REVIEW ARTICLE

Potential use of Red Palm Oil in Combating Vitamin A deficiency in India

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Abstract | Introduction | References | Citation | Tables / Figures

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Abstract

Deficiency of vitamin A has long been recognized as a serious and preventable nutritional disease. Various intervention strategies have been implemented to combat the problem. Massive dosing of the vitamin has the advantage of immediate implementation but suffers from the disadvantage in that it applies to the isolated nutrient and requires repetitive administration. Natural food sources regularly included in diets offer a more viable long term solution. Red palm oil (RPO) can emerge as a viable alternative to other vitamin A rich foods, since it contains enormous amounts of natural carotenoids to the tune of around 700 PPM, the predominant ones being α and β carotene which have the highest biological potential for vitamin A conversion. Value addition of palm oil for edible purposes results in several nutritionally rich products like edible grade red palm oil (RPO), deacidified, deodourised RPOlein, isolated carotenoids and refined, bleached and deodourized palmolein oil RBD palmolein). RBD palmolein oil can serve as a replacement for any other commonly used edible oil, but has little additional advantage over other edible oils, stripped of its carotenoids. However, it's naturally rich composition of tocopherols and tocotrienols, as well as the balanced fatty acid composition, makes it more superior to other edible oils used for dietary purposes. Addition of RBD palmolein to hydrogenated vegetable oil confers no advantage, and paradoxically, decreases it's beneficial properties making it a more harmful vegetable oil from the cardiovascular health angle, because of conversion of fatty acids from the cis to trans type.

Use of red palm oil for edible cooking purposes could solve the problem of vitamin A deficiency in countries where it exists as a public health problem. However, since acceptability of the unusual colored, viscous oil may prove to be hurdle for its commercialization, production of deacidified, deodourized palmolein oil by physical refining gives an excellent edible grade product with 85% of carotenoids and tocopherols intact. There exists an urgent need to devise strategies for delivery of red palm oil in an acceptable form to vulnerable groups of population from developing countries, who suffer from or are at risk of vitamin A deficiency.

Key Words

Red palm oil; Vitamin A deficiency; Dietary supplementation

Introduction

Vitamin A deficiency (VAD) has been long recognized as a public health problem among the population that exist below poverty line, especially in developing countries that are even otherwise burdened with other related 'underlying' causes that are economical, social and political. VAD prevention and control represents a public health problem where very real progress has been made [1]. Although the international goal of elimination by the year 2001 may not have been realized, xerophthalmia, which is the most visible form of VAD, is not prevalent at present even in those countries where VAD has been a major public health problem. However, VAD disorder remains a problem in most countries where it has been recognized. 73

countries are now listed as having VAD based on the most recent estimates from the World Health Organization (WHO), United Nations Children's Fund (UNICEF) and the International Vitamin A consultative group (IVACG) [2].

Though prevalence of clinical vitamin A deficiency is less than 1% in India, subclinical deficiency is quite high and the decline in subclinical vitamin A deficiency over the last decade has been insignificant. India remains to be the home of more than a quarter of the world's preschool children suffering from sub-clinical VAD and one third of preschool children suffering from xerophthalmia [3].

Three strategies that have been in use and widely promoted to combat VAD are, supplementation with high dose vitamin A capsules/drops, food fortification and dietary diversification (food-based production and promotion of vitamin A and carotene rich foods) strategies [4]. However, a broader approach that targets those vulnerable groups of population (women, adolescents, children and infants) affected at crucial periods throughout the life cycle and uses a combination of these different strategies, has been adopted by many countries and organizations to control VAD [5].

Recent reports [6] estimate that, the annual cost per child dosed is 1.14 USD (Rs.68) which includes: (i) programme-specific costs 0.42 USD (Rs.26), (ii) personnel cost 0.55 USD (Rs.33) and (iii) capital costs 0.17 USD (Rs.6). The total number of under five children in country will be about 160 million (15% of 1200 million). A cost of Rs. 8,000 million (160 million x Rs. 50) is being spent and a large proportion of this expenditure is being undertaken for questionable health benefits of VA supplementation to non-deficient children. Apart from the cost of the micronutrient, the programme also consumes precious human and material resources meant for delivery of primary health care.

