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An Update

USAID

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OMNI Opportunities for Micronutrient Interventions

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Abstract

Food fortification is recognized as being the most effective way to eliminate dietary micronutrient deficiencies The challenge for developing countries is to identify suitable food vehicles as well as appropriate micronutrient compounds that remain stable and biologically available after processing, during storage, and during normal food preparation This paper focuses on fortification of wheat flour with vitamin A Countries that fortify wheat flour generally do so with iron and some of the B-complex vitamins With the exception of U S food aid programs, no national programs exist to fortify wheat flour with vitamin A although a number of pilot studies have been carried out to show that this may be a feasible option This paper discusses the technology and issues related to stability of vitamin A, sensory characteristics, quality assurance and control, and cost of wheat flour fortified with vitamin A and other micronutrients

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I Summary

Experience shows that wheat flour can be fortified with vitamin A Stability trials were conducted in the 1970s, when a proposal for increasing the number of nutrients added to wheat flour from four to ten was being considered in the U S Although this proposal was never enacted in the U S , adequate preparatory work was done, which showed that vitamin A added to wheat flour was sufficiently stable during storage under controlled conditions, and during cooking and baking of products made with fortified wheat flour

At various times and at various scales, vitamin A has been added to wheat, wheat flour, or bread in Bangladesh, India, Jordan, and Tunisia Most wheat flour provided by the U S Title II Food Aid Program has been routinely fortified with vitamin A for over 25 years, along with B vitamins, calcium, and iron However, the retention of vitamin A during storage and distribution, and at the time of consumption, has not been monitored Thus the efficacy of this intervention remains unknown

A stabilized form of dry vitamin A powder for use in wheat flour fortification is available Modern wheat mills are likely to have the equipment necessary to allow the addition of a vitamin/mineral additive to flour Considering typical per capita consumption of wheat of 150 to 350 grams in most wheat consuming communities, fortification of wheat flour at a level between 10,000 IU and 20,000 IU vitamin A per kilogram of flour is likely to be effective and safe

A major limitation of fortifying wheat flour with vitamin A is cost Almost all synthetic vitamin A used in the world is produced by one of two large multinational companies Vitamin A fortification may increase the cost of wheat flour by up to 2 percent, with additional costs of regulatory control incurred by the public sector

In countries where vitamin A deficiency is a public health problem, and in which wheat is widely consumed, wheat flour fortification with vitamin A should be explored as an approach to improving vitamin A status

II Introduction

Micronutrient deficiencies are common public health problems in many developing countries They affect an estimated two billion people worldwide and can result in an increased risk of serious illness, blindness, and death The most common deficiencies of vitamin A, iron, and iodine stem primarily from a lack of adequate and varied food supplies and inadequate public health measures to prevent infections and illness that block nutrient absorption and utilization USAID/OMNI together with UNICEF are committed to assisting countries to prevent and control these deficiencies One way to combat widespread micronutrient deficiencies is through food fortification or enrichment[1], which has been used for decades in many industrialized countries as a means to deliver nutrients to the population at large The main advantage of fortification is that it is a more reliable, safe, and cost effective means to control micronutrient deficiencies where a widely consumed and centrally processed food can be used as the vehicle (Nestel 1993) Fortification is becoming more feasible for less industrialized countries as their economies and technical capabilities grow

[1] Codex defines *fortification* as the addition of one or more essential nutrients to a food whether or not it is normally contained in the food for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups (FAO/WHO 1994) *Enrichment* refers to the addition of nutrients that are naturally present in the food and are lost during processing

and food industry develops Indeed, food fortifica tion is considered to be among the most cost effective strategies to address micronutrient defi ciencies (World Bank 1994)

In many developed countries, wheat flour has been traditionally enriched with the nutrients lost in milling riboflavin, thiamin, niacin, and iron This paper, however focuses on fortification of wheat flour with vitamin A Fortification of whole wheat may be appropriate where it is distributed directly to recipients through welfare programs, but is not practical as nutrients will be lost in the milling process Wheat flour is more suitable than whole wheat as a carrier where it is widely consumed as a staple food and where most of the wheat is cen trally milled

