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Enrichment of the diet with synthetic and natural sources of provitamin A

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SUMMARY. The use of available food rich in provitamin A and retinol as well as fortification of local food are known to result in adequate vitamin A status. In Brazil, several regional foods are known to be good sources of provitamin A such as buriti, several palm oils, mango and others. Improving the consumption of these locally available natural sources of provitamin and vitamin A would cover the needs of the vulnerable population. At the same time fortification of industrialized foods with natural and/or synthetic forms of provitamin A could speed up and fill the gap between requirement and low intake of this vitamin in many parts of the country. This approach has been considered by many as the most effective intervention program to prevent micronutrient deficiencies in developing countries. Our previous studies on the subject have shown that cooking vegetable oil, mainly soybean oil, is a very good alternative vehicle to be fortified and supply vitamin A to the population. Lately we have also enriched the same soybean oil with ß-carotene. Addition of this provitamin A to the oil showed it to be stable when heated at cooking and frying temperatures (retention of 92.4±6.7% and 65.4±8.6%, respectively). When rat or human food was prepared with carotene-enriched cooking oil, its bioavailability in experimental animals and absorption in humans were shown to be adequate. An alternative for Brazil, besides adding chemical forms of the vitamin to the cooking oil, would be to mix available carotene-rich palm oil to the soybean oil. There are already regional uses of carotenoid-rich palm oils in the preparation of local dishes in some parts of Brazil and this would facilitate its acceptance by the population. Enrichment of common foods in Brazil, such as soybean oil, with chemical forms of ß-carotene or mixing rich sources of provitamin A can be a good alternative to improve the intake of vitamin A by the Brazilian population.

Key words: ß-carotene, micronutient fortification, soybean oil fortification, Brazil.

RESUMO. Enriquecimento da dieta con pró-vitamina A usando fontes naturais e sintéticas. O uso de alimentos localmente disponíveis, ricos em pró-vitamina A e retinol, bem como a fortificação de alimentos, apresenta resultados conhecidos na melhora do estado nutricioal em relação a esse nutriente. No Brasil, diversos alimentos regionais são conhecidos como boas fontes de pró-vitamina A tais como o buriti, azeite de dendê, manga o outros. O aumento do consumo desses alimentos poderia suprir as necessidades de vitamina A da população vulnerável. Ao mesmo tempo, a fortificação de alimentos industrializados com forma sintética ou natural de pró-vitamina A poderia contribuir para uma adequação mais rápida da quantidade de vitamina A ingerida em muitas partes de nosso país. O enriquecimento de alimentos tem sido considerado por muitos como método mais efetivo para prevenir a deficiência de micronutrientes em países en desenvolvimento. Nossos estudos prévios sobre esse assunto têm mostrado que o óleo vegetal, especialmente o de soja, é um bom veículo alternativo para a fortificação com vitamina A. Mais tarde, nós também enriquecemos o óleo de soja com ß-caroteno. Nossos estudos mostraram que o ß-caroteno é bastante estável quando aquecido a temperatura de cozimento e fritura (retenção de 92,4±6,7 e 65,4±8,6%, respectivamente). O cozimento de alimentos preparados com óleo enriquecido não alterou significativamente a biodisponibilidade do ß caroteno sintético em ratos nem sua absorção em humanos. O enriquecimento do óleo de soja com óleos de palma naturalmente ricos em pró-vitamina A pode ser uma alternativa para o Brasil. Oleos de palma são utilizados no preparo de pratos regionais em algumas partes do país, e isso poderia facilitar a aceitação pela população. O enriquecimento de alimentos, como o óleo de soja, usualmente consumidos no Brasil, con ß-caroteno sintético ou através da mistura de fontes naturais de pró-vitamina A pode ser uma boa alterenativa para aumentar a ingestão de vitamina A pela nossa população.

Palavras chave: ß caroteno, fortificação com micronutientes, fortificação do óleo de soja, Brasil.

INTRODUCTION

Studies on the biological and functional effects of carotenoids are lately growing and there is a great interest on their results. The provitamin A activity and availability of several carotenoids are important, considering that almost 60% of dietary vitamin A is supplied as provitamin A (1), reaching 85% in developing countries because of the high cost of animal foods (2).

The best sources of carotenoids are green leafy vegetables, carrots, sweet potatoes, pumpkins, yellow and orange tropical fruits and several palm fruits, quite common in Brazil and other tropical countries (3).

For a food to be considered a good source of provitamin A, it is necessary to have not only a large amount of the carotenoids, but also a high bioavailability. The presence of dietary fiber

and fat has influence on their absorption (3,4). The effect of industrial processing on their utilization is also known, increasing or decreasing it (3).