The recommended approaches have therefore been to focus our efforts on sustainable food based approaches to combat vitamin A deficiency, as the era of gross and rampant vitamin A deficiency leading to blindness is past in India [7].

Carotenoids represent the most widespread group of naturally occurring pigments in nature. They are the major source of vitamin A in vegetarian diets. Yellow-orange fruits and vegetables, green leafy vegetables, and alternate sources like spirulina and dunaleilla algae have been the common sources of carotenoids used in the diets of varied population in many parts of the world. Of the approximately 50 carotenoids with provitamin A activity, β -carotene has the greatest biological potency. In addition, they are powerful anti-oxidants and anti-carcinogens because of their ability to quench singlet oxygen.

Red palm oil, which is a extracted from the mesocarp of the oil palm fruit, Elaeis guineensis, is a natural edible oil that is one of the richest natural sources of and β -carotene . In red palm oil, carotenoids are naturally lipid soluble, making them more bioavailable than from any other source. Plant sources of carotenoids have not been able to effectively eliminate the problem of vitamin A deficiency due to their poor bioavailability. In this regard, red palm oil could prove to be the most efficiently utilized plant source of β -carotene that could well be the answer to solving the problem of vitamin A deficiency.

Red palm oil derives its characteristic red color from the carotenoid content, having 11 different carotenes naturally present in the oil [8]. Retaining the carotenoids in red palm oil could provide a compelling reason to use it to serve in the public health effort to eradicate VAD. For this reason a consolidated effort was made to evaluate this viscous, red colored oil with a strong fruity odor, for safe edibility. Even though refined, bleached and deodorized palmolein oil (RBD palmolein) is widely used for edible purposes in the global market, and there have been no adverse effects due to its consumption. Nevertheless, the unrefined, unbleached, crude red palm fruit oil which is viscous, dark red colored, and having a strong fruity odor is only known to be consumed by some African populations in Nigeria, Cambia and the Ivory coast. Here, the fruit is consumed after traditional processing and incorporated into several local foods [9].

Studies on red palm oil:

Since there are no known published reports on the safe use of red palm oil as a dietary source of edible oil, a detailed study was undertaken to evaluate the crude red palm oil produced in India conforming to the standards of the Central Committee for Food Standards. A multi generation study was conducted on Wistar/NIN/inbred albino rats with one group of rats fed crude red palm oil and two control groups

using refined groundnut oil and RBD Palmolein oil at 10% level in the diets [10]. Reproductive parameters including percentage conception, birth weight, litter size, weanling weight, sex ratio at birth and weaning, pre-weaning mortality and number of days for delivery from introduction to mating, were recorded. Behavioural and reflexological tests were conducted on pre-weaning animals and adult animals were subjected to weekly observation. No differences were found between control groups and the red palm oil group indicating no adverse effects on RPO consumption. No teratological abnormalities were observed in any of the animals. Organ weights were also in the normal range comparable to controls. Histopathological analysis of organs removed after sacrifice did not reveal any abnormalities.

As a part of the safe edibility tests, mutagenicity tests were also conducted on repeatedly heated crude and refined palmolein oil [11], in the Ames bacterial system, using Salmonella typhimurium strains TA100 and TA 98 with metabolic activation using rat liver microsomes S9 fraction. Since foods are a mixture of a wide array of chemicals, they may undergo altered composition or formation of mutagens during processing. Heated fats can interact with amines in foods to produce heterocyclic compounds. Thus there is a lot of concern about the formation of mutagens during frying in oils at high temperatures. Since chemical, nutritional and toxicological evaluation in three generations of albino rats have revealed no adverse effects on using red palm oil, mutagenicity studies were also considered necessary. Results did not show any mutagenicity in the heated as well as unheated samples of both, crude and refined palm oils.