The consumption of wheat flour, either domestic or imported, as a staple food is increasing in many countries, largely because of its versatile use in bread, pasta, and other products as well as its relatively low cost in the international market The purpose of this paper is to provide program mers with an overview of current information relevant to fortifying wheat flour with vitamin A Figure 1 shows the prevalence of vitamin A deficiency and the per capita consumption of wheat in selected countries

III Wheat Flour Enrichment and Fortification

The general principles established by the Codex Alimentarius Commission for the addition of essential nutrients to foods specify that fortification is to be the responsibility of national authorities because the types and amounts of essential nutrients to be added, and the foods to be fortified, will depend on the food consumption patterns and nutrition needs of that country and target groups (FAO/WHO 1994)

A recent review by FAO of legislation pertaining to wheat flour fortification provides information on practices of selected countries (Clarke 1995) Of practices reported for 38 countries, 18 countries allow voluntary fortification of wheat flour Ten countries, including three developing countries (Ecuador, Philippines, and Honduras) have legisla tion allowing voluntary wheat flour fortification with thiamin, riboflavin, niacin, and iron A few countries (Lebanon, New Zealand, Finland, and Norway) specifically prohibit fortification of wheat flour

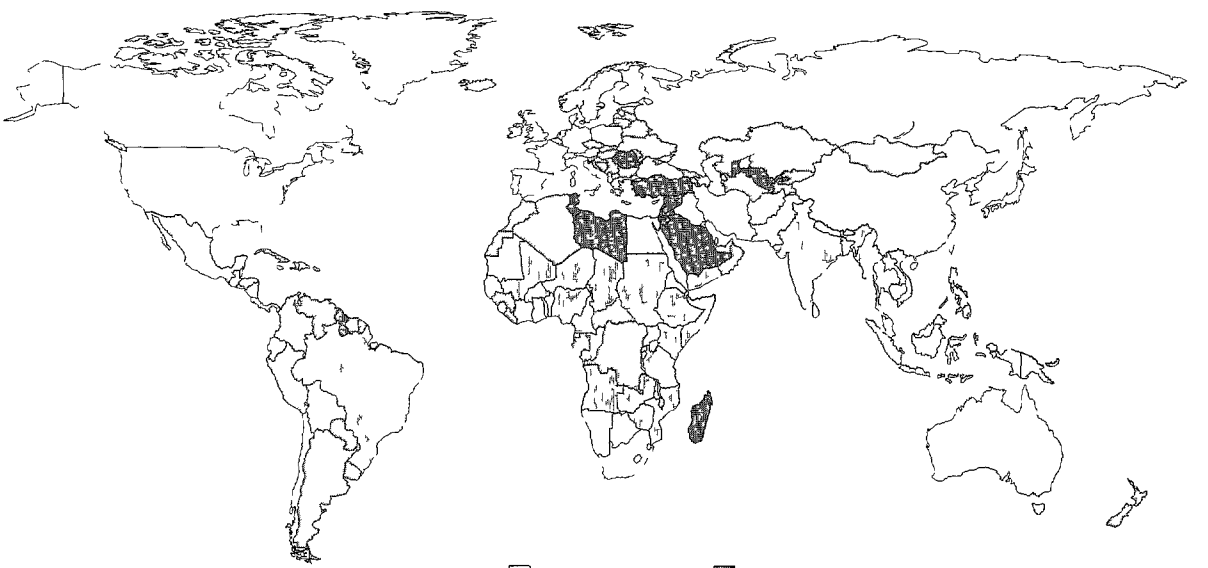
In countries allowing fortification, levels of thiamin, riboflavin, niacin, iron, calcium and, in some cases, folate, usually are specified (Raunhardt and Bowley 1996) The fortification level is ordinarily indicated in terms of mg per kilogram or mg per pound of wheat flour or stated in terms of meeting a percent age of the national recommended daily intake (RDI) of a particular nutrient Examples include

