Review Article

# A place for palm fruit oil to eliminate vitamin A deficiency*

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There is general consensus that food-based approaches are viable and sustainable options for addressing vitamin A deficiency in populations. One such example is the fortification of food which, if properly monitored, could make a significant contribution towards improving the vitamin A status of populations throughout the world. Red palm fruit oil (RPO) with its high content of natural carotenoids, lends itself exceptionally well to this purpose at both household and commercial level. Results are now available from several feeding trials incorporating RPO into diets at household level or into commercially manufactured products. RPO in the maternal diet was shown to improve the vitamin A status of lactating mothers and their infants. Consumption of RPO incorporated in a sweet snack or biscuits significantly improved plasma retinol concentrations in children with subclinical vitamin A deficiency. There is evidence that if only 35-50% of the recommended daily intake for vitamin A were to be provided by RPO, it may be sufficient to prevent vitamin A deficiency (hypovitaminosis A). Red palm oil has a highly bioconvertible form of alpha- and beta-carotene, a long shelf life, and a higher cost/benefit ratio when compared to other approaches such as high-dose-vitamin A supplements and fortification of foods with retinyl ester fortificants. Consumption of RPO is safe and cannot produce hypervitaminosis A. Considering all the current information about RPO, the initiation of food-based interventions involving its use in developing countries with an endemic vitamin A deficiency problem, appears to be a logical choice.

**Key Words: red palm oil, vitamin A deficiency, fortification, developing countries, food-based approaches**

## Introduction

According to a recent report, the global prevalence for clinical vitamin A deficiency for preschool children in 1995 was estimated to be 1.2%.[1] For subclinical vitamin A deficiency, on a global basis, it is estimated that 140 million preschoolers are affected by subclinical vitamin A deficiency.[1] The highest prevalences of both clinical and subclinical vitamin A deficiency occur in south Asia and Sub-Saharan Africa where 30-40% of preschool children are at an increased risk of ill health and death because of this deficiency. Of the 140 million preschoolers world-wide who are affected by subclinical vitamin A deficiency, 60 million live in south Asia and 40 million in Sub-Saharan Africa.[1]

Several strategies for alleviation of vitamin A deficiency have been proposed. These include: 1) high-dose vitamin A capsule supplementation, 2) food fortification, and 3) food diversification and nutritional education. Although supplementation with high-dose vitamin A capsules, when targeted exclusively at the young child population who is at a higher risk for hypovitaminosis A, is the most cost-effective intervention, there is global consensus that food-based strategies are viable and sustainable options for addressing micronutrient deficiencies in populations. Fortification of food, when universal coverage is the goal, appears to be the least expensive strategy.

## Addressing vitamin A deficiency through food fortification

Retinyl palmitate is the vitamin A fortificant most commonly used in food fortification and has been used to fortify sugar in Guatemala[2], monosodium glutamate in the Philippines and Indonesia[3,4], and wheat flour in the Philippines.[5] The Guate-malan sugar fortification programme was evaluated over a period of two years, and documented a significant improve-ment in vitamin A status in preschool children, especially in those with low serum retinol levels at baseline.[2] In the intestinal lumen retinyl palmitate is hydrolysed to retinol and absorbed by carrier-mediated diffusion or simple diffusion. The absorption of vitamin A is considered to be a non-saturable mechanism,[6] and uncontrolled and excessive intake may therefore lead to vitamin A toxicity.

Beta-carotene, a precursor of vitamin A, has been used as a safe colourant in foods and beverages for many years; it turns out that it also has the potential for use as a vitamin A fortificant. The amount of beta-carotene that is converted to vitamin A in the intestinal mucosa depends on the vitamin A status of the individual[7] which, when adequate, has an inhibitory effect on the enzyme that cleaves beta-carotene into retinal.[8] The risk of vitamin A toxicity through over-consumption is therefore eliminated if beta-carotene is used as a vitamin A fortificant.