Nutritional evaluation studies were also conducted on Wistar/NIN/albino rats, in a 90-day feeding study, apart from their physic-chemical properties [12]. Refined groundnut oil and RBD palmolein were used as controls, and fat was fed at 10% level. Daily food intake and weekly body weights were measured. Diet and fecal samples were analysed for nitrogen, fat, calcium and phosphorus. Net protein Utilization (NPU), protein efficiency ratio (PER) and protein digestibility (PD) were measured after sacrificing 50% the animals at the end of the experiment. For the remaining animals, serum cholesterol and triglycerides, liver and heart lipids, cholesterol and triglycerides, serum enzymes like alkaline phosphatase, serum glutamic oxalic transaminase and glutamic pyruvic transaminase were also estimated to detect any abornamalities in heart and liver functions. This study served to indicate that there were no adverse nutritional effects noticed in red palm oil fed animals compared to the control groundnut oil and RBD palmolein groups. Hypocholesteremic effects were observed in red palm oil and RBD palmolein oil fed groups. HMG-CoA reductase, the rate limiting enzyme in cholesterol biosynthesis, levels were also reduced in both palm oil fed groups, indicating that other minor constituents may be playing a role in producing this effect.

Hepatic drug metabolizing enzymes which represent the host detoxification system, were also studied [13] in Wistar/NIN/albino rats. Phase II glutathione S transferase (GST) activity was measured in the liver of the third generation of rats from the multi-generation study described above. It is one of the detoxifying enzymes involved in the conjugation reactions of phase II metabolism. The experiment was continued for another generation and the fourth generation rats were fed the same red palm oil, groundnut oil and RBD palmolein oil for another 9 weeks, and GST activity was measured. In addition, reduced glutathione, microsomal total cyt-P450, aminopyrine-N-demethylase, and ethoxyresorufin-O-deethylase activity were also measured, to eludicidate the effect of red palm oil in comparison with controls on both, Phase I and Phase II drug metabolizing enzymes. Phase I enzymes and total cyt-P450 levels were comparable between red palm oil and control groups, while Phase II GST levels were found to be induced in the red palm oil group. These results suggest that red plam oil has served to increase the level of GST, thus increasing protection against chemical carcinogens, probably due to its carotenoid content.

Effect of processing on β-carotene content:

Carotenoids are known to be unstable during heating and processing. Since the objective was to use red palm oil as a cooking medium to deliver nutritionally important carotenes to vulnerable children and women lacking in Vitamin A, a study was undertaken to evaluate the effect of processing on carotene retention in food products [14]. Different cooking methods like baking, seasoning, deep fat frying and shallow frying were used to make cakes, sweet and

savory preparations common to India. β -carotene content of the foods products was analyzed along with un-processed crude palm oil. Retention of Total and β -carotene content of different preparations ranged from 69 to 86 % for total carotenes and 70 to 80 % for β -carotene . When oil was used repeatedly for frying French fries, upto 60% was retained until two repetitions, but 65 to 100% loss of b-carotene was observed after the 3rd, 4th and 5th repetition, indicating that red palm oil may not be suitable for repeated frying operations as far as retention of β -carotene is concerned.

Sensory evaluation of different recipes made with red palm oil indicated that it is well accepted by a panel of judges selected by standard procedures of sensory evaluation [15]. 50:50 blends of red palm oil with sunflower oil showed better acceptability that using 100% red palm oil alone. Since these preparations were made using crude red palm oil, the strong fruity odor was slightly less well accepted, unless masked by other ingredients and the added flavours due to processing.

Bio-availability of β -carotene from red palm oil:

Since the main purpose of the whole exercise was to use red palm oil as an affordable solution to eradicate vitamin A deficiency in vulnerable groups of population in developing countries, it was considered imperative to assess the effect of its supplementation on vitamin A levels in school children. The bio-availability was assessed using a modified relative dose response assay [16]. This assay was developed to serve as an indicator of vitamin A status in undernourished children, as serum retinol alone does not correlate with adequate body stores of the vitamin. The test uses 3, 4-didehydroretinol (DR) as a ligand for binding accumulated apo retinol binding protein (RBP) in a vitamin A depleted liver. DR is a naturally occurring analogue of retinol which is found as an RBP complex in serum after 5 hours of dosing. Hence, the DR/R ratio was reported to be inversely related to liver stores and provides a valid quantitative measure of marginal vitamin A status, which is widespread in most populations known to suffer from VAD.