- Canada, which defines and requires fortifica tion of all wheat flour with thiamin, ribofla vin, niacin, and iron
- United Kingdom, where flour is fortified with thiamin, niacin, iron, and calcium at stipulated levels
- Philippines, which allows voluntary fortifica-tion of wheat flour with iron and B-vitamins to provide one third of the U S RDI for each nutrient
- United States, where wheat flour is enriched with niacin, thiamin, riboflavin, iron, and folic acid at specified levels

In 1974, it was proposed that enriched wheat flour in the U S be fortified with 4,333 IU[7] of vitamin A per pound of flour (9,533 IU/kg) as well as other nutrients including pyridoxine, folate, magnesium,

[7] 1 IU = 0 3 RE

Figure 1



Clinical
Severe subclinical
Moderate subclinical
Mild sporadic or high risk
No data problem likely
Problem under control

WHO XVII IVACG Meeting Guatemala 1996

Countries with a per capita wheat consumption of >100 kg/yr

Algeria	214 55
Argentina	115 35
Bulgaria	154 63
Chile	118 78
Cyprus	107 47
Czech Republic	107 11
Egypt	145 46
Greece	138 38
Hungary	113 33
Iran	172 80
Ireland	103 69
Israel	134 72
Italy	147 80
Jordan	133 36
Lebanon	124 31
Libya	164 39
Malta	132 84
Mongolia	110 78
Morocco	178 43
Macedonia	103 60
Pakistan	127 49
Poland	109 07
Romania	146 92
Russian Federation	139 28
Saint Lucia	102 60
Saudi Arabia	127 31
Slovakia	101 65
Syria	217 32
Tunisia	189 81
Turkey	203 33
Yemen	118 80
Yugoslav FR	125 82

Countries with a per capita wheat consumption of 50 100 kg/yr

Albania	89 69
Antigua Barbados	64 81
Australia	80 15
Austria	67 32
Bahamas	50 45
Barbados	64 42
Bel lux	93 26
Bermuda	89 57
Bolivia	56 80
Belize	55 55
Canada	84 39
Cuba	57 02
Denmark	68 40
Dominica	83 94
Fiji	95 16
Finland	56 13
France	95 45
French Guiana	67 92
French Polynesia	77 13
Djibouti	59 60
Germany	64 34
Grenada	68 27
Guadeloupe	79 74
Guyana	63 23
Hong Kong	53 47
Croatia	87 33
Iceland	70 95
India	57 76
Iraq	81 44
Jamaica	67 61
Korea Republic	50 09
Kuwait	74 55
Maldives	75 60
Martinique	78 94
Mauritania	61 02
Mauritius	79 51
Netherlands	57 77
Netherland Antilles	63 36
New Caledonia	91 36
New Zealand	75 99
Norway	91 70
Portugal	98 03
Reunion	53 47
Sri Lanka	55 97
St Kitts Nev	52 83
Sao Tome Prn	52 17
Seychelles	56 66
Slovenia	87 22
South Africa	72 88
Spain	92 12
Swaziland	51 60
Sweden	74 60
Switzerland	87 80
Trinidad Tobago	75 74
UAE	60 68
UK	84 99
Uruguay	83 83
USA	85 23

FAOSTAT Database FAO 1990 1997

and calcium (NAS 1974) Stability studies demonstrated the technical feasibility of adding these nutrients, but the proposed policy was not implemented because the benefit for the population of the United States from the addition of these nutrients was not clear

While fortification of wheat flour with the B-vitamins and iron is widely practiced, the addition of vitamin A to wheat flour has only reached the pilot test level in developing countries (Table 1) Only "Modern Bakeries," a Government of India undertaking, adds thiamin, riboflavin, niacin, iron, and vitamin A (2,200 IU/400 g loaf) to white and fruit breads (Ranhotra 1979)

