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Vitamin A Fortification of P.L. 480 Vegetable Oil

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Vitamin A Fortification of PL 480 Vegetable Oil

EXECUTIVE SUMMARY

USAID is a leader in the global effort to prevent and control vitamin A deficiency. Vitamin A deficiency is the single most important cause of childhood blindness in developing countries and contributes significantly to morbidity and mortality from common childhood infections. Where the deficiency is widespread, the risk of childhood mortality can be reduced on average by 23% through provision of sufficient vitamin A.

The technology of vegetable oil fortification with vitamin A is well established, fairly simple and easily achievable by producers. No change in current oil packaging is required except for labeling. Analysis shows no potential problems with safety or excessive vitamin A intakes at the suggested level of fortification.

The stability of vitamin A in oil is greater than other currently used food vehicles such as flour, sugar or corn soy blends. Losses are estimated at 5% during shipping and 10% during open storage in the field. Cooking losses will range from 5% for boiling or simmering to 20% when the food is fried. Higher losses, over 50%, would occur with very high temperature and/or repeated frying, but this type of application is not believed to be common with PL 480 vegetable oil.

The cost of the vitamin A fortificant at 60 IU/g is $3.30/MT of oil. The total cost to fortify the 81,540 MT of non-monetized oil used in 1997 would have been $269,000 plus an estimated 5% overhead and profit. This paper provides information on the technical and economic aspects of fortifying vegetable oil with vitamin A and recommends the following:

1. Vitamin A should be added to refined vegetable oil at a level of at least 60 IU/g.
2. The level of vitamin A in fortified PL 480 vegetable oil should be specified with a range of 60 to 75 IU per gram of oil.
3. The added vitamin A should be in the form of vitamin A palmitate oil containing antioxidants.
4. Vitamin A should <u>not</u> be added to bulk, crude, degummed oils used in monetization programs, since subsequent refinement would destroy most of the vitamin and most monetized oil does not reach the target population.
5. The stability and uniformity of vitamin A in the fortified oil scheduled for shipment to Pakistan should be tested.
6. Additional information on how PL 480 vegetable oil is used in the field should be collected to determine whether fortification should be pursued with packaged, refined shipments of monetized oil as well as to evaluate potential impact.
7. Additional data on the effect of antioxidants on cost and vitamin A stability should be collected.

I. BACKGROUND & RATIONALE

A. Requirement for Vitamin A

Vitamin A is essential for normal growth. Vitamin A functions in vision cell differentiation, embryonic development, spermatogenesis, the immune response, taste, hearing, appetite, and growth. Vitamin A deficiency (VAD) can cause eyesight problems, blindness, reduced resistance to infection, and an increased risk of mortality. Vitamin A activity is expressed in *retinol equivalents (RE)* or *International Units* (IU). A conversion table is supplied in Appendix A.

The World Health Organization's recommended dietary intakes (RDI) and basal requirements for vitamin A for different groups appear below in Table 1. Please note that basal requirements, which reflect the minimum needs of the body at rest, are substantially lower than the RDI. WHO's requirements are stated in the RDI and are lower than the 5000 IU/day US Recommended Daily Allowance (RDA) used in the US to label foods. Thus, a serving of food that contains 10% of the US RDA, would provide 38% of the WHO RDI for children. Since it is most commonly used by donors, the WHO RDI should be considered the operating RDI with PL 480 foods.

Table 1: Vitamin A Requirements

Source: WHO, 1995

	RDI: IU/day	Basal Requirement: IU/day
Infants: 0-1 yrs	1167	600
Children: 1-6 yrs	1333	665
Women: Adult	2000	1230
Women: Lactating	2833	1500

B. Rationale of Vitamin A Fortification

USAID is a leader in the global effort to prevent and control vitamin A deficiency. Vitamin A deficiency affects more than 250 million children worldwide (*1*). It is the single most important cause of childhood blindness in developing countries. Even at sub-clinical levels vitamin A deficiency contributes significantly to morbidity and mortality from common childhood infections. Where it is widespread, the risk of childhood mortality could be reduced by an average of 23% through the provision of sufficient vitamin A(*2*).

Fortification of food staples, including those provided in food aid programs, is one of the strategies promoted by USAID and employed in some of their programs. This strategy can have an impact on child health both by directly increasing vitamin A intake of children and indirectly by raising levels obtained by children from breast milk. It may also reduce health problems associated with iron deficiency anemia and improve the overall health of the mother.

Vitamin A has been required as a fortificant in processed cereals (wheat flour, corn meal, bulgur) and blended foods (CSB, WSB) provided under the PL 480, *Food for Peace* program; however, it has not been added to vegetable oil (vegoil), an important food aid commodity. Fortification of PL 480 vegetable oil with vitamin A would be an effective way to deliver vitamin A to deficient populations. CIDA (Canadian International Development) and the World Food Program now require vitamin A to be added to vegoil.

II. OIL & VITAMIN A

A. Vegetable Oils

Oils and fats are major components of the human diet, along with carbohydrates and proteins. They can be of animal or vegetable origin. Animal fats (lard, butter) contain vitamin A. There is no vitamin A naturally present in vegetable fats and oils (soy, canola, and corn) but unrefined oils may contain carotene, a vitamin A precursor. Red palm oil contains high levels of carotene but its intense red color makes it unacceptable for many applications. Fats and oils are energy dense, useful in achieving a minimum, necessary level of caloric intake. They provide food with flavor, palatability and help reduce the feeling of hunger. Fats and oils are necessary for the delivery and absorption of the fat-soluble vitamins (A, D, E and K).

Oils are composed of triglycerides containing polyunsaturated fatty acids (PUFA). PUFAs are long chain fatty acids with multiple double bonds, making them susceptible to oxidation. This oxidation occurs on exposure to air and heat resulting in a rancid odor with time. The presence of certain metals will accelerate the oxidation. The degree to which oil has been oxidized is indicated by its peroxide value. Antioxidants, such as BHA, BHT, tocopherol and TBHQ[1], are added to reduce the rate of oxidative rancidity.

Oils are cheaper than solid (margarine) and semisolid (mayonnaise) fats and easier to handle in food aid programs. The higher heat achieved with oil frying helps break down vegetable matter, making it more tender and easier to digest in a shorter cooking time than by boiling in water. Oil is also used in small amounts to prevent food from sticking to cooking surfaces. Because of these properties, vegoil is nearly always included with cereal and legume staples in a food aid basket of rations. Nearly everyone consumes some oil, but consumption is self-limiting because of their satiating and laxative effects at high intake levels. Oils are used sparingly in developing countries since they are fairly expensive compared to other food staples.

B. Vitamin A

Vitamin A is a yellow, oil soluble crystal, which can be uniformly distributed in oil. The body easily absorbs added vitamin A in the presence of oil. Vitamin A is unstable when exposed to light (particularly UV light), air, oxidizing agents and heat. Heavy metals and acids, even in trace quantities, can accelerate decomposition. Vitamin D exhibits similar stability in fats and oils.

It can be assumed that there is a direct relationship between the stability of the vitamin and the oxidation status or peroxide value of the oil. The higher the peroxide values the greater the loss. Using high quality oil and protecting the oil from oxidization and rancidity is therefore basic to preserving the vitamin A. Moreover, on a percentage basis stability of vitamin A depends on the level of fortification. Since there are a given amount of oxidative components in the oil with which the vitamin A can react, the percentage of retention will be greater when higher levels of vitamin A are added[2].

III. STABILITY OF VITAMIN A IN OIL

A. Stability of Vitamin A in Sealed Containers

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[1] BHA is butylated hydroxyanisole, BHT is butylated hydroxytoluene, TBHQ is tertiary butylhydroquinone

[2] Personal Communication: Karoly Nagy, Hoffman LaRoche.