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Synthetic beta-carotene was used as a fortificant in a wafer given to lactating women in Indonesia, and proved to be more effective in improving the vitamin A status of these women than the same amount of beta-carotene provided by dark green leafy vegetables.[9] Synthetic beta-carotene has also been used to fortify soybean cooking oil in Brazil, and studies have shown that the bioavailability of beta-carotene in the oil was not influenced by heat treatment.[10]

**Characteristics of crude and refined red palm fruit oil**

Oil from the African palm (genus *Elaeis)* is a rich natural source of provitamin A carotenoids and can be used as an alternative vitamin A fortificant. Crude palm oil is obtained from the mesocarp of the African palm fruit[11] and contains 500-700 ppm of carotenoids of which 56% and 35% are comprised of beta- and alpha-carotene, respectively.[12] Although the proportion of these two carotenes is similar in palm oil and carrots, red palm fruit oil (RPO) contains about 15 times more carotenes than that present in the same weight of carrots, and 44 times that of leafy vegetables.[13]

Crude palm oil has a very strong taste and odour and is not very stable, due to free fatty acids and other impurities. It can be refined, however, to a palatable red oil that is odourless, tasteless and very stable, but in which 80% of the carotenes and vitamin E originally present in the crude palm oil are retained.[11] The process developed in Malaysia to produce deodorised and deacidified red palm oil involves two stages, namely pretreatment of the crude palm oil followed by decolourisation and deodorisation by molecular distillation.[11] The product has been given the name Carotino.

**Value of red palm fruit oil for combatting vitamin A deficiency**

Results from several efficacy trials have confirmed the value of red palm fruit oil in improving vitamin A status. A few of them from various nations and foci of interest are reviewed below.

**Red palm oil in the maternal diet - vitamin A status of mothers and their nursing infants**

Canfield *et al.*,[14] studied the effect of refined RPO supplementation in a population of lactating mothers and their nursing infants in Honduras. Mothers received either a placebo (N=8), 15 mg beta-carotene (N=20), or 15 mg beta-carotene (N=26) as RPO, on six occasions over a period of two weeks. At the beginning of the study, approximately 60% of the infants had serum vitamin A concentrations indicative of borderline vitamin A deficiency (<0.7 µmol). At the end of the supplementation period, serum retinol of infants of mothers receiving beta-carotene or palm oil was significantly increased relative to the placebo group. The authors conclude that RPO in the diet of lactating mothers has the potential to enhance vitamin A status of their nursing infants and thereby enhance their resistance to morbidity due to respiratory and intestinal infections.

**Effect of red palm oil on vitamin A status of school children**

Manorama and co-workers[15] reported results from three feeding trials on schoolchildren receiving sweet snacks containing red palm oil supplying the Indian recommended dietary allowances (2400µg) of beta-carotene. In the first trial, children of 7-9 years of age[24] received the snack for two months, after which time significant increases were seen in serum retinol levels. Serum retinol levels increased from basal 0.86 ± 0.13 to 1.89 ± 0.023 µmol/L. These changes were similar to those seen in children receiving 600µg of vitamin A daily. Liver reserves of retinol, as determined by the Modified Relative Dose Response Test, indicated a saturation of liver reserves of retinol.

In the second trial, one group of schoolchildren (N=18) again received the red palm oil snack for one month, while a second group (N=18) received 100 000 IU of synthetic vitamin A as a single massive dose. Serum retinol concentrations increased significantly in both groups, 1.40 ± 0.05 to 1.76 ± 0.09 and 0.95 ± 0.05 to 1.85 ± 0.008 µmol/L in the vitamin A and RPO groups, respectively. In the third trial, three groups of children (12 per group) received either a single massive vitamin A dose of 100 000 IU as vitamin A palmitate, 4 g red palm oil for 30 days providing 50 000 IU vitamin A, or 8 g red palm oil for 30 days providing 100 000 IU vitamin A.[15]

All treatment groups showed significant increases in serum retinol levels measured 30 days after the single vitamin A dose or daily supplementation with palm oil. Although all children had serum retinol levels < 0.7 µmol/L at baseline, none had levels < 0.7 µmol/L after 30 days. Six months after cessation of supplementation with RPO, mean serum retinol levels were maintained at > 0.7 µmol/L in the vitamin A and 8 g per day RPO groups. Mean values in the 4 g red palm oil group were lower than 0.7 µmol/L six months after cessation of supplementation. Even when children were fed 50% of the Indian recommendations from the RPO snack, normal serum levels of retinol were maintained six months after cessation of supplementation. However, 33% of children in this group had retinol levels <0.7 µmol/L at the end of the 6-month period.