Table 1

Levels of Vitamin A Added to Wheat Flour

Country	Level
Australia[1]	20 830 IU per kg
United States[2] **(1974 proposal)**	4 333 IU per pound (9 533 IU/kg)
United States PL 480 Title II[3]	10 000 to 12 000 IU per pound (22 000 to 26 400 IU/kg)
India (Pilot)	3 636 IU per pound (8 000 IU/kg)
Tunisia (Pilot)	4 545 IU per pound (10 000 IU/kg)
Bangladesh (Pilot)	5 000 IU per pound whole wheat (11 000 IU/kg)
Philippines (Pilot)	4 900 RE per kg (16 333 IU/kg)

[1] Revised food laws do not allow the addition of vitamin A after June 1997
Only indicated in proposal not enacted
[3] United States export wheat flour food aid

Pilot Trials on Wheat Flour Fortification

Food processing trials conducted in India in 1966 on fortifying wheat flour for use in bakeries demon strated the technical feasibility of adding a vitamin/mineral premix containing vitamin A (8,000 IU/kg flour) However, due to lack of government regulations, fortification or enrichment of baked products is rarely practiced

Only one efficacy trial has been carried out, in Tunisia, using wheat flour as a food vehicle for fortification with vitamin A (10,000 IU/kg), thiamin, riboflavin, niacin, vitamin D, iron, and calcium The evaluation, however, focused on the health effects of lysine (Gershoff 1978, NRC 1984) No organoleptic changes were reported and consumer acceptability of the fortified flour was high Despite these positive outcomes, there were no measurable positive health effects on the study population from lysine fortification, thus, the program was discontinued

An efficacy trial was planned in Jordan following encouraging results of a feasibility trial in which vitamin A was added to wheat flour along with riboflavin, thiamin, niacin, and iron The level of added vitamin A was stable during storage, and vitamin A losses in baking Arabian bread were negligible (2 percent) However, the project was discontinued due to political unrest (Arroyave 1992)

Vitamin A fortification of whole wheat was considered in Bangladesh because most Bangladeshi households tend to buy locally milled whole wheat flour in the market (Nestel 1993) Fortified whole wheat kernels were used in experi mental tests, which demonstrated the technical feasibility and high stability of vitamin A during grinding, storage, and baking, vitamin losses amounted to only 7 percent during grinding and 12 percent during baking However, the project was terminated before any efficacy trials were con ducted

In Iran, a unique method of enrichment using vitamin A palmitate or acetate combined with yeast into tablets was employed to enrich *sangak*, a Persian-type sheet bread After baking at 204°C for 2-3 minutes, 68 percent of vitamin A palmitate added at a level of 484 2 mg/kg flour, and 74

percent of vitamin A acetate added at a level of 490 2 mg/kg flour were retained (Vaghefi and Delgosha 1975) No efficacy trial is known to have followed this feasibility study

The Nutrition Center of the Philippines has conducted a pilot trial of wheat flour fortified with vitamin A at two big flour mills One month after fortification, the *retention* of vitamin A in flour was 81 4 percent, and 80 3 percent in a popular bread *(pan de sal)* However, three months after fortifica tion, the *losses* of vitamin A were also reported to be good 45 5 percent loss in flour and an addi tional 40 percent loss due to baking of *pan de sal* No adverse effects were seen on the sensory properties of flour or *pan de sal* (Solon 1996) when used within one month of fortification Due to these encouraging results, an efficacy trial to evaluate the biological effect of vitamin A fortification (490 µg RE/100 g) of wheat flour is underway

It is important to note that none of these pilot studies resulted in national fortification programs for various reasons, including a lack of biological efficacy and cost-effectiveness measurements, as well the lack of knowledge of storage losses under practical conditions

Addition of Vitamin A to Food Aid Commodities

Wheat flour is the most commonly shipped processed cereal commodity within food aid programs, accounting for about 270,000 MT shipped in 1993 The United States and the European Union are the two primary donors of wheat flour In addition, the World Food Program purchases wheat flour from other countries for use in food aid programs Generally, fortification and enrichment policies for food aid commodities vary by donor (Dexter 1995)