In sealed and opaque containers that protect vitamin A and oil from light and air, losses of vitamin are negligible for up to a year. Favaro, et al.(*3*) found almost no loss through 9 months in sealed containers at 23º C. However, there were significant losses at 18 months. In similar laboratory conditions, Bauerenfeid (*4*) found 91% of vitamin A surviving after 6 months. Documents provided by Hoffman LaRoche report that vitamin A in soybean oil stored at 20-25º C retained 95 to 100% of its original content over 3 months and 90 to 95% over 6 months. This is generally superior to stability found by Roche in margarine: 90 to 95% retention after 3 months and 85 to 90% after 6 months. Two studies measured stability under field conditions where shipping and storage time is typically 2-4 months. Atwood (*5*), et al. found that an average of 98% vitamin A survived shipment to Indian ports and inland distribution points. Health Canada found that 87% of vitamin A survived shipments from Canada to Sierra Leone.[3]

Table 2: Stability During Storage In Sealed Containers

Study	Storage Time	Storage Conditions	Vitamin A Retention
Favaro, et al. (*3*)	3 Months	Lab @ 23º C	99.5%
Nagy/Roche (*6*)		Lab @ 20-25º C	95-100%
Atwood, et al. (*5*)		Field @ 35º C	98%
Health Canada		Field @ 32º C	87%
Favaro, et al.	6 Months	Lab @ 23º C	99.5%
Bauerenfeid		Lab @ 23º C	91%
Nagy/Roche		Lab @ 20-25º C	90 – 95%
Favaro, et al.	9 Months	Lab @ 23º C	99%
Favaro, et al.	18 Months	Lab @ 23º C	33%

B. Stability of Vitamin A in Opened Containers

Two studies consider the stability of fortified oil in open cans. Working in a laboratory at 23º C. Favaro, et al. (*3*) measured stability in open cans stored in the dark as well as open cans exposed to light for 10 hours a day. In both instances, they detected no deterioration at all for the first 6 months. In fact, no difference in stability between sealed cans and open cans, even those exposed to light, for the first 6 months was found. However, after three additional months, Favaro, et al. found only 48% of original vitamin A level in the opened cans exposed to light and 76% in opened cans kept in the dark. Projections made in this paper will discount Favaro's figures for months 1-6 and utilize the findings for months 6-9. Calculating on the basis of a linear deterioration, after 30 days, 92% of vitamin would be recovered from cans left in the dark and 83% from the cans exposed to light. In fact the deterioration is not linear but logarithmic, with most vitamin A deterioration at the end of the time period, so this calculation provides a conservative estimate[4]. These extrapolated figures can be compared to Atwood's measurements of fortified oil after opening cans for 30 days at final distribution sites in India. Although there was some variation, Atwood, et al. (*7*) report recovering an average of 70-88% of the original vitamin A after 30 days from open pails exposed to light, air, and temperatures of up to 35º C.

Table 3: Stability In Open Cans Under Exposure To Light And Air

Study	Duration of Oil Exposure	Conditions	Vitamin A Retention
Favaro, et al. (*3*)	6 Months	Open/Dark 23 C	99%

[3] Personal Communication: Barbara McDonald, CIDA.

[4] Personal Communication: Hector Cori, Hoffman LaRoche.

Favaro, et al.	6 Month	Open + 10 hrs light @ 23 C	99%
Favaro, et al.	3 Months (Months 6-9)	Open/Dark 23 C	76%
Favaro, et al.	3 Months (Months 6-9)	Open + 10 hrs light @ 23 C	48%
Atwood, et al. (*7*)	1 Month	Open in Field @ 35 C	70 – 88%
Favaro, et al.	1 Month	Extrapolated from 3 Months	92%
Favaro, et al.	1 Month	Extrapolated from 3 Months	98%

C. Stability of Vitamin A during Cooking

There is wide variation in vitamin A stability during cooking, depending on time and temperature. The studies reviewed indicate that the deterioration of vitamin A in cooking oil is related more to the temperature. Therefore studies reviewed for this assessment are grouped by temperature.

1. Boiling, Simmering, and Stewing: 100-120 º C

Vitamin A is quite stable at these temperatures even when heated over an extended period of time. Favaro, et al. (*3*) found 99% retention when oil was added to rice and cooked for 15 minutes. Favaro also found 88% of vitamin A in beans boiled for 90 minutes. In two separate studies Bauerenfeid (*4, 8*) reports recovering 71% of vitamin A from a cornmeal mixture cooked for 30 minutes and 100% vitamin A after cooking for 40 minutes. Atwood, et al. (*5*) simulated conditions found in Indian feeding programs supplied by PL 480 Oil, where oil is added to mixtures of rice, beans and pulses. 93% of vitamin A survived after 15 minutes and 90% after 30 minutes. Working with vanaspati, a common hydrogenated oil used in India, Gopal, et al. (*9*) reported 92 % retention after simmering vegetables at 100º C for 30 minutes.

Table 4: Stability During Boiling, Simmering Or Stewing

Study	Cooking Time	Medium	Vitamin A Retention
Favaro (*3*)	15 minutes	Rice	99%
Atwood (*5*)	15 minutes	Rice/Pulses	93%
Atwood	30 minutes	Rice, Pulses	90%
Bauerenfeind (*8*)	30 minutes	Corn Meal	66-75%
Gopal (*9*)	30 minutes	Onions, Potatoes	92%
Bauerenfeind	40 minutes	Margarine (no oil)	100%
Brooke	60 minutes	Tea (no oil)	100%
Favaro, et al.	90 minutes	Beans	88%

2. Low Temperature Frying: 130-170 º C

At higher temperatures, due to light frying or deep frying of potatoes, vitamin A is lost at increasing rates. Favaro (*3*) heated oil and deep fried four servings of potatoes at 130-170º C. After the first two fryings, 83% and 81% of vitamin A were recovered. 71% was retained after the third and 52% after the fourth frying. After cooling and storing, successive fryings indicated increasingly significant losses. In Unilever laboratories, Sagredos (*10*) recovered 59% of vitamin A from margarine after heating to 150º C for 10 minutes, 45% after 20 minutes, 33% after 30 minutes and 27% after 45 minutes. Roche reported retention at 90 to 95% after frying at 160º C for 20 minutes. In Table 5, these various results are organized by length of cooking time. It is assumed that the length of each potato frying period reported by Favaro was roughly 3 minutes.

Table 5: Stability During Low Temperature Frying

Study	Cooking Time	Medium	Vitamin A Retention
Favaro	1 Frying	Potatoes	83%
Favaro	2 Fryings	Potatoes	81%
Favaro	3 Fryings	Potatoes	71%
Sagredos/Unilever	10 Minutes	Margarine (no oil)	59%
Favaro	4 Fryings	Potatoes	52%
Favaro	6 Fryings	Potatoes	43%
Nagy/Roche	20 minutes	Chips	90%
Sagredos/Unilever	20 Minutes	Margarine (no oil)	49%
Favaro	8 Fryings	Potatoes	27%
Sagredos/Unilever	30 Minutes	Margarine (no oil)	33%
Sagredos/Unilever	45 Minutes	Margarine (no oil)	27%

3. High Temperature Frying: 180-200 ºC

At higher temperature wok or deep-frying, vitamin A losses can be quite significant. Tests at Unilever (*11*) simulated Indonesian frying conditions with LPG flame at temperatures around 193º C. After two rounds of heating oil for up to 8 minutes, frying for up to 2 minutes and allowing the oil to cool overnight, 78% of vitamin A was recovered. When the process was repeated with the same oil, retention was 22%. Samples without BHA retained much less vitamin A (discussed in the following section on antioxidants). Working with Rama™ margarine, after heating two batches of oil at 180º C for ten minutes, Unilever labs recovered 51-56% of vitamin A after 10 minutes and 17% after 20 minutes. At 30 and 45 minutes levels fell to single digits. Gopal, et al. (*9*) report that when deep frying pahkoras in vanaspati (about 1 minute 15 seconds per pahkora) at 200º C, retention ranged from 71% after 5 minutes, to 41% after 15 minutes to 17% after 30 minutes. When shallow frying kabobs in temperatures up to 220º C, they found retention much poorer: 20% after 10 minutes and 0% after 20 minutes. In Table 6 these tests are arranged by increasing temperature.

Table 6: Stability During High Temperature Frying

Study	Cooking Time	Temperatureº C	Vitamin A Retention
Rama/Unilever	10 minutes	180	51 - 56%
	20 minutes	180	14 - 21%
	45 minutes	180	6 - 12%

Indonesia/Unilever (*11*)	2 fryings (3 ½ mins) plus cooling overnight	193	78%
	4 fryings (7mins) plus cooling overnight	193	22%
Gopal (*9*)	5 minutes	200	71%
(vanaspati)	10 minutes		55%
	15 minutes		41%
	20 minutes		32%
	30 minutes		17%
Gopal	10 minutes	220	84%
(vanaspati)	20 minutes		20%
	30 minutes		0%

D. Effect of Antioxidants on the Stability of Vitamin A

While several studies have documented the performance of various antioxidants to improve the stability of oil, there is very little documentation specifically on the use of antioxidants to enhance the stability of vitamin A in oil[5]. Antioxidants are used in PL 480 Corn Soy Blend (CSB) and Wheat Soy Blend (WSB). They are not added to Canadian or WFP vegetable oil. Antioxidants are rarely added to liquid oils for the consumer market, since they are packed in relatively small and airtight bottles and used in a relatively short time. However, they are often used in fats and shortenings to preserve the oil in more demanding conditions found in industrial processing and frying. About 10-20% of pourable liquid shortening have antioxidants added[6].

