PREVENTION OF VITAMIN A DEFICIENCY BY FORTIFICATION OF SUGAR. A FIELD STUDY

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SUMMARY

The small amount of vitamin A in the diet of people living in some regions of Chile can be increased by adding this vitamin to sugar.

In order to evaluate the effectiveness of a sugar fortification program, vitamin A fortified sugar was distributed to four indian villages in the mountainous region of Arica, whose inhabitants showed a severe vitamin A deficiency. The results of this study demonstrate that sugar fortification program is able to correct vitamin A deficiency by elevating the vitamin intake and consequently improve the circulating retinol, without substantially increasing the cost or modigying the organoleptic characteristics of sugar.

INTRODUCTION

During the last years, the importance of vitamin A in Nutrition has been studied extensively (1,2). It has been described that its deficit produces growth retardation and modifications in different tissues, especially epithelial membrane and mucosa, reducing at the same time resistance to infections (3). Visual alterations are probably the more severe leading to total blindness (4). Lately it has been demonstrated that vitamin A deficit interferes with the utilization of proteins in the diet (5).

Different analyses done in underdeveloped countries have concluded that hypovitaminosis A constitutes a great problem in Public Health, probably being the most important vitamin deficiency (1,6). Studies done in Chile have also confirmed this situation (7,8).

The logical recommendation to solve this deficiency would be to increase the ingestion of natural sources of this vitamin, such

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as those of animal origin (codfish liver oil, bovine etc.), and vegetables rich in β -carotene. However, this is not easy, especially in those low income socioeconomic groups, due to their low purchasing power or poor food habits or to a deficiency in the infrastructure of marketing. The administration of oral individual doses of vitamin A, especially in the poorer areas has been proposed (9). This procedure, however, appears to face some difficulty and for this reason it seems convenient to look for other solutions to assure adequate and continued supply of vitamin A to the whole population. In Latin America the INCAP (Instituto de Nutrición de Centro América y Panamá) was pioneer in developing a process for the fortification of sugar with vitamin A. (10). Considering what has been done to fight iodine deficiency, we have also, thought to add vitamin A to a low cost foodstuff widely consumed. We have chosen different possibilities in search of an appropiate vehicle; this vehicle should have the following characteristics (10):

1. A wide and constant consumption by the population.
2. The addition of vitamin A should not change the organoleptic characteristics of the original product.
3. The vehicle should have a long shelf life.
4. The fortification process should not substantially raise the price of the product.

From an analysis of the Chilean diet, two types of foods display these characteristics:

a) Wheat flour, widely consumed by all of the population, especially in those groups of low socio-economic conditions, to whom wheat flour means 50% of their daily calories (a percentage that diminishes in groups of higher socio-economic level) and

b) sugar: according to the National Nutrition survey, a consumption of 30-40 grs. per person per day is average and this amount is distributed to the population more or less evenly. At first thought it seems more logical to fortify wheat flour which could more easily cover the eventual organoleptic alterations, but the implementation seems difficult because in our country there are 200 mills producing wheat flour. Eighty percent chilean sugar however, is produced in only two plants.

At present there are water dispersable vitamin A preparations among them retinol palmitate 250-SD and retinol acetate 325-L, Hoffmann La Roche, whose absorption in vitamin A depleted experimental animals is very efficient (11). For this reason we have analyzed in a population study, the feasibility of preventing vitamin A deficiency by the fortification of sugar.

MATERIALS AND METHODS

Study of absorption of retinol acetate in normal individuals

As a verification of previous studies (done on experimental animals) (11). the absorption of retinol acetate 325 L was evaluated in the human. In a group of ten normal individuals, all volunteers, the fasting basal levels of serum retinol were determined. After administering a single dose of 25.000 I.U. (7.5000 ug of retinol equivalents), blood samples were drawn two, three and four hours later, thus obteining an absorption curve. Seven days later, the individuals were submitted to the same test, but vitamin A was given together with a breakfast consisting of a cup of coffee and cheese sandwich. The total caloric intake was 380 Kcal and the total lipid content of the food was 8 g.