The bioavailability of carotenoids as a source of vitamin A in humans have been analyzed in several studies (Table 1). As vitamin A deficiency is a great public health problem in several parts of the world, it is necessary to know the utilization and effectiveness of different foods on the prevention of this micronutrient problem and to improve the consumption of vitamin A-rich foods, mainly by children.

TABLE 1
Effect of provitamin A on the improvement of nutritional status of children living in high prevalence areas of vitamin A deficiency

Food	Author	Country	Effects observed
Buriti (sweet of buriti)	Mariath et al (5)	Brazil	Restoration of liver reserves - relative dose response. Regression of clinical xerophthalmia
Spinach (boiled)	Hussein & El Tohamy (6)	Egypt	Increase in plasma retinol levels
Carrots (grated)	Hussein & El Tohamy (7)	Egypt	Increase in plasma retinol levels
Palm oil	Lian et al. (7)	Indonesia	Increase in serum vitamin A levels Decrease in prevalence of xerophthalmia
Palm oil	Rukmini C. (8)	India	Increase in serum vitamin A levels Restoration of liver reserves - modified relative dose response
Dark-green leafy vegetables	Charoenkiatkul et al. (9)	Thailand	Increase in serum vitamin A levels
Carrot, papaya and coriander-mint chutney	Wadhwa et al. (10)	India	Increase in serum vitamin A levels

The ACC/SCN Consultative Group (11) suggested four activities to improve consumption of vitamin A from local diets in risk populations: (a) nutrition education or communication, using social marketing approach, to improve practices related to the consumption of available vitamin A-rich food sources; (b) horticultural interventions and home food gardens to increase availability of vitamin A-rich foods; (c) economic/food policies affecting availability, price and effective demand for vitamin A-rich foods; (d) technological advances concerning food preservation, plant breeding, etc.

There is no doubt that improving consumption of vitamin A-rich foods is a good and inexpensive approach to prevent this micronutrient deficiency, when these foods are available and consumed locally. At the same time these foods are, sometimes, sources of other vitamins and minerals. When food behaviour changes are needed, the problems is much more complicated. Success of this intervention is linked to several other socio-economic and cultural factors that should be solved simultaneously.

On the other hand, enrichment of industrialized food is considered by many experts as the most effective method to prevent micronutrient deficiencies, including vitamin A (2).

Several food products have been used to increase the intake of vitamin A in different parts of the world. Vehicles such as sugar, tea, cereals, monosodium glutamate were tried and some of them are still currently used (12-15).

The literature is limited in relation to food fortification with carotenoids as a source of vitamin A. It has a large industrial use, mainly as food improvers and colorants (16,17).

In Brazil, several pasta manufacturers add ß-carotene in the amount of 2,000 to 4,000 IU/kg of their product. There is a high consumption of macaroni in Brazil and its consumption is considerable among low socio-economic level people. It is inexpensive and can be a good alternative for enrichment.

Pereira et al. (16) verified the amount of total carotenoid and ß-carotene in 41 samples of fortified spaghetti from the six largest plants in Brazil and found amounts as specified in the labels, in the greatest part of the samples. They also cooked several samples and measured the amount of ß-carotene before and after heating. A good retention of ß carotene was found after cooking. Their conclusion was that the fortification of dried pasta could be valid.

In Brazil, Chile, Colombia, Mexico, Honduras, El Salvador, Guatemala, Panamá, Equador and Peru, the addition of vitamin A to margarine is compulsory. ß-carotene is sometimes added to the product, but only as a coloring agent. Our laws do not specify the percent of vitamin A that may be present as ß-carotene. Rader et al. (17) analysed 19 margarine and similiar products sold in Washington in relation to the amount of retinyl ester and ß-carotene. Except in one product, ß-carotene

was equivalent to 20-40% of the total vitamin A content.

We have been studying for the last 6-8 years the fortification of cooking vegetable oils, mainly soybean oil, as a carrier to supply vitamin A to the population in need (18-20). The product is consumed daily all over the country by the population, including low socio-economic groups. Soybean oil has many characteristics which make it a very attractive and useful carrier of oil-soluble products such as vitamin A and carotene. Brazil is the second largest world producer of soybean. The crop is industrially processed in a few large industrial plants, from where it is distributed all over the country. There is good industrial quality control and the oil is rich in energy, unsaturated fatty acids and vitamin E. It favors the homogenization of fat-soluble vitamins and their absorption.