1. Antioxidants in Premix

A commonly used commercial vitamin A product used to fortify oil (Roche vitamin A palmitate, type B1.8BH) contains 5 mg of BHA and 5 mg of BHT for every million IU of vitamin A. These antioxidants are added to insure the stability of the raw material in the premix. If, for example, this premix was used to attain a fortification level of 60 IU/g of vitamin A in the oil, it would add 0.3 mg of BHA and BHT per kg or only 0.3 ppm. Since antioxidants protect vitamin A by "presenting themselves to oxidizing agents as a substitute" for vitamin A, this would represent a negligible amount and provides little protection of the vitamin A in the vegoil[7].

2. *Evidence of Impact on Vitamin A Stability*

There is little data specifically on the impact of BHT, BHA, TBHQ or other antioxidants on the stability of vitamin A in vegetable oil. With two exceptions, all the stability tests reported above included BHA or BHT. First, Unilever tests (*11*) with and without BHA under Indonesian frying conditions at temperatures up to 193º C indicate a significant impact of 200 ppm of BHA, more than doubling vitamin A retention after the first series of fryings, from 37% to 78% retention. In the second series of frying oil with BHA 22%

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[5] Personal Communication: Megan Cobcroft, Unilever and Varghese Abraham, Caravelle Foods.
[6] Personal Communication: Varghese Abraham, Caravelle Foods.
[7] Personal Communication: Hector Cori, Roche.

of vitamin A was retained while none was measured in the sample without antioxidant. Increased stability in sealed cans due to antioxidants can be inferred from a comparison of the various studies cited above in Table 2. Those studies including antioxidant reported 93-100% recovery while CIDA test of oil without anti oxidant recovered 87% of added vitamin A.

Battna, et al. (*12*) reported on the impact of Ronoxan A™ and two of its components (ascorbyl palmitate, lecithin) and of tocopherol acetate for stabilization of fats and retinyl acetate. Results obtained in sunflower oil, soybean oil, and milk fat along with mixtures of these fats indicate a protective effect. All antioxidant combinations caused a significant retardation of fat autoxidation. Ronoxan A had the best effect in all cases tested. Berge, et al. (*13*) found that ascorbyl palmitate, but not alpha -tocopherol, had a protective effect on vitamin A in vitamin A-fortified semi-skimmed milk.

Gopal, et al. (*9*) compared stability of vanaspati with Vanatin (tocopherol and lethicin) with samples that also included BHA. These tests report improved stability at all temperatures with BHA – although impact at lower temperatures was minimal. After simmering for 30 minutes, losses in oil without BHA were 8% as opposed to 8.9% without BHA. At higher temperatures the improvement with BHA is more pronounced. After 5 minutes of frying at 200º C, retention was 71% with BHA and 60% without. This gap progressively narrows over time. Gopal's work with vanaspati indicates that the protective effect of antioxidants may be more pronounced at higher temperatures when destruction of vitamin A is most extreme.

Steiner, et al. (*14*) at the University of Vienna report that in the presence of terephthalic acid, retention of vitamin A and D increased by 25% in samples heated for short times or at low temperatures. In addition, although no research data was identified, several sources suggested TBHQ might offer superior protection, particularly in soybean oil[8].

[8] Personal Communication: Varghese Abraham, Caravelle Foods and Megan Cobcroft, Unilever.

Table 7: Potential Impact Of Antioxidants

Study	Conditions	Time	Retention w/Antioxidant	Retention w/o Antioxidant
Health Canada	Storage & Shipping	3 Months		87%
Various Cited		3 Months	93 –100%	
Unilever/ Indonesia	Frying @ 193 C	2 Fryings	77%	37%
		4 Fryings	22%	0
Gopal	Deep Frying 200 C	5 minutes	71%	60%
(vanaspati)		10 minutes	55%	44%
		15 minutes	41%	32%
	Shallow Frying 220 C	10 minutes	20%	14%
	Simmering 100 C	30 minutes	91%	92%

3. Potential Cost of Antioxidants

Cost calculations are not possible without a prior determination of levels needed to significantly enhance the retention of vitamin A. Industry sources report that when antioxidants are added to commercial cooking oil a level of 200 ppm BHA or BHT is standard. This is in fact the level used in the Unilever's Indonesian frying tests cited in this report. Several industry sources stated that when customers specify BHA/BHT be added to cooking oil it does not affect the price at all. Lacking better information on the need for additional antioxidants, the cost of additional antioxidants is not included in the cost calculations offered in this report.

4. *Recommendations on Antioxidants*

Since most of the studies of stability cited conclusions with the use of antioxidants, the analysis provided at the conclusion of this report will also assume the use of antioxidants. For the optimal use of antioxidants to increase vitamin A retention in oil, a number of areas require further research:

- The relative effectiveness of various antioxidants and various levels on the stability of vitamin A should be tested, particularly in environments of exposure to light and air as well as high heat.

- The cost savings of adding antioxidant versus the cost higher fortification levels should be evaluated.

- It may be useful to review the food regulations of various recipient nations with respect to restrictions on the use of these antioxidant compounds.

IV. EFFICACY AND SAFETY OF VITAMIN A ADDED TO OIL

A. Biological Efficacy of Fortified Oil

Vitamin A is readily absorbed in the presence of oils and fats. After the introduction of vitamin A fortified margarine in Denmark at the end of 1917, the number of cases of xeropthalmia reported at a Copenhagen Hospital fell by more than 90% and by 1918 the condition had disappeared (*15*). Studies before and after the fortification of margarine in Newfoundland in 1944 report that the percent of subjects with serum vitamin A below 20 ug/dl declined from 48% to 2% over 4 years (*16*). More recently, a shelf stable margarine in the Philippines was fortified with vitamin A. After consuming the margarine for six months, the baseline prevalence of children with serum retinol levels below 20 ug/dl fell from 25.6% to 10.1%[9]

The biological value of vitamin A fortified oil has been reported in two studies. Dutra de Oliveira, et al. (*17*) demonstrated that soybean oil with vitamin A in the form of retinal palmitate is well absorbed in humans given fortified oil along with a rice-based diet. Significant increases in plasma retinol were reported. Differences in plasma retinol for subjects receiving uncooked versus cooked soybean oil were not statistically significant. Favaro, et al. (*18*) report increased weight gain, plasma retinol and liver stores in rats consuming diets which included fortified soybean oil. However, the improvement in plasma retinol and liver stores for rats consuming diets of food cooked at 170º C was 55% less than those given diets cooked at 100º C.

B. Safety and Toxicity Considerations

Vitamin A toxicity can be classified into three categories: acute, chronic, and teratogenic. Acute toxicity results from one or several closely spaced very large doses of vitamin A, usually more than 100 times the safe RDI. The signs are usually transient and disappear after a few days. Chronic toxicity occurs with recurrent intakes over a period of months to years of excessive doses of vitamin A, which are usually at least 10 times the safe RDI. Most people recover fully from chronic toxicity.

Teratogenic toxicity, in pregnant women, is known to result from substantial doses (more than 7,500 ug or 25,000 IU) of vitamin A taken daily, from larger doses (more than 30,000 ug or 100,000 IU) taken for several days or weeks, or from a single large dose (150,000 ug or 500,000 IU). Pregnant women, however, have taken daily doses of 4,500 ug or 15,000 IU, for significant periods without apparent harm to their offspring. The most sensitive period for toxic effects at all doses is the first trimester of pregnancy. Beyond the first trimester, the risk to the fetus is much lower. Teratogenic toxicity results in fetal resorption, abortion, birth defects, and permanent learning disabilities in the offspring as well as toxic effects on the mother[10]. To protect against teratogenic toxicity, WFP programs project the maximum safe level for pregnant women at a lower level, 10,000 IU per day over an extended period of time in accordance with WHO/UNICEF 1997 statement at IVACG[11].

V. TECHNOLOGY OF FORTIFYING OIL WITH VITAMIN A

[9] A Case Report on the Fortification of Margarine with Vitamin A, Florentino Solon, in Food Fortification to End Micronutrient Malnutrition, MI, 1998

[10] NGONUT e-mail: Penny Nestel, OMNI.