Stability Study

To study the stability of vitamin A added to sugar, samples were kept at 5°C in a cold room, at room temperature (18°C – 30°C) with varying humidity and at room temperature with high humidity (80%). Stability was determined after three, six and eight months respectively.

The method of Nield and Pearson adapted by Hoffmann La Roche was used to determine vitamin A content of the fortified sugar.

Population Study

To carry out the field studies an isolated population of very low socioeconomic level with a high prevalence of vitamin A deficiency (90% of the population consumed less than 1250 I.U. (375 ug) per day was chosen. The test area was four native villages with about 1600 inhabitants situated along the borders between Chile, Peru and Bolivia in a mountainous area near Arica at 3.000 to 3.500 m above sea level. Sugar was provided by four stores operated by the Government. The were no other inhabited places for more than 200 km. so there was no obvious possibility for this population to consume sugar other than that supplied by these stores.

Sugar was fortified with water dispersable retinol acetate 325 L (Hoffmann La Roche product) which consists of a pre-mixture of sugar and vitamin A acetate with similar particle size to that of the end product.

The selection of the level of the fortification was based on

the recommended daily allowance of vitamin A for the adult as cited by the National Research Council (12).

Inasmuch as the National Survey showed 40 grams of sugar to be the average intake of the population from which our volunteers came it was decided to fortify to the level that each 40 grams of sugar would contain sufficient vitamin A to meet the National Research Council recomendation or 5000 IU (1.500 ug).

In the four villages (Chapiquiña, Socoroma, Belén and Putre) a previous study was done that included following parameters:

I. Nutritional survey: Designed to show the daily consumption of vitamin A in 10 – 15% of the population.
II. Clinical Examination: The same population sample was used to evaluate the nutritional status of the population and to detect symptoms and signs attributable to vitamin A deficiency.
III. Serum levels of retinol and β – carotene from a total of 160 school children and 60 adults. (13).

After initial sampling and examination of the sample, the whole of the population was given sugar fortified with vitamin A for a three month period. This was a blind study with consumption ad libitum. At the end of this period, blood serum determination of retinol and β Carotene were carried out on the same individuals as previously described.

After those three months of ingestion of fortified sugar, this was replaced by regular sugar, and three months later, the same parameters were determined in the population.

RESULTS

Study of vitamin A absorption in normal adults.

Table 1 shows fasting retinol levels at time O. (Basal levels) and at the maximal level reached after the administration of a single dose. The same table shows the results of a modified repetition of the test in which vitamin A was administered with a breakfast. In the first case, the maximal improvement level was close to 50% of the basal value. The administration of vitamin A together with caloric and lipidic intake also produced an increase in retinol plasma concentration significantly higher ($p < 0.001$) if compared with the previous test in which vitamin A was given without food.

Stability study of the mixture of sugar and vitamin A.

Table 2 shows the values in percentage of retinol acetate activity in sugar when the samples were subjected to the conditions previously described for periods of three, six and eight months.

TABLE 1

Absorption study of water dispersable Vitamin A, (retinol acetate 325-L, Hoffmann La Roche) in 10 normal adult individuals submitted to a single dose, on two different occasions (single dose: 25.000 I.U. (7500 ug of retinol equivalents)

	Fasted	Breakfast, 380 Kcal
	X S.D.	X S.D.
Blood serum retinol at zero time (ug/100 ml)	46 ± 20.6	48 ± 15.1
Blood serum retinol; maximun observed (ug/100 ml)	65 ± 25.0	104 ± 44.2 $p < 0.01$
	$p < 0.01$	$p < 0.001$
Average percent increase over zero time	48.5%	116%

TABLE 2

Stability study of fortified sugar with water dispersable vitamin A, during a storage period of 3, 6 and 8 months. Retinol acetate 325-L, Hoffmann La Roche (37.5 ug/g sugar)

	0	3 months	6 months	8 months
A	100%	98.7%	95.0%	80.3%
B	100%	89.2%	82.4%	95.6%
C	100%	91.6%	86.0%	88.4%

A: Cold room at 5°C
B: Room temperature (18°C – 30°C) with varying humidity
C: Room temperature with high humidity (80%)

Study of organoleptic changes.