Our present studies with the fortificatin of cooking soybean oil with ß-carotene (21) showed that after cooking (100°C-20 min.) ß-carotene retention was 92.3±6.7% and after frying (170°C/3 times) 65.4±8.5% (Table 2).

TABLE 2
Stability of ß-carotene in fortified soybean oil after heat treatment (21)

Sample	Retention of ß-carotene (%) 100°C 20 min	170°C three times
1	99.7	48.7
2	89.5	63.6
3	80.1	60.7
4	92.0	70.1
5	90.0	71.5
6	97.6	72.4
7	97.6	70.6
Mean ± SD	92.3±6.7a	65.4±8.5b

Values with different letters in the same line are significantly different at $p < 0.05$ (Tukey's test)

Evaluation of bioavailability of the carotenoid added to oil before and after heating, were carried out in rats (21). It was found that the amount of retinol stored in the liver of animals receiving diets with 4 RE/g of ß-carotene, when heated at 100°C during 20 minutes, did not show statistical difference from the group which received the same amount of carotene in unheated oil. The group which received the diet with the enriched oil heated at 170°C three times had reduced liver levels of vitamin A, but had values similar to those of the control group that received unheated oil, having 2 RE/g (Table 3). Higher temperature and succesive heating seem to reduce levels of stored vitamin A, but reasonable levels are still kept.

In our last paper on the subject (22), the absorption in humans of ß-carotene added to soybean oil was measured before and after heating, when the oil was used to cook Brazilian food. Sixteen healthy adults, males and females, received on the first trial day the same meal including rice cooked with carotene-enriched oil or unenriched oil. The meal consisted of rice, beans and meat in the same proportion and quantity. Blood was collected five fasting times (1,2,3,7,11 days of study) and plasma carotene was measured. Absorption was calculated by the peak rise and the area under the curve (Figure 1 and Table 4). Results showed that the ß-carotene added to the soybean oil was well absorbed with or without heating.

TABLE 3
Plasma and liver total vitamin A of rats fed diets containing ß-carotene-fortified soybean oil with and without heat treatment (21)

	Plasma (µmol/L)	Liver (µmol/g)
Diet 1-2 RE/g, no heat	1.29±0.23a	0.47±0.09a
Diet 2-4 RE/g, no heat	1.19±0.39a	0.64±0.08b
Diet 3-8 RE/g, no heat	1.23±0.19a	0.97±0.14c
Diet 4-4 RE/g, heat 100°C	1.11±0.32a	0.72±0.06b
Diet 5-4 RE/g, heat 170°C	1.12±0.28a	0.45±0.04a

Values are expressed as means ± SD. Values with different letters in the same column are significantly different at $p < 0.05$ (Tukey's test)

FIGURE 1
Plasma fasting levels of ß-carotene after rice intake with fortified soybean oil, added during or after cooking

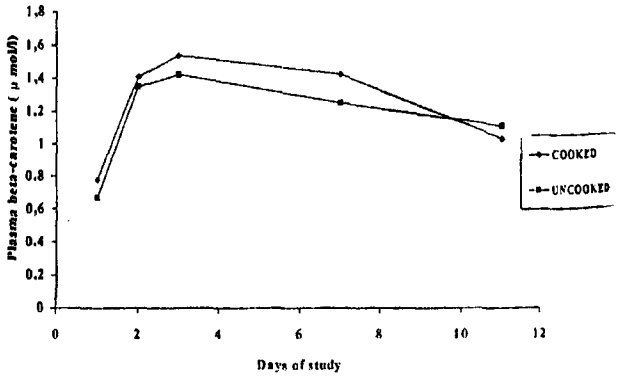

TABLE 4
Efect of heat treatment during rice cooking with ß-carotene-fortified soybean oil and its impact on postprandial absorption of ß-carotene in human subjects. Data as X ± SEM (22)

	Area under curve (µmol/h/L) Cooked	Uncooked	Peak rise (µmol/l) Cooked	Uncooked
Men (n=6)	1.69±0.260	1.33±0.232	0.66±0.097	0.49±0.062
Women (n=10)	2.25±0.358	2.86±0.584	1.04±0.117	1.14±0.238
Total (n=16)	2.04±0.248	2.27±0.415	0.90±0.091	0.90±0.168

The possibility of enriching cooking soybean oil with other provitamin A-rich natural oils available in Brazil, as

buriti and palm oil, is a good alternative for Brazil because the amount of provitamin is quite high and the Brazilians are used to their taste and color. It can be a good local alternative to supply carotenoids to the population. It confers on the oil a nice orange color that can help foster its acceptance. Further studies should be carried out on this subject.