[11] Personal Communication: Pieter Dijkhuizen, World Food Program.

A. Market Forms

Vitamin A acetate and palmitate are the most common market forms available for the addition of vitamin A to oil. Both have superior stability compared to pure retinol. Hoffman LaRoche and BASF are the dominant suppliers of these market forms worldwide. A list of products available in the United States is provided in the Appendix B at the end of this report. Costs are identical for acetate and palmitate forms on an equivalent activity basis[12]. The palmitate oil products are predominantly used in commercial markets for margarine and in currently fortified vegetable oils. Acetates appear to be preferred in pharmaceutical preparations and supplements[13]. The powder vitamin A forms, such as the 250 SD product specified for the cereal based PL 480 commodities like CSB, corn meal, bulgur and wheat flour or used in sugar fortification programs in Latin America and Africa are about three times more expensive on an equal activity basis.

Acetate and palmitate have similar properties. However, there are indications that palmitate may feature slightly superior stability. After storing the premix for 24 months at 20º, Roche Food Applications Laboratory reports 95.7% retention of palmitate versus 93.6% retention of the acetate form (*19*). Slightly superior stability has also been reported for palmitate in peanut oil and acetate in milk[14]. Tests at Unilever (*10*) indicate palmitate is more stable in aqueous solution in colored bottles at 45º C. Gopal, et al. (*9*) report higher recovery of palmitate under a range of temperatures in tests at Roche (*20*) and in two Indian laboratories as indicated in Table 8 below. After 25 minutes at 180º C, Gopal, et al. found 56% of the acetate was retained compared to 80% of the palmitate.

Table 8: Comparative Stability Of Retinol Palmitate Vs Acetate

Source: Gopal, et al. 1955

Heat º C	Minutes	Vitamin A Retention: Acetate	Vitamin A Retention: Palmitate
95	25		92%
110	5	75%	
150	5	57%	
180	25	56%	80%
200	25	4%	18%

B. Process Technology

The technology required for the addition of vitamin A to refined oil is simple and low cost. Dosing technology for adding antioxidants and other micro ingredients to oil is routine (*6*). While for many oils a temperature of 40-50º C is required to assure uniform mixing, the threshold to insure uniform liquid state for soybean oil is less - about 25º C. Producers in Canada report minimal adjustments to add vitamin A. Since other additives are often used, personnel and technology are already in place. Canadian packagers report that the mixing is easily accomplished in an agitated tank in one hour[15].

VI. CURRENT EXPERIENCES IN FORTIFICATION OF VEGETABLE OIL

[12] Personal Communication: Karl Nagy, Hoffman LaRoche.
[13] Personal Communication: Megan Cobcroft, Unilever.
[14] Personal Communication: Simone Koenig, Hoffman LaRoche.
[15] Personal Communication: Dave Forster, Canamera.

A. Developed Markets

While most margarine is fortified with vitamin A in Europe and North America, vegetable oils are generally not fortified. In general, the industry regards vegetable oil a commodity product with less value-added, lower markup and less profit potential than margarine. Therefore the additional cost of fortification is more easily absorbed for margarine products and the market is more developed. While there is interest among multinationals in vitamin A fortification, business issues remain problematic[16]. Table 9 shows some commercial products for developed markets as well as some products in Asia and South America.

Table 9: Commercial Oils With Added Vitamin A

Product	Company	Country	Vitamin A Level	Other Vitamins	Packaging
Cristal –Soya	Unilever	Chile	14 IU/g	E	Box Bottle 500ml & 1L
Sundrop	ITC	India	20 IU/g		Plastic Pouch 100 Mil
'Bbakken en braden'	Unilever	Netherlands	25 IU/g	D	Opaque plastic 400g
Remia - 25% butter + oil	Remia	Netherlands	25 IU/g	No	opaque plastic 432ml
Mediteranne Mixed Oils	Brinkers	Netherlands		D,E	opaque plastic 400g
Carotino – Canola/Palm	Carotino	Malaysia	Carotene in palm oil)	E (in oil)	opaque plastic 500ml
Gouda's Glorie	Van Dijk Foods	Netherlands	28 IU/g		opaque plastic
Sunnuntai – liquid margrn	Raisio	Finland		D, E	
Pura – Sunflower oil	Pura foods	UK		D,E	opaque plastic bottle

B. Developing Countries

In developing countries, there are several cases of mandatory fortification of cooking oils with vitamin A. In Pakistan all oils are required by law to be fortified at 33 IU/g. In India, *vanaspati* -- a hydrogenated oil, with about 10% market share of all oils in that country -- is fortified by law to a level of 20 IU per gram. The legislation was enacted in the 1950's in order to make *vanaspati* nutritionally equivalent to the animal based *ghee* product. In both these instances, quality assurance and marketing systems are not in place and evaluations have not developed.

C. World Food Program

In FY 1997 the WFP shipped 83,000 MT of vegetable oil. Of this, 57,000 were donated and 26,000 purchased. With the exception of USAID, all donated oil is fortified -- although levels of addition vary from 50 IU/g from EU nations to 60 IU/g from Canada. Specification for oil

[16] Personal Communication: Megan Cobcroft, Unilever.

purchased by WFP includes 30 IU/g of vitamin A with either synthetic vitamin A or fortification with natural palm oil. WFP is discussing the situation of multiple levels in the program and will be reviewing the possibility of raising the 30 IU/g level for purchased oil. A consultant has been hired to review levels of fortification in all commodities including vegetable oil and a workshop on this subject is being discussed for 1999. Vitamin D is added to vegoil shipped to populations in colder climates or where women are kept covered for religious reasons. No antioxidants are specified. WFP policy is to deliver fortified oil to all recipient nations.[17].

Table 10: Vegetable Oil Contributions To World Food Program

Source: World Food Program, 1998

Country	Metric Tons
USA	35,000
Canada	1,000
European Union	20,000

Quality Assurance

WFP stipulates that suppliers purchase premix from either Roche or BASF and requires that vendors produce a certificate proving purchase of sufficient quantity of premix to fortify the specified amount of oil. Before accepting delivery from Malaysian suppliers, WFP requires independent verification of levels of fortification at the point of packaging by approved labs[18].

Regulatory Issues

WFP reports that regulations allowing vitamin A addition to oil is not specifically addressed in most countries. However, they indicate no problem acquiring the required certificates. WFP believes the operative legal document is the Consumer Rights Declaration of General Assembly.

D. Canada

Since July 15, 1994, fortification at the level of 60 IU/g oil (1.8 mg RE with a tolerance to 2.25 mg RE) has been an official CIDA specification for refined oil in tender calls. These specifications are for refined oil only and do not apply to bulk shipments. NGOs are asked to use CIDA specs when purchasing with CIDA funds. No antioxidants are specified although there seems to be some discussion of including vitamin E. This level of 60 IU/g was established in order to compensate for projected losses and to deliver 50 IU/g to program destinations. Health Canada indicated that the level was certainly safe and could be increased to provide an additional protective benefit[19]. Canadian packagers report that incremental costs are minimal and mainly reflect the cost of fortificant[20].

Quality Assurance

CIDA specs require independent confirmation of the level of Vitamin A and CIDA/WFP do some random testing of shipments at the point of distribution where unopened bottles are returned to Canada for testing. Health Canada conducts the analysis. Information is also sent on the dates of delivery to port, type of transport, distance to final destination, and mean temperatures. Several

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[17] Personal Communication: Pieter Dijkhuizen, World Food Programme.

[18] Personal Communication: Pieter Dijkhuizen World Food Programme.

[19] Personal Communication: Barbara McDonald, CIDA

[20] Personal Communication, Dave Forster, Canamera

of these tests have been indicating satisfactory stability of vitamin A to the point of distribution[21]. Sources at independent labs providing tests for vitamin A in this matrix indicate the margin of error in their tests seem to be less than 10%.[22]

VII. PL 480 PROGRAM VEGETABLE OIL DONATIONS

In the last full fiscal year PL 480 delivered more than 150,000 tons of vegetable oil through a variety of PVOs. For Fiscal year 1997, 58,000 MT were shipped to Africa 52,830 MT to Latin America and 32,750 MT to Asia (Adapted from USAID FFPIS). Peru and India received approximately half of this donation for FY 1997. Other major recipient nations include Ethiopia, Mozambique, Rwanda, Angola, Sudan, and Bosnia. Appendix C provides a full breakdown of PL 480 shipments for FY 1997 by region and nation. As illustrated in Table 12 below, expenditures for vegetable oil have run from 20- 25% of total commodity dollars for the past 3 full fiscal years.