In order to determine the possible organoleptic changes in sugar due to vitamin A fortification, a taste panel was made up of previously trained personnel working at the Department of Nutrition and Food Technology, University of Chile.

The paired and triangular tests were used in this study using a

level of probability of 1% in samples of coffee, powdered juices and cakes.

The acceptability study showed good results and there was no rejection of the products with fortified sugar.

While fortified sugar with vitamin A showed no flavor changes when added to cakes and powdered juices it could be detected when mixed with coffee. The taste was not described as disagreable but as a slightly medicinal taste.

Field study

A clinical and anthropometric study was conducted prior to the fortification of sugar with vitamin A. A representative sample of the population was taken, and important differences were detected when compared to the parameters given for the population measurements of Iowa. (Table 3). At the same time, a high frequency of clinical signs attributable to a vitamin A deficiency (specially in skin and conjunctival xerosis) were observed. Approximately 70% of the population showed some of this signs, but only one adult showed keratomalasia.

Table 4 shows the results obtained from the nutritional surveys made during different periods of the experiment; before starting the fortication of sugar, receibing the fortified sugar, and three months after having discontinued the fortified sugar. The mean caloric intake was low and showed little variation during all

TABLE 3

Anthropometric study in adults and children of four native villages of the mountanious area near Arica, Chile

	Over 18 years of age	
	Weight (kg)	Height (cm)
Males	59.5 ± 1.4	160.8 ± 0.9
Females	53.1 ± 1.2	148.9 ± 0.7
	Under 18 years of age Percentage below 25th Percentile Iowa (13)	
	Weight (%)	Height (%)
Males	63.5	88.5
Females	61.5	96.3

TABLE 4

Intake of nutrients in children and adults of four native villages of the montainous area of Arica, before and after three months of fortified sugar consumption and three months after it was discontinued

		N	Calories	Proteins total (g)	Proteins, animal source (%)	Carbohydrates drate (g)	Lipids (g)	Retinol Natural sources (g)	Retinol Natural sources ± retinol from fortified sugar (ug.)
	0 (basal)	60	1.561	50.3	46.0	271.3	32.4	423	—
	3 months	100	1.663	51.0	39.0	294.0	35.0	219	1.221
ıildren	6 months	100	1.580	48.0	31.0	257.7	33.6	344	—
	Recommendations: (12)		2.500	43.0	75.0	350.0	97.0	1.300	1.300
	0 (basal)	60	1.586	53.0	32.0	349.0	23.6	306	—
	3 months	20	2.057	73.0	45.0	381.0	51.0	344	1.298
ıdults	6 months	20	1.391	41.0	11.0	246.0	25.4	193	—
	Recommendations: (12)		2.300	50.0	25.0	320.0	90.0	1.500	1.500

study periods. The same low intake was true regarding protein intake from animal origin and also the natural vitamin A intake from the meal pattern. This observation was similar in both adults and children.

Table 5 shows the serum retinol concentration and of β carotene before starting the experiment, after three months fortified sugar and three months after discontinuing the fortified sugar. Before giving vitamin A fortified sugar, 76% of the infantile population showed serum retinol levels below 20 ug/100 ml, 59% of the adult population showed retinol serum levels below 20 ug/100 ml. β-carotene serum levels were also low. Some 57% of the infantile population and 61% of the adults showed values below 50 ug/100 ml.