Twenty four school children of 7–9 years of age were divided into two groups of six boys and six girls each. One group was given a daily supplement of 'Suji halwa', a sweet snack made with semolina and red palm oil, supplying 2400 µg of β-carotene and the second group was the control group which was given 600 µg of oral vitamin A palmitate, for 60 days. Vitamin A status before and after supplementation was assessed by the Modified Relative Dose Response Assay (MRDR). Results indicated that serum vitamin A levels increased from the basal level of 0.80±0.13 µmol/l to 1.89±0.23 µmol/l in the Red Palm oil (RPO) group and from 0.74±0.09 to 1.94±0.21 µmol/l in the control vitamin A group. Dehydroretinol/Retinol (DR/R) ratio decreased from 0.073±0.025 to 0.023±0.004 in the RPO group and from 0.095±0.023 to 0.023±0.004 in the vitamin A group, indicating liver saturation with vitamin A after feeding RPO snacks, comparable to synthetic vitamin A. This study indicated that RPO is an efficient source of β-carotene which is found to be bioavailable in all the subjects tested, hence it can be used for supplementary feeding programs to combat vitamin A deficiency in target population.

Another study was conducted in school children in Orissa, to assess the protective effect of red palm oil in comparison with massive vitamin A dose in combating vitamin A deficiency in Orissa, India (17). The study was carried out for a period of three months in 36 school children. Twelve children received a massive dose (50,000 IU) of vitamin A, another twelve children received 4g of red palm oil containing B-carotene equivalent to 25,000 IU of vitamin A in "Besan laddu" and the remaining twelve received 8g of red palm oil containing β -carotene equivalent to 50,000 IU of vitamin A in "Besan laddu". Serum vitamin A levels were estimated initially, after 15 days of supplementation and 3 months after termination of supplementation. The levels were maximum 15 days after the supplementation and, though it fell by the end of 3 months, yet it was significantly higher than that of the initial levels in all the three groups. Among both, the levels of red palm oil supplement, 8g RPO was as efficient as was a massive vitamin A dose in providing protection for three months, after cessation of supplementation. Red palm oil was found to be equally effective in maintaining serum retinol levels as a megadose vitamin A in those prone to vitamin A deficiency. In planning supplementary feeding programmes, rather than regular daily feeding, periodic feeding of red palm oil at regular three monthly intervals may be successful in maintaining normal childhood vitamin A nutriture.

After the launch of 'Carotino' a carotene rich red palm oil, in Malaysia in 1996, a number of studies were conducted in human subjects to assess the lipid profile, vitamin A, β -carotene and tocopherol levels(18). Effect of feeding 'Carotino' to human subjects for 15 days after a 15 day period of sunflower oil (SNO) rich in polyunsaturated fatty acids (PUFA), followed by a 15 day period of ghee (clarified butter) rich in saturated fatty acids (SFA) on serum lipids and anti-oxidants, namely, vitamin A, β -carotene and α -tocopherols is shown in Fig. 6 and 7.

The impact of red palm oil consumption on hemoglobin status of subjects given iron supplements, along with Vitamin C was also studied (19). A combined deficiency of vitamin A and iron is almost always seen in the developing countries. The impact of such a deficiency leads to consequences that exacerbate the problem even more, causing increased risk of mortality and morbidity along with impaired cognitive performance and physical work output. When subjects were fed iron supplements, followed by red palm oil, followed by iron, red palm oil and vitamin C, in required daily doses, it was observed that feeding iron alone had lowest levels of hemoglobin, retinol and β -carotene . Addition of red palm oil increased all levels, with a further increase in all three nutrients when vitamin C was also supplied, as expected.

All these studies have emphasized the role that red palm oil in improving vitamin A status as well as overall nutritional status of populations. Several other studies have also been reported to prove the efficacy of using red palm oil in various forms for elimination of VAD (20).

Biotechnological approaches for supply of vitamin a rich foods:

Global efforts to supply vitamin A/carotene rich foods has focused on biotechnological approaches recently. Breeding staple foods that are dense in minerals and vitamins provides a low-cost, sustainable strategy for reducing levels of micronutrient malnutrition. Getting plants to do the work of fortification, referred to as "biofortification," can reach relatively remote rural populations that conventional interventions are not now reaching and can even have benefits for increased agricultural productivity. Biofortification, thus, complements conventional interventions. Genetic engineering offers elegant ways to fortify food with vitamins and minerals, as demonstrated with rice, canola and tomato.

Golden rice is a variety of Oryza sativa rice produced through genetic engineering to biosynthesize beta-carotene, a precursor of vitamin A, in the edible parts of rice. The research was conducted with the goal of producing a fortified food to be grown and consumed in areas with a shortage of dietary vitamin A, a deficiency which is estimated to kill 670,000 children under 5 each year.