Table 11: Vegetable Oil Share Of PL 480 Commodity Expenditures

Source: USDA, Monthly Purchase Trend, 1998

	FY 1995	FY 1996	FY 1997
Vegetable Oil Dollars	$120,015,800	$102,021,602	$106,063,239
Total Commodity Dollars	$511,146,524	$510,366,025	$435,628,077
Vegetable Oil Share of Total	23%	20%	24%

A. Packaging

Vegetable oil shipments are made in 4- and 20-liter containers, 208-liter barrels and by bulk. All containers and barrels are opaque and sealed, effectively protecting the oil from the effects of light and air. Quantities shipped in the various containers are provided in Table 13 below. 208-liter barrels also include a layer of nitrogen to more effectively protect the oil. This added protection reduces the amount of oil in each barrel by 5 pounds. This technique may also provide added stability for vitamin A in 4- and 20-liter containers. However, a cost benefit analysis is recommended prior to any change in packaging. This is due to the fact that any gains in vitamin A stability would be achieved at an increased cost of adding the nitrogen as well as additional packaging and shipping costs. (Adding nitrogen entails slightly less oil per container and therefore involves filling and shipping more containers.) These incremental expenses will be relatively small but must be balanced with the cost of vitamin A saved.

B. Relief and Development Programs

In FY 1997 approximately 81,540 MT (adapted from FFPIS) or about 55% of all PL 480 shipments were utilized by PVOs undertaking a variety of disaster and relief programs as well and health and development activities. These programs are estimated to reach more than 22 million people. A breakdown of oil delivered through these programs is provided in Appendix D These programs focus on direct feeding or distributing to disadvantaged populations who are at higher

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[21] Personal Communication: Barbara McDonald, CIDA.

[22] Personal Communication: Hugh Black, Diversified Research Laboratories Inc., Markham Ontario

risk of VAD. A number of programs specifically target women and children, such as MCH, School feeding and Parent Child Feeding.. These programs will generally provide an effective pathway for providing additional vitamin A to at risk populations. Moreover, limited rations reduce the risk of over-consumption. The following factors will influence the effectiveness of fortified oil in these programs.

Transport from Packager in US to Program Area Overseas
The time required for shipments to get from the point of packaging to their arrival at overseas ports can be as much as 4 months but is typically less. In most cases, PL 480 oil is delivered from the port of entry overseas to the distribution site in a matter of weeks or even days. In many cases, most of this oil is used or distributed within a matter of weeks – usually sooner[23]. For an interim of 2-6 months, the stability of vitamin A in sealed containers will be quite high. However, in some cases such as Disaster Preparedness and Repositioning Programs, 10-12,000 MT in 1997, the oil may be stored for 6-8 months before transfer to final destination[24]. Losses of vitamin A during this period of storage in sealed and opaque containers should be slight.

Packaging in 4 & 20 Liter Containers
As shown in Table 12 below, oil in relief and development programs is distributed almost exclusively in sealed 4-liter and 20-liter opaque containers. These effectively seal out light and air until opened. In FY 1997 54,480 MT or about 67% of all non-monetized shipments, were delivered in 4-liter containers. 20-liter containers accounted for about 25,160 or about 31%. After these small containers are opened and exposed to light and air, the oil will be consumed in 1 to 30 days depending on the distribution program, as indicated below.

Table 12: Shipments for Relief and Development Programs
By Package Type for Fiscal 1997

Source: FFPIS, USAID

Packaging	MT Oil	Oil Value	Oil + Freight
208L Total	1,900.00	1,341.40	1,613.90
20L Total	25,160.00	19,977.00	23,731.80
4L Total	54,480.00	43,196.90	54,676.10
Grand Total	**81,540.00**	**64,515.30**	**80,021.80**

Wet Feeding versus Distribution/Take-Home Programs
When used in wet feeding programs -- school feeding, orphanages, camp kitchens, health centers and therapeutic feeding -- the whole container of oil is normally used and consumed within the day it is opened. As a result, loss of vitamin A from contact with light and air prior to cooking is minimal. When oil is distributed for use at home, the situation is more complex. In some cases, this oil is distributed to a family or group of families in sealed 4-liter containers. In other cases, oil is poured out of the original container into a variety of jars brought by recipients. These programs distribute weekly, bi-weekly and sometimes monthly. Consequently, the oil may be

[23] Personal Communications: Thoric Cederstrom, Save the Children; Joe Gerstel, Catholic Relief Services; Gwen Gessle, ADRA International; Ben Hoskins, World Vision, Pieter Diekhausen, World Food Program; Page Harrigan, Food Aid Management; Dave Evans, Food for the Hungry; Tom Ewert, Merci Corps; Ann Henderson World Vision, Tom Valle, American Red Cross
[24] Personal Communication: Ben Hoskins, World Vision.

exposed to light and air for a maximum of up to 30 days prior to consumption[25]. For a number of reasons it was not possible to segregate how much vegoil was used in feeding programs, where conditions are most favorable to vitamin A stability, as opposed to distribution programs, where conditions are least favorable to vitamin A stability. However, we can presume that a 30-day ration in a glass jar is the worst case scenario for vitamin A stability.

Cooking Practices: Simmering versus Frying

While no definitive assessment was possible, conversations with a number of sources confirmed that most PL 480 oil is utilized in situations of boiling, stewing or simmering at around 100º C or light frying at slightly higher temperatures. In most feeding programs oil is typically used as a calorie or energy enhancer. It is added in small quantities to the staple food which is boiled or simmered at low temperatures. In these cases, losses will be relatively small. When distributed and used in the home, it is used sparingly for flavor or texture. It is used to make sauces, to flavor staple foods, or is added directly to boiling rice, beans or cornmeal. It is used in light frying or simmering vegetables prior to adding beans, grains or other staples for stewing. Often it is used in the preparation of sauces. In these cases of low temperature cooking, losses will be minimal.[26].

Sometimes oil is used in frying grain and vegetable dumplings or patties to prevent sticking to the pan. In these cases, the oil is typically absorbed completely in one frying and therefore is only used once. Multiple fryings with the same oil -- as is common with urban street -- are therefore quite rare [27]. Losses in the case of frying will be higher. However, since the oil is used sparingly, is completely absorbed into the food, and temperatures are generally below 170º C, the significant losses seen in high temperature multiple frying are probably rare.

Fires and Heating for Cooking

While butane gas – capable of delivering high temperatures - is sometimes found in PVO and institutional feeding situations, most cooking either in feeding programs or in the home is done on a wood or charcoal fire[28]. This fuel is used sparingly. This fire is usually sufficient for boiling, simmering or slightly higher temperatures for light sautéing in preparation for stewing. Losses during cooking at these temperatures are minimal.

C. Monetization Programs

In FY 1997 PVOs monetized approximately 69,430 MT (adapted from FFPIS[29]) or about 45% of roughly 150,000 MT of PL 480 oils shipments. A full breakdown of monetized oil shipments for

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[25] Personal Communications: Thoric Cederstrom, Save the Children; Joe Gerstel, Catholic Relief Services; Gwen Gessle, ADRA International; Ben Hoskins, World Vision, Pieter Diekhausen, World Food Program; Page Harrigan, Food Aid Management; Dave Evans, Food for the Hungry; Tom Ewert, Merci Corps; Ann Henderson World Vision, Tom Valle, American Red Cross

[26] Personal Communications: Thoric Cederstrom, Save the Children; Joe Gerstel, Catholic Relief Services; Gwen Gessle, ADRA International; Ben Hoskins, World Vision, Pieter Diekhausen, World Food Program; Page Harrigan, Food Aid Management; Dave Evans, Food for the Hungry; Tom Ewert, Merci Corps; Ann Henderson World Vision, Tom Valle, American Red Cross.

[27] Personal Communications: Ben Hoskins, World Vision, Pieter Diekhausen, World Food Program.

[28] Personal Communications: Thoric Cederstrom, Save the Children; Joe Gerstel, Catholic Relief Services; Gwen Gessle, ADRA International; Ben Hoskins, World Vision; Tom Ewert, Merci Corps; Ann Henderson World Vision, Tom Valle, American Red Cross.