After receibing vitamin A fortified sugar for three months, a marked increase of serum retinol concentration was observed. Only 29% of the children and no adults showed values below 20 ug/100 ml. β-Caratone serum levels showed no substantial difference, the same percentage of individuals with values below 50 ug/100 ml persisted. Three months after discontinuing the fortification of sugar with vitamin A, a marked increase was observed in the number of individuals reverting to low serum retinol levels; 51% of the infantile population and 50% of the adult population. There were no significant changes during the study period in serum β-carotene concentrations. This was to be expected in that eating habits remained constant.

Surprisingly clinical symptoms attributable to a vitamin A

TABLE 5

Serum retinol and carotene in 160 school children and 60 adults of four native villages of the mountanious area of Arica, before and after three months of receiving sugar with vitamin A and three months after it was discontinued.

		Basal	Fortified sugar	Non-fortified sugar
		0	3 months	6 months
Serum retinol: Percent of individuals below 20 ug/100 ml.	School Children	76%	29%	51%
	Adults	59%	0%	50%
Serum carotene: Percent of individuals below 50 ug/100 ml.	School Children	57%	60%	63%
	Adults	61%	51%	61%

deficiency showed no modifications in their frequencies during the three periods studied.

During the study no individual, adult or child, perceived organoleptic changes in the vitamin A fortified sugar. We must point out however that our studied population belonged to a low socioeconomic and non-western cultural category (Indian population).

DISCUSSION

Different surveys have pointed out the fact that an important part of the world's population, especially in underdeveloped areas, shows a deficit in vitamin A intake (1, 2, 6) and that this interferes in the processes of grouth, development and health conditions.

Because of the poor socioeconomic development of these populations and their low purchasing power, the probability of correcting this deficit in a short period of time by increasing the consumption of the conventional foods rich in preformed vitamin A or even β–Carotene is very low. Results obtained in this experiment showed that it is feasible to fortify a widely consumed and low cost food with vitamin A to obtain increases in serum concentrations of vitamin A. In the populations studied after three months of receiving vitamin A fortified sugar, a significant increase in serum retinol level could be observed. It could further be shown that this level decreased with interruption of the fortification. From this experiment it seems evident that changes observed in serum retinol were the result of an increase in vitamin A intake the population received when sugar was fortified with this nutrient.

On the other hand, during whole of the study period, no variations were observed in serum carotene values, which was not unexpected since that carotene was exclusively received from the vegetables of the ordinary meals. The β–carotene intake during the study period was not modified as shown by the dietary survey made in each period.

The clinical signs attributed to vitamin A deficiency showed no changes among the population during the administration of vitamin A fortified sugar. This could be because the administration period was short, the evaluation was relatively subjetive and/or because the clinical signs are not necessarily pathognomonic. There may be some stresses resulting in alterations which interfere with the interpretation of the clinical signs.

These results indicate that the procedure of fortifying a determined product that is widely consumed by the population, especially that of low incomes, could be a desirable solution. In this case, sugar seems to be the most adequate product to be fortified but undoubtedly, other populations can fortify other pro-

ducts in relation to their food habits, marketing systems or socio-economic conditions.

RESUMEN

La prevención de la deficiencia de Vitamina A mediante la fortificación del azúcar, un estudio de campo.

El escaso aporte de vitamina A en la dieta de los habitantes de algunas regiones chilenas, puede ser mejorada incluyendo esta vitamina en un vehículo alimenticio de amplio y regular consumo.

Para evaluar un programa en terreno, se distribuyó azúcar fortificada con vitamina A en cuatro poblados indígenas de la precordillera de Arica, cuyos habitantes presentaban una severa deficiencia de vitamina A. La evaluación de este programa demuestra que una medida de este tipo puede corregir la ingesta insuficiente de este nutriente, acercándola al óptimo requerido y consecuentemente elevar los niveles del retinol circulante, sin introducir modificaciones sustanciales en las características organolépticas y costos del azúcar.

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