Golden rice differs from its parental strain by the addition by genetic transformation of three β – carotene biosynthesis genes, namely, phytoene synthase, phytoene desaturase and lycopene □-cyclase. This pioneering work in transgenics was first published in Science in 2000(21), the product of an eight-year project by Ingo Potrykus of the Swiss Federal Institute of Technology and Peter Beyer of the University of Freiburg. At the time of publication, golden rice was considered a significant breakthrough in biotechnology, as the researchers had engineered an entire biosynthetic pathway, even though they were able to produce only 1.6 □g/g of β -carotene .

In 2005, a new variety called Golden Rice 2, which produces up to 23 times more β -carotene (37 □g/g) than the original golden rice, was announced.(22)Although golden rice was developed as a humanitarian tool, it has met with significant opposition from environmental and anti-globalization activists. Golden Rice is still being developed and evaluated and has not yet been approved for wide scale commercial use in any country.

Apart from golden rice, other crops like Canola oil, sweet potato and tomato were also transformed genetically to produce more β -carotene . However, none of these products have been commercialized as they have to undergo stringent bio-safety evaluation before they gain approval for commercial release by regulatory bodies.

Hence, it would be of considerable benefit if a product like red palm oil which has already been commercialized and available for purchase, be popularized for use as a supplement for VAD population all over the world.

Concerted efforts for complete eradication of VAD in the world:

A large number of countries are still quantifying or identifying that they have a VAD public health problem(1), e.g., Angola, parts of Brazil, Cameroon, Cape Verde, parts of China, Federated States of Micronesia, Ghana, Haiti, Iran, Jordan, Myanmar, Pakistan and Zimbabwe. Although not newly identified, of the 16 Economic Cooperation of West African States countries in western Africa, 14 are known to have a problem of VAD, and two are presumed to have public health problem. Consequently, one could say all 16 of these countries have evidence or likely evidence of VADD. An estimate of lives saved by vitamin A intervention programs in those countries was around 60,000 young children and infants. If global organizations like the UNICEF, IVACG, Micronutrient Intervention, Helen Keller foundation, FAO, WHO and many other organizations involved in eradication of vitamin A deficiency could take into account that feeding a child 1 teaspoon of red palm oil per day for three to six months in a year could protect them from crossing the border towards marginal or severe VAD, and they could in turn purchase the oil from the sources of manufacture and distribute it on humanitarian grounds among those countries which have a prevailing problem of VAD, and this action would go a long way in reaching the goals for eradication faster. In addition, countries like India which also produce red palm oil and process it for more commercial applications should again re-visit the need for producing edible grade red palm oil, side by side educating the population on it's potential health benefits.

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Tables

TABLE 1

Country	Children		
	Deaths prcptd (no.)	<6w/sub clinical VAD (%)	<6w/clinical VAD (%)
Afghanistan	50000	53	-
Bangladesh	28000	28	0.7
Bhutan	600	32	0.7
INDIA	330000	57	0.7
Nepal	6900	33	1
Pakistan	56000	35	-
S.A region	471500	-	-
World Total	1150000	-	-

TABLE 2 STABILITY OF CAROTENES AND TOCOPHEROLS IN COOKED FOODS

FOOD ITEMS	TOTAL	β CAROTENE	TOTAL
TESTED	CAROTENE	TOCOPHEROLS	
Cakes	78-83	35-85	33-90
Biscuits	71-86	61-86	30-87
Sweets	52-81	60-90	3586
Pickels	50-71	33-67	55-84