**Red palm oil-based baking fat as a food fortificant for combatting vitamin A deficiency**

Van Stuijvenberg *et al.*,[16] evaluated the response of serum retinol concentrations in rural schoolchildren (N=115) 6-11 consuming biscuits fortified with beta-carotene at 50% of their RDA for retinol. From these feeding trials, it was concluded that beta-carotene can be used as a food fortificant for combatting vitamin A deficiency.

The use of beta-carotene in the baking process was fraught with technical difficulties such as weighing errors in the preparation of the premix, instability of beta-carotene when exposed to light and air, and a wide variation in the beta-carotene content of the biscuits baked at different sites. Furthermore the baking fat used in the baking process was hydrogenated fat containing large amounts of *trans* fatty acids which are known to be associated with negative health effects.[17]

The manufacturers of Carotino were subsequently requested to develop a baking fat containing all the nutritional properties of Carotino oil, and without *trans* fatty acids. This lead to the development of Carotino baking fat which was subsequently evaluated in terms of its value as a food fortificant for combatting vitamin A deficiency. In a placebo controlled trial,[18] schoolchildren 5-11 of age were randomly assigned to three different treatment categories, namely: 1) a biscuit containing no added beta-carotene (N=137); 2) a biscuit with synthetic beta-carotene (N=130);

3) a biscuit with the refined red palm oil shortening as a source of beta-carotene (N=133). Biscuits were distributed daily during the school week for three months. The synthetic beta-carotene and RPO biscuits were designed to provide a similar amount of beta-carotene, providing approximately 34% of the RDA for 7-10-year-old children, assuming a conversion factor of beta-carotene to retinol of 6:1.[19] There was a significant improvement compared to the control group in both the synthetic beta-carotene and the RPO group. The effects of the two treatments were found to be equivalent. The percentage of children with serum retinol concentrations below 15 µg/dL dropped from 17.5% to 13.1% in the control group, from 17.7% to 4.6% in the synthetic ß-carotene group, and from 15.8% to 6.8% in the RPO group (the authors used <15 µg/dL as a cut-off value, instead of the normal cut-off of <20 µg/dL, because the majority of the values for this population lay around 20 µg/dL and, as such, this cut-off value was not sensitive enough for illustrating differences in prevalence changes between the control and intervention groups) (Table 1).

**Potential of Carotino shortening as food fortificant for vitamin A in the baking industry**

It is now well established that Carotino baking fat lends itself exceptionally well to application as a food fortificant in the food industry. Calculations based on the carotene content of Carotino (assuming that 6 µg of dietary all-*trans*-beta-carotene equals 1 µg of all-*trans*-retinol) and the fat content of a variety of bakery products showed that Carotino shortening could supply between 46% and 70% of the RDA for vitamin A[20] for children 7-10 of age (Table 2).

**Table 1.** Serum retinol (mg/dL) in primary schoolchildren before and after three months of intervention with biscuits fortified with synthetic ß-carotene or red palm oil biscuit

| Measurement | Control biscuit (N = 137) | ß-Carotene-fortified biscuit (N = 130) | Red palm oil biscuit (N = 133) |
|---|---|---|---|
| Baseline | 20.6 (5.8)[a] | 20.4 (6.0) | 20.8 (7.0) |
| | 17.5%[b] | 17.7% | 15.8% |
| 3 months | 21.6 (5.9) | 24.4 (5.6) | 24.0 (6.7) |
| | 13.1% | 4.6%[c] | 6.8%[c] |

[a]Mean (SD); [b][percentage of children with low serum retinol levels] using a cut-off of <15 mg/dL; [c]p<.005 compared with change in control group (ANOVA); Reproduced from 18.