REFERENCES

1. Simpson KL. Relative value of carotenoids as precursors of vitamin A. Proc Nutr Soc 1983;42:7-17.
2. McLaren DS, Frigg M. Sight and life malnutrition vitamin A deficiency disorders (VADD). Basel: Task Force Sight and Life, 1997.
3. Rodríguez-Amaya DR. Carotenoids and food preparation: The retention of provitamin A carotenoids in prepared, processed and stored foods. Arlington: Opportunities for Micronutrient Intervention (OMNI), 1997.
4. Rock CL, Servendseid ME. Plasma ß-carotene response in human after meals supplemented with dietary pectin. Am J Clin Nutr 1992;55:96-9.
5. Mariath JGR, Lima MCC, Santos LMP. Vitamin A activity of buriti (*Mauritia vinifera* Mart.) and its effectiveness in the treatment and prevention of xerophthalmia. Am J Clin Nutr 1989;49:849-53.
6. Hessein L, El-Tohamy M. Effect of supplementation with vitamin A or plant carotenes on plasma retinol levels among young Egyptian males. Int J Vit Nutr Res 1988;59:229-33.
7. Lian OK, Tie LT, Rose CS, Prawiranegara DD, Gyögy P. Red palm oil in the prevention of vitamin A deficiency. Am J Clin Nutr 1967;20:1267-74.
8. Rukmini C. Red palm oil to combat vitamin A deficiency in developing countries. Food Nutr Bull 1994;15:126-9.
9. Charoenkiatkul S, Valyasevi A, Tontisirink. Dietary approaches to the prevention of vitamin A deficiency. Food Nutr Bull 1985;7:72-6.
10. Wadhwa A, Singh AM, Sharma S. Dietary intervention to control vitamin A deficiency in seven-to twelve-year-old children. Food Nutr Bull 1994;15:53-6.
11. ACC/SCN Consultative Group. Controlling vitamin A deficiency. ACC/SCN State-of-the-Art Series, Nutrition Policy Discussion Paper nº 14, Ottawa: United Nations, 1994.
12. Arroyave G, Mejia LA, Aguilar JR. The effect of vitamin A fortification of sugar on the serum levels of preschool Guatemalan children: a longitudinal evaluation. Am J Clin Nutr 1981;34:41-9.
13. Muhilal A, Murdiana I, Azis S, Saidin S, Jahari AB, Karyadi D. Vitamin A fortified monossodium glutamate and vitamin A status: a controled field trial. Am J Clin Nutr 1989;48:1265-70.
14. Brooke CL, Cort WM. Vitamin A fortification of tea. Food Technol 1972;26:50-2.
15. Murphy P, Smith B, Hauck C, Connor KO. Stabilization of vitamin A in a synthetic rice premix. J Food Sci 1992;57:437-9.
16. Pereira MR, Amaya-Farfan J, Rodriguez-Amaya DB. ß-carotene content of Brazilian fortified pasta. Food control 1999;10:81-5.
17. Rader YI, Weaver CM, Patrascu L, Ali H, Anyal G. α-Tocopherol, total vitamin A and total fat in margarine and margarine-like products. Food Chem 1997;58:373-9.
18. Fãvaro RMD, Ferreira JF, Desai ID, Dutra de Oliveira JE. Studies on fortificatin of refined soybean oil with all trans retinyl palmitate in Brazil: stability during cooking and storage. J Food Comp Anal 1991;4:237-44.
19. Fávaro RMD, Miyasaaka CK, Desai ID, Dutra de Oliveira JE. Evaluation of the effect of heat treatment on the biological value of vitamin A fortified soybean oil. Nutr Res 1992;12:1357-63.
20. Dutra de Oliveira JE, Desai ID, Fávaro RMD, Ferreira JF. Effect of heat treatment during cooking on the biological value of vitamin A fortified soybean oil in human. Int J Food Sci Nutr 1994;45:203-7.
21. Dutra de Oliveira JE, Fávaro RMD, Junqueira Franco MVM, Carvalho CG, Jordão AA Jr, Vannucchi H. Effect of heat treatment on the biological value of ß-carotene added to soybean cooking oil in rats. Int J Food Sci Nutr 1998;49:205-9.
22. Dutra de Oliveira JE, Fávaro RMD, Leonardo IR, Jordão AA Jr, Vannucchi H. Absortion by humans of beta-carotene from fortified soybean oil added to rice: Effect of heat treatment. J Amer Coll Nutr 1998;17:361-5.