Figures

FIGURE 1 XEROPHTHALMIA DUE TO VAD; 2-CONJUNCTIVAL XEROSIS; 3-CORNEAL XEROSIS; 4-BITOT'S SPOTS; 5-KERATOMALACIA

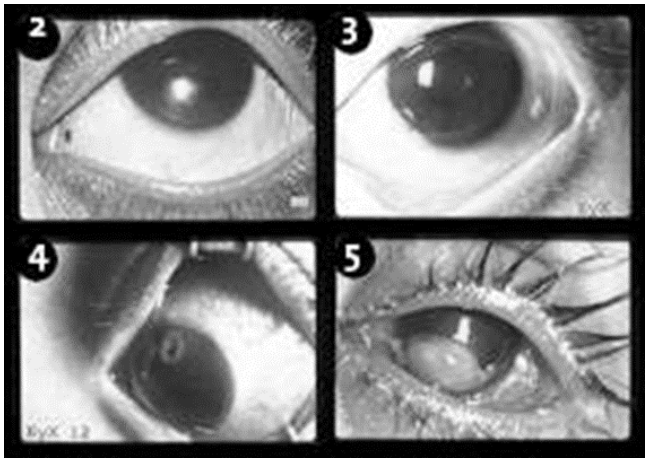

FIGURE 2 GLOBAL SCENARIO OF VITAMIN A DEFICIENCY SOURCE:

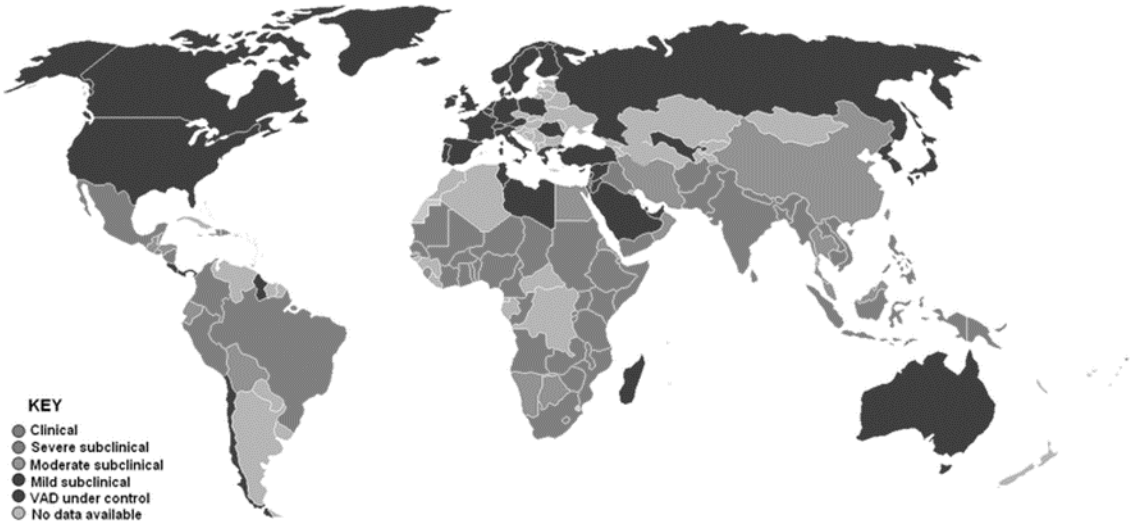

FIGURE 3 CAROTENOID CONTENT OF DIFFERENT VEGETABLE SOURCES (MG/100G)