**Additional benefits of Carotino shortening**.

Apart from its potential as a food fortificant for vitamin A in the food and baking industry, incorporation of Carotino in a variety of consumer products offers several additional advantages.

**Carotino contains no *trans* fatty acids**

The health implications of *trans* fatty acid consumption are well established. However, hydrogenated fat, containing variable amounts of *trans* fatty acids, is extensively used in the baking industry. Because of the process used in the manufacture of Carotino baking fat, Carotino does not require hydrogenation, and is therefore free of *trans* fatty acids. *Trans* fatty acids are known to behave metabolically like saturated fat and are atherogenic.[21,22]

**Vitamin E activity of Carotino baking fat**

Carotino baking fat is a rich source of tocopherols and tocotrienols which have different vitamin E activity and which are also natural antioxidants. They act as scavengers of the damaging oxygen-free radicals that are suggested to play a role in cellular aging, atherosclerosis and cancer.[23-25]

**Carotenoid content of Carotino baking fat**.

Carotino baking fat contains a broad spectrum of carotenoids,[26] some of which could serve as precursors of vitamin A while others have antioxidant properties.

**Stability and safety of Carotino baking fat**

Because of the high natural antioxidant content of Carotino baking fat, it does not require the addition of synthetic or other antioxidant to consumer products containing Carotino baking fat. Biscuits baked with Carotino fat proved to have a shelf life exceeding 6 months when stored at temperatures

**Table 2**. Retinol equivalents (RE) and tocopherol equivalents (TE) per portion of various food products

| Product | Fat content (%) | Portion (g) | % RDA RE | | % RDA TE | |
|---|---|---|---|---|---|---|
| | | | 7-10 yr | >10 yr | 7-10 yr | >10 yr |
| Carotino biscuits | 16.0 | 45 | 62 | 54 | 37 | 26 |
| Banana loaf | 10.8 | 50 | 46 | 41 | 27 | 19 |
| Bread, maize meal | 11.3 | 50 | 48 | 42 | 29 | 20 |
| Cake, home-made | 11.8 | 50 | 48 | 42 | 29 | 20 |
| Chocolate cake | 12.9 | 50 | 55 | 48 | 33 | 23 |
| Cookies, plain | 13.4 | 20 | 23 | 20 | 14 | 10 |
| Oat crunchies | 23.4 | 25 | 50 | 44 | 29 | 20 |
| Carrot cake | 19.7 | 50 | 85 | 74 | 51 | 36 |
| Fruit cake | 12.9 | 50 | 55 | 48 | 33 | 23 |
| Cookies, shortbread | 27.2 | 20 | 46 | 41 | 27 | 19 |
| Crackers | 24.6 | 33 | 70 | 62 | 41 | 29 |
| Gingerbread | 12.6 | 50 | 54 | 47 | 33 | 23 |
| Scone, whole wheat | 12.6 | 50 | 54 | 47 | 33 | 23 |
| Muffin, oat bran | 9.7 | 50 | 41 | 37 | 24 | 17 |

Reproduced from 20, with addition

of 20-30°C in the dark. Close monitoring of school learners consuming Carotino biscuits over a period of one year revealed no negative side-effects on health (Benadé AJS: unpublished observation).

**Quality control of beta-carotene content of biscuits baked with Carotino fat**

Because the carotene content of Carotino fat is controlled at the point of manufacture, it is possible for different manufacturers to produce products with exceptional uniformity in terms of its beta-carotene content.

**Conversion of beta-carotene from Carotino baking fat to retinol**

It has been suggested that the conversion factor of beta-carotene in oil to retinol is 2:1.[19] Based on this assumption, the amount of fat in products could be adjusted accordingly, which will not only reduce cost, but will also reduce the intensity of the yellow colour in products prepared with Carotino.

**Summary and Conclusions**

Results from several studies have confirmed the value of red palm oil as a food fortificant for combatting vitamin A deficiency. Based on current knowledge regarding the composition of red palm oil and the potential health benefits of these components, the value of RPO as a functional food justifies further investigation. Although the colour of the oil may hamper its acceptability by consumers as a day-to-day cooking oil, new innovative products containing RPO could overcome this problem.

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