[29] Food for Peace Product Information Sheet

FY 1997 is provided in Appendix E. This oil is sold to traders, often in urban areas. Some of this oil finds its way into retail markets as a mid- to premium-priced oil. Most of the monetized oil is sold to industry for reprocessing and packaging or for use as an ingredient in a variety of value-added food products. This is particularly true of bulk shipments and 208-liter barrels. Most sources doubt that this oil reaches the target population since mid-priced oil products or value added products are generally not found in the daily diet of the poor, particularly in rural areas. Interviews with several PVOs indicate that some PL 480 oil does reach the urban poor in the form of street foods. However, these are often deep fried foods where oil is used multiple times at a high temperature frying[30]. Retention of vitamin A in significant amounts is therefore doubtful.

1.) Bulk Shipments of Crude Degummed Oil

About 52,000 MT or 75% of monetized oil is shipped in bulk. A break-out of monetized shipments by packaging type is provided in Table 13 below. While some refined vegetable oils included in Title I programs are shipped in bulk, Title II PL 480 vegoil shipments are crude degummed soybean oil or crude sunflower oil [31]. CIDA does not add vitamin A to its bulk oil shipments. Fortification of crude degummed oil is problematic for a number of reasons listed below.

a.) The refining, bleaching and deodorization process involved in producing consumer oil from the crude degummed will effectively destroy vitamin A.

b.) Much of this oil is used directly by the food industry which subjects the oil to a variety of processes where oxidation and vitamin A destruction potential is high.

c.) A higher acid and mineral content will react with added vitamin A, significantly lowering its stability. Consequently, even in the event that some is sold directly to consumers, much of the vitamin A will be lost[32].

Table 13: Shipments of Monetized Oil by Package Type: FY 1997

Source: FFPIS, USAID, 1998

Packaging	MT Oil	Oil Value	Oil+Freight
208L Total	8,470.00	5,979.80	7,018.50
20L Total	1,250.00	992.50	1,155.00
4L Total	7,500.00	5,955.00	7,562.50
BULK Total	52,210.00	28,976.50	35,502.80
Grand Total	**69,430.00**	**41,903.80**	**51,238.80**

Since most PVOs do not track the uses of monetized oil after selling to local businesses, it was not possible to quantify the ultimate utilization of monetized PL 480 oil. This data should be gathered if USAID is to consider the fortification of monetized bulk oil.

[30] Personal Communications: Thoric Cederstrom, Save the Children; Joe Gerstel, Catholic Relief Services; Gwen Gessle, ADRA International; Tom Ewert, Merci Corps; Ann Henderson World Vision, Tom Valle, American Red Cross.

[31] Personal Communication: Ken Martin, USDA.

[32] Personal Communication: Varghese Abraham, Caravelle Foods.

However, this analysis indicates that due to variety of conditions negative to the stability of vitamin A, fortification of bulk crude oil will not provide for an efficient vitA vehicle.

2.) Packaged Refined Oil

As reflected in Table 13, during FY 1997 about 17,220 MT of monetized oil was shipped in 208-liter barrels or in 20- and 4-liter containers. This represented approximately 25% of the monetization program. Interviews with several PVOs indicate that 208-liter barrels are destined mainly for industrial sources, while the utilization of 4- and 20-liter containers is more varied. As indicated above, very little of this oil will be consumed by those at risk. However, adding vitamin A to this segment of the monetized oil may be considered, because it will not be subjected to the negative stability environment of the bulk shipments. Moreover, since it is often not possible to target specific containers of oil to specific PVOs or recipients (because shipments are sometimes diverted from one area to another or mixed together in cargo holds of freighters), fortifying all packaged refined oil may prove simpler from a programmatic viewpoint[33]. While fortification of monetized oil is not recommended in this report, a further analysis of these programmatic implications may indicate that all oil shipped in 4- and 20-liter containers, both monetized and non-monetized, should be fortified with vitamin A.

Table 14: Trends In Packaging For PL 480 Purchases

Source: USDA, Monthly Purchase Trend, 1998

Package	FY 1995 in MTs	FY 1996 in MT	FY 1997 in MT	FY 1998 MT (to date)
4 Liter	87,770	66,230	61,580	36,200
20 Liter	25,230	28,100	24,080	22,480
208 Liter	12,220	3,760	10,140	1,580
Bulk	13,000	35,140	49,210	42,760
TOTAL MT	138,220	133,300	145,010	103,020
	% Total MT 1995	**% Total MT 1996**	**% Total MT 1997**	**% Total MT 1998(to date)**
4 Liter	63.5%	49.7%	42.5%	35.1%
20 Liter	18.3%	21.1%	16.6%	21.8%
208 Liter	8.8%	2.8%	7.0%	1.5%
Bulk	9.4%	26.4%	33.9%	41.5%

3.) *Trends in Bulk Shipments of PL 480 Oil*

As indicated in Table 14 above, over the past four years the share of bulk crude degummed oil increased from 9% to 34% of total PL 480 vegoil shipments. This increase is mainly at the expense of 4-liter packages, which fell from 64% to 43% of total during the same time period. As noted above, fortifying bulk crude degummed oil, which is monetized, may provide little or no public health impact (Please note that total tonnage reported by USAID and USDA is slightly different for FY 1997).

D. Estimated Costs of Fortifying PL 480 Refined Vegetable Oil

The cost effectiveness of delivering vitamin A through vegoil as opposed to CSB was discussed by Atwood, et al. (*7*) who determined that cost of delivering vitamin A in oil is considerably cheaper than CSB. Also, the losses appear to be less than those estimated for CSB by Atwood

[33] Personal Communication: Bill Hudson, Calwestern.

and in the SUSTAIN MAP study.

The price of the fortificant is the major ongoing cost of oil fortification. US packagers indicate that costs above and beyond the expense of the premix will be less than 5% of the total[34]. Based strictly on the cost of retinol palmitate and costs to fortify 81,540 MT, the non-monetized PL 480 shipments in FY 1997, are calculated in Table 15 below for fortification levels ranging from 30-120 IU/g. WFP currently specifies a level of 30 IU/g, while Canada adds 60 IU/g. Based on a cost of $55/kg for retinol palmitate premix[35], the incremental cost of adding a fortificant ranges from $134,000-538,000 depending on the level. Based on the $79,980,000 expense of purchase and shipping for 81,540 MT of non-monetized oil FY 1997, this incremental cost represents less than 1% of total costs. The cost for 3 IU of Vitamin D is approximately 25 cents per ton[36]. Please note that the costs indicated in Table 15 relate to the fortificant only. Final costs are estimated to be about up to 5% higher, i.e. an addition $7,000 for fortification at 30 IU/g.

Table 15: Premix Cost Of Fortifying PL 480 Non-Monetized Oil FY 1997

Source: USAID, FFPIS, 1998

Fortification Level	Incremental Cost w/ Vitamin A	% of Purchase Costs (inc. Freight)
30 IU/g @ $1.65	$134,541	0.17%
60 IU/g @ $3.30	$269,082	0.34%
90 IU/g @ $4.95	$403,623	0.50%
120 IU/g @ $6.60	$538,164	0.67%

E. Initial PL 480 Experience

Recently, PL 480 tendered a WFP request for 3000 MT of oil bound for Pakistan to be fortified at 30 IU/g of vitamin A and 3 IU/g of vitamin D. All potential packagers bid. Although they indicated guidelines could be clarified, packagers also said there was no problem satisfying this tender. In the words of one manufacturer (John Phelps, Calwestern), “We have several options for how to add the vitamin A, but none of them are complicated.”

Price of Initial Shipment

Due to some confusion over the fortification level in the original tender offer, the first bid for this shipment for WFP was originally quoted at an incremental cost of $13 per MT. After the specification were clarified, the order was re-bids and awarded at an increment of about $5.00 per MT[37]. This still exceeds the expected incremental cost of about $2.00 per MT ($1.90 for fortificants plus 5% overhead) for the indicated levels of vitamin A and D[38]. Canadian suppliers and WFP report that in most cases premiums paid for fortification reflect mainly the incremental cost of the fortificant itself[39]. Conversations with suppliers indicate that this relatively large premium over the cost of fortificant was due to start-up issues in developing an essentially “new

[34] Personal Communication: John Phelps, Calwestern.
[35] Personal Communication: Karl Nagy, Hoffman LaRoche.
[36] Personal Communication: Hector Cori, Hoffman LaRoche.
[37] Personal Communication: John Phelps, Calwestern.
[38] Personal Communication: Hector Cori, Hoffman LaRoche.
[39] Personal Communication: Dave Forster, Canamera; Pieter Dijkhuizen World Food Programme.

product.” Should fortification become a standard requirement involving larger volumes, future costs should be no more than 5% over the cost of fortificant[40].

