC (1991)
12 - 23	19.9	20.8	34.3	15.4
24 - 35	17.7	21.2	28.4	24.8
36 - 47	13.1	15.4	35.4	20.2
48 - 59	11.9	14.8	26.5	18.3
r with age	- 0.977	- 0.899	- 0.485	0.134
General Deficiency	15.8	17.7	31.3	19.6

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