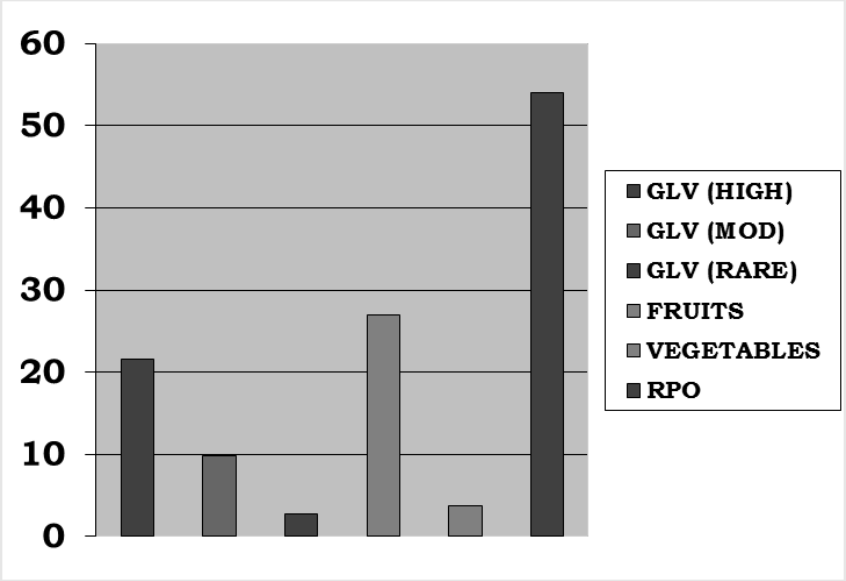

FIGURE 4-5

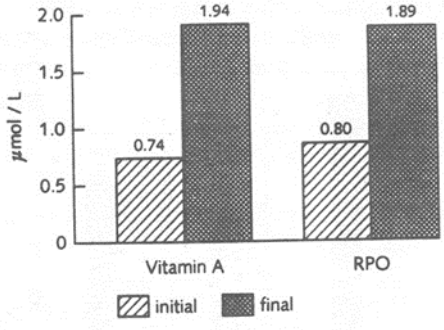

FIG. 4. Increases in serum retinol levels in schoolchildren given a dose of vitamin A or a snack containing RPO daily for 60 days

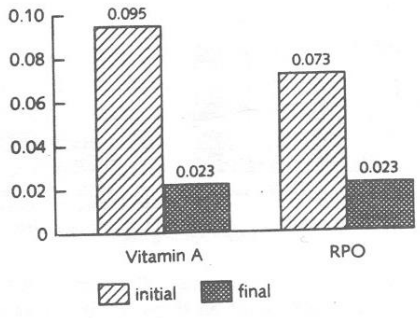

FIG. 5. Decreases in DR:R ratios in school-children given a dose of vitamin A or a snack containing RPO daily for 60 days

FIGURE 6 SERUM LIPIDS OF HUMAN SUBJECTS FED DIFFERENT EDIBLE SOURCES OF FAT MMOL/L).

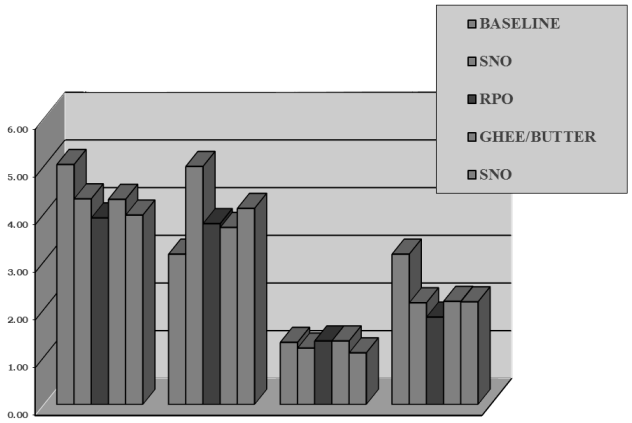

FIGURE 7 SERUM RETINOL, β-CAROTENE AND α-TOCOPHEROL OF HUMAN SUBJECTS FED DIFFERENT EDIBLE SOURCES OF FAT

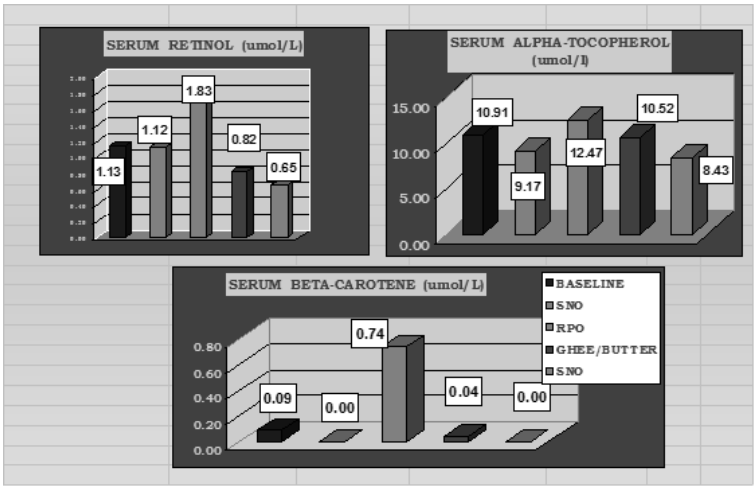

FIGURE 8 MEAN HEMOGLOBIN, RETINOL AND β-CAROTENE LEVELS IN SUBJECTS FED IRON CAPSULES, RED PALM OIL AND VITAMIN C SUPPLEMENTS.