Suggested Guidelines for Fortification
Representatives of packagers indicate that performance specifications are all that is required[41]. These would take the form of a paragraph in the tender stipulating a minimum level of vitamin A per 100 grams or per liter as well as higher tolerance. A requirement for testing by the Federal Grain Inspection Labs should be included[42]. It is also recommended that when expiration dates are used in labeling that they only reflect the shelf life for the oil rather than any additional expiration dates for vitamin A[43].

VIII. ESTIMATING POTENTIAL IMPACT

To calculate impact of fortified oil and to forecast efficient and safe levels, it is crucial to establish assumptions for consumption and vitamin A stability. These are established below in order to make preliminary calculations of actual impact on vitamin A status.

A. Ration Size Assumption
Category recipients data is available for 50,443 MT (USAID, FFIS) or approximately 62% of all non-monetized oil shipments for FY 1997 (outliers in 3 programs have been excluded). By adding all available category recipients and dividing by the total metric tons of oil destined for those recipients, an average ration of 5.92 kg/year or 16.2 g/day per recipient can be calculated. This calculation is itemized in Appendix F. The ration sizes calculated most commonly fall in the range of 5g to 30g per day. This tends to agree with internal ration targets of around 0.5 kg/month or 16-17 g/day reported by various PVOs interviewed. Certain programs, such as therapeutic feeding, report higher target rations, in the 50 g/day range. While these figures are extremely rough and may not hold on a year round basis, they provide a basis for estimating impact.

From the data obtained it was not possible to identify average portion sizes for young children, the highest risk group. The RDI for children is about a third less than that of adults. Consequently, if the consumption of oil by children is less than one-third of an adult’s, the following projections of impact may not hold for children. While we may assume that children’s oil portions in wet feeding programs is sufficient, more information on the division of foods within families is necessary to determine more precisely the consumption of oil by young children. Since children are a major risk group, the issue of children’s consumption levels is crucial.

B. Stability Assumptions
There are three critical links in the survival of vitamin A from producer to PVO to ultimate recipient.

1. In sealed opaque containers during shipping and storage to distribution point
For most programs and in most instances, oil arrives at the overseas port in less than 4 months

[40] Personal Communication: John Phelps, Calwestern.
[41] Personal Communication: Bob Sindt, Attorney.
[42] Personal Communication: Ken Martin, USDA.
[43] Personal Communication, Thoric Cederstom, Save the Children; Pieter Dijkhuizen World Food Programme.

and sometimes as low as 1-2 months. For many programs, oil is transported to the program distribution site within a few weeks of arrival.

> *Assumption:* Based on a rough average of studies cited through 6 months of storage in sealed containers we shall assume 95% retention of vitamin A from the point of fortification to the point of opening the container in the field.

2. Between opening containers and cooking (exposing to light, air and oxidation)
In feeding programs, oil containers will be completely utilized in the day they are opened, resulting in minimal losses. However, the assumptions below will be based on a worst-case scenario of distribution on a monthly basis indicating an open container for 30 days.

> *Assumption:* An average of results by Atwood and Favaro (from months 6-9), indicate approximately 80% survival of vitamin A stored in open cans over the course of 30 days. Assuming the loss of vitamin A as well as the consumption by recipients is evenly distributed over 30 days, the average stability figure is obtained at 15 days. This would indicate half the 20% loss over 30 days or 10% (an average vitamin A retention of 90%).

3. Stability during cooking
The utilization of PL 480 oil is varied. However, interviews affirm that much, if not most, of the oil is utilized in situations of boiling or simmering at around 100º C or light frying at temperatures well below 170 º C. In cases of light frying the oil is rarely used more than once.

> *Assumption:* Most studies indicate vitamin A survival of 88-100% during cooking at around 100º C for 15-90 minutes and around 80% for one frying at up to 170º C. Presuming cooking over wood fires and few multiple fryings of the same oil, it is reasonable to project two scenarios with cooking losses of vitamin A projected at either 5% or 20%.

C. Calculations for Potential Impact
Based on the assumptions indicated above, the table below illustrates two scenarios of potential impact for various fortification levels. Both scenarios assume 5% losses in shipping and 10% losses due to exposure to light and air after opening. However, Scenario #1 reflects assumptions of 5% losses during cooking while Scenario #2 reflects 20% losses during cooking.

Providing RDI with Fortified Oil
Table 16, Scenario #1 with a 5% cooking loss, indicates that a fortification level of 60 IU/g will provide about 39% of RDI @ 2000 IU/day based on average consumption of 16 g/day. This ranges from 12% of RDI for the lower range of 5g/day and 73% based on the upper range of 30g/day. Fortification at 90 IU/g indicates delivery of an average 59% of RDI ranging from 18 - 110% for the range of typical consumption. Table 17, Scenario #2 with a 20% cooking loss, indicates an average provision of about a third of the RDI when fortified at a level of 60 IU/g. Based on these assumptions of 20% loss in cooking, about 50% of RDI will be provided by an average ration fortified at 90 IU/g. One might note that the varying impacts on RDI illustrated in these tables is related much more to ration size than to cooking loss. For example, on average a 16-gram ration of oil fortified at 60 IU/gr is projected to provide about 33% of RDI with a 5% cooking loss versus a 39% RDI with a 20% cooking loss. In other words, an average ration at 60 IU/g will provide about one-third of RDI whether the oil is used in simmering, boiling or frying.

Table 16: Scenario #1: Proportion Of RDI Delivered With 5% Cooking Loss

Added Vitamin A Level (IU/g)	Shipping: 5% Loss	Open Can: 10% Loss	Cooking: 5% Loss	Ration: 30 g/day	% RDI: 2000 IU/day	Ration: 5g/day	% RDI: 2000 IU/day	Ration: 16 g/day	% RDI: 2000 IU/day
30	28.5	25.7	24.4	731.0	36.6%	121.8	6.1%	389.9	19.5%
60	57	51.3	48.7	1462.1	73.1%	243.7	12.2%	779.8	39.0%
90	85.5	77.0	73.1	2193.1	109.7%	365.5	18.3%	1169.6	58.5%
120	114	102.6	97.5	2924.1	146.2%	487.4	24.4%	1559.5	78.0%

Table 17: Scenario #2 Proportion of RDI Delivered with 20% Cooking Loss

Added Vitamin A Level (IU/g)	*Shipping: 5% Loss*	*Open Can: 10% Loss*	*Cooking: 20% Loss*	*Ration: 30 g/day*	*%RDI: 2000 IU/day*	*Ration: 5g/day*	*% RDI: 2000 IU/day*	*Ration: 16g/day*	*% RDI: 2000 IU/day*
30	28.5	25.7	20.5	615.6	30.8%	102.6	5.1%	328.3	16.4%
60	57	51.3	41.0	1231.2	61.6%	205.2	10.3%	656.6	32.8%
90	85.5	77.0	61.6	1846.8	92.3%	307.8	15.4%	985.0	49.2%
120	114	102.6	82.1	2462.4	123.1%	410.4	20.5%	1313.3	65.7%

Providing Basal Requirement for Vitamin A with Fortified Oil

For some purposes it may be useful to calculate the impact of fortified oil based on the basal requirement which reflects minimal needs rather than on the RDI necessary to sustain a normal active lifestyle. In this case, Table 18, Scenario #1 at 5% cooking loss indicates fortification at a level of 60 IU/g will provide about 63% of the basal requirement of 1230 IU/day based on average consumption of 16 g/day. This ranges from 20% of basal requirement for the lower range of 5g/day to 119% based on the upper range of 30g/day. Fortification at 90 IU/g indicates delivery of an average 95% of the basal requirement ranging from 30-178% for the range of typical consumption. Table 19, Scenario #2 at 20% cooking loss, indicates an average provision of 53% of the basal requirement when fortified at a level of 60 IU/g. Based on these assumptions of 20% loss in cooking, about 80% of the basal requirement will be provided by an average ration fortified at 90 IU/g.

Table 18: Scenario #1: Proportion Of Basal Requirement Delivered With 5% Cooking Loss

Added Vitamin A Level IU/g	*Shipping: 5% Loss*	*Open Can: 10% Loss*	*Cooking: 5% Loss*	*Ration: 30 g/day*	*%BR 1230 IU/day*	*Ration: 5 g/day*	*% BR: 1230 IU/day*	*Ration: 16 g/day*	*% BR 1230 IU/day*
30	28.5	25.7	24.4	731.0	59.4%	121.8	9.9%	389.9	31.7%

60	57	51.3	48.7	1462.1	118.9%	243.7	19.8%	779.8	63.4%
90	85.5	77.0	73.1	2193.1	178.3%	365.5	29.7%	1169.6	95.1%
120	114	102.6	97.5	2924.1	237.7%	487.4	39.6%	1559.5	126.8%

Table 19: Scenario # 2 Proportion of Basal Requirement Delivered with 20% Cooking Loss

Added Vitamin A Level IU/g	Shipping: 5% Loss	Open Can: 10% Loss	Cooking: 20% Loss	Ration 30 g/day	% BR 1230 IU	Ration 5 g/day	% BR 1230 IU/day	Ration: 16 g/day	% BR 1230 IU/day
30	28.5	25.7	20.5	615.6	50.0%	102.6	8.3%	328.3	26.7%
60	57	51.3	41.0	1231.2	100.1%	205.2	16.7%	656.6	53.4%
90	85.5	77.0	61.6	1846.8	150.1%	307.8	25.0%	985.0	80.1%
120	114	102.6	82.1	2462.4	200.2%	410.4	33.4%	1313.3	106.8%

D. Safety Considerations

Table 20 illustrates worst-case scenarios for high consumption, which may approach or exceed thresholds for safe intake by pregnant women of 10-15,000 IU/day for extended periods. These are calculated on the basis of 60 IU/g and 90 IU/g fortification levels and 5% cooking losses of vitamin A (the worst-case scenario for this safety calculation). The calculation includes ranges of vitamin A from other dietary sources ranging from 100 IU/day or 5% of RDI to 3000 IU/day or 150% of RDI. The intakes exceeding the WHO safety threshold of 10,000 IU/day are highlighted. For oil fortified at 60 IU/g vitamin A, women approach these levels of intake after consuming 90 grams of oil per day as well as 100-150% of the RDI for vitamin A from other sources. 90 grams is almost 6 times the average ration of 16 g/day and 3 times the high range of 30 g/day. For oil fortified at 90 IU/g, the WFP safety threshold is crossed when consumption reaches 60 g/day and when 150% of the RDI for vitamin A is also obtained from other dietary sources. 60 g/day is 375% of the average ration. It should be noted that this abnormally high consumption scenario would have to unfold on a consistent basis, day after day, for a long period of time. Consumption of 90 g/day equals an excess of 32 kg/yr – more than the highest per capita consumption for oil indicated by FAO balance sheets (27 kg/yr for Greece).

Table 20: High Consumption Scenario

Vitamin A from diet	IU/day from oil @ 60 IU/g Vitamin A and consumption of:			IU/day from oil @ 90 IU/g Vitamin A and consumption of :		
	30 g/day	60 g/day	90 g/day	30 g/day	60 g/day	90 g/day
100 (5% RDI)	1562	3124	4686	2293	4586	6879
200 (10% RDI)	1662	3324	4986	2393	4786	7179
300 (15% RDI)	1762	3524	5286	2493	4986	7479

500 (25% RDI)	1962	3924	5886	2693	5386	8079
1000 (50% RDI)	2462	4924	7386	3193	6386	9579
2000 (100% RDI)	3462	6924	***10386***	4193	8386	***12579***
3000 (150% RDI)	4462	8924	***13386***	5193	***10386***	***15579***

E. CSB plus Oil Scenarios

Fortified oil is not the only vehicle utilized to provide vitamin A to PL 480 recipients. In the field, oil is often used in conjunction with blended fortified foods such as CSB. Table 21 below illustrates the combined impact of CSB fortified at 20 IU/g together with oil fortified at 60 IU/g and 90 IU/gr. A range of CSB ration sizes is provided for various PVO programs and CSB losses of vitamin A are calculated at 35% for shipping and storage and an additional 20% during cooking. Retention for fortified oil is based on 5% cooking losses. The figures in Table 21 illustrate both efficacy and safety of the CSB/oil combination. With an oil fortification level of 60 IU/g , an average 16 gram ration of oil together with various servings of CSB provide range of 1300 to 3380 IU/dy of vitamin A or from 65% to 169% of RDI. At 90 IU/gr the combined impact of CSB and fortified oil ranges from 1690 IU to nearly 4000 IU. On the other hand, only when the highest reported consumption levels of CSB (250-266 g/day) as well as the average oil ration are tripled, is the safety threshold of 10,000 IU/day crossed.

Table 21: COMBINED VITAMIN A INTAKES: CSB plus Fortified Oil

CSB plus Fortified Oil @ 60 IU/gr	**CSB Ration**	**Retained**	**Oil Ration**		**Average x 3**
	@ 20 IU/gr	Vitamin A	16 gr/dy	30 gr/dy	3 x CSB + oil rations
PVO TARGET RATION	in gr/dy	in IU/dy	in IU/dy	in IU/dy	in IU/dy
SCF (High Range)	183	1903	2683	3365	8050
SCF (Low Range)	110	1144	1924	2606	5772
ADRA (MCF)	167	1737	2517	3199	7550
WFP Emergency	50	520	1300	1982	3900
WFP Supplementary (High Range	250	2600	3380	4062	***10140***
WFP Supplementary (Low Range)	100	1040	1820	2502	5460
CARE India (ICDS Feeding)	65	676	1456	2138	4368
CRS (High Range)	266	2766	3546	4228	***10639***
CRS (Low Range)	67	697	1477	2159	4430
CSB plus Fortified Oil @ 90 IU/gr	**CSB Ration**	**Retained**	**Oil Ration**		**Average x 3**
	@ 20 IU/gr	Vitamin A	16 gr/dy	30 gr/dy	3 x CSB + oil rations
PVO TARGET RATION	in gr/dy	in IU/dy	in IU/dy	in IU/dy	In IU/dy
SCF (High Range)	183	1903	3073	4096	9219
SCF (Low Range)	110	1144	2314	3337	6942
ADRA (MCF)	167	1736	2906	3929	8720
WFP Emergency	50	520	1690	2713	5070
WFP Supplementary (High Range)	250	2600	3770	4793	***11310***
WFP Supplementary (Low Range)	100	1040	2210	3233	6630
CARE India (ICDS Feeding)	65	676	1846	2869	5538

CRS (High Range)	266	2766	3936	4959	***11809***
CRS (Low Range)	67	696	1866	2889	5600

IX. CONCLUSIONS

1. Potential Impact of Vitamin A in Oil

Although impact will vary depending on distribution and cooking methods, under most conditions encountered in PL 480 programs, packaged refined vegetable oil can deliver significant levels of vitamin A to target populations**.**

2. Defining Fortification Levels

According the assumptions made in this report, providing 32-58% of RDI for an average daily ration of 16 grams of oil would indicate fortification at 60-90 IU/g levels.

3. Cost to PL 480 Program

The incremental cost of fortification at 60 IU/g is about one-third of one percent while fortification at 90 IU/g would represent an added expense of about one half of one percent.

4. Safety Considerations

In distribution and feeding programs where ration sizes are relatively small and controlled and where populations are not usually not consuming sufficient vitamin A from other dietary sources, the risk of vitamin A overdose is extremely unlikely.

5. Technology of Fortification

Eligible packagers indicate that the addition of vitamin A presents no technical obstacles.

6. Crude Oil Shipments

Monetized shipments in bulk of crude degummed soybean oil or crude sunflower oil should not be fortified as conditions for the retention of vitamin A are negative and little, if any, of this oil will reach populations at risk of VAD.

X. ISSUES AND NEXT STEPS

1. Tender Specifications

There is a need to develop more precise guidelines and quality assurance procedures for packagers bidding on fortified oil shipments, including conversion factors, allowable batch to batch variability, etc. This may include gathering data to define how long oil used in fortification can be held in storage prior to adding vitamin.

2. Data on Utilization of Oil in the Field

Additional information on the utilization of PL 480 oil by PVOs in the field may be needed to project impact of various levels more precisely.

3. Role of Antioxidants

The role of antioxidants should be further explored to determine which are most effective under field conditions. In addition to developing data for increased stability with antioxidants, information should be gathered on the acceptability of these compounds in the regulatory structures of the various recipient nations.

4. Evaluate Stability of Pakistani Shipments

Request from WFP that samples of the current USAID shipment of fortified oil to Pakistan be returned for analysis for surviving vitamin A. Batch to batch variability at the point of packaging should also be measured.

5. Explore Role of Monetization Programs

An additional evaluation should be conducted to determine the impact of fortifying that portion of monetized shipments that are refined and packaged in 4- and 20-liter containers.

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