The U S PL 480 Title II program donates agricultural commodities to support emergency and regular food aid programs Much of the wheat flour shipped under Title II is used in child feeding and emergency feeding programs The nutrients to be added to wheat flour are specified by USDA in the purchase announcements (USDA 1994) Since 1969, vitamin A has been added to wheat flour shipped under PL 480 Title II Iron, thiamin, riboflavin, niacin, and calcium are also added

Vitamin A is added in the form of retinyl palmitate and is further detailed in the USDA specifications given in the purchase announcements (Appendix 1) In 1988, levels of vitamin A added to processed cereals including wheat flour were increased from between 8,800 IU and 13,200 IU/kg to between 22,000 and 26,400 IU/kg Product information from premix suppliers indicate that 10,700 IU/g of vitamin A are included in the USDA-specified premix provided for enrichment of wheat flour

To determine safe and effective levels of vitamin A to be added to food aid commodities, USAID (1988) reviewed the minimum and maximum intakes of the commodity, based on available information of likely intakes by food aid recipients Upper and lower levels of vitamin A daily intake were also determined It was agreed that a daily intake of 10,000 IU is a safe level for use as a maximum in food fortification programs This level would be attained if 500 g of vitamin A fortified wheat flour were consumed Symptoms of vitamin A toxicity usually occur only after long periods of intakes of at least 20,000 IU/day for children and 50,000 IU/day for adults (Bauernfeind 1980)

Stability specifications are defined in the purchase announcement (Appendix 1) Limited studies on the stability of vitamin A and other nutrients added to PL 480 Title II commodities have been conducted, but it has been difficult to draw firm conclusions due to a lack of baseline estimates (Combs et al 1994) USAID is currently reviewing the stability of nutrients added to PL 480 commodities and developing protocols for further investigation

Fortification premixes containing vitamin A are routinely tested by manufacturers Periodically, the final flour product is also tested The finished fortified product is regularly spot tested at the production site for the presence of iron to indicate

the presence of other nutrients, but there may be additional losses once the flour is in the distribution system, and thus the final retention of nutrients remains unknown Considering this, as well as concerns regarding effective implementation of quality control measures, USDA is currently reviewing additional measures that may be taken to ensure the fortification and enrichment levels of nutrients in food aid commodities

IV General Considerations in Wheat Flour Fortification with Vitamin A

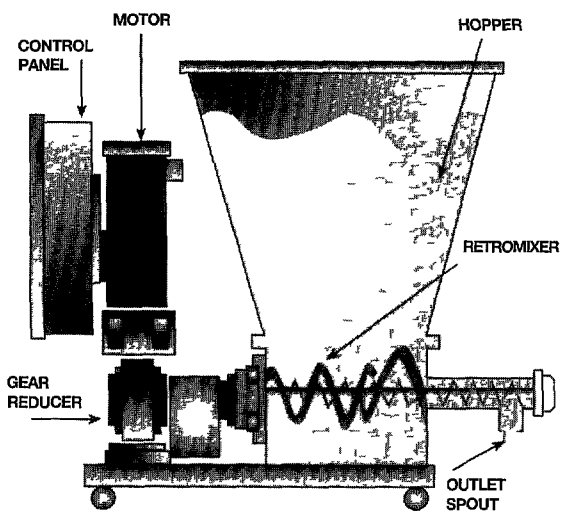
Technology

Commercially available concentrated dry vitamin-mineral premixes are used in fortification programs A dry vitamin-mineral premix can be metered into a continuous flour stream using a volumetric feeder (Figure 2) followed by mixing for uniformity A simplified flow chart of wheat milling and fortification processes is presented in Figure 3 A typical composition of a multivitamin-iron premix that can be added to wheat flour is presented below

Nutrient	Fortification level/kg flour
Vitamin A (IU)	23,540
Thiamin (mg)	5 7
Riboflavin (mg)	4 0
Niacin (mg)	46
Iron (mg)	37

Figure 2

Volumetric Feeder Used in the Addition of Micronutrient Premix to Wheat Flour



Personal communications F Hoffmann La Roche Ltd 1997

Various types of vitamin A fortificants[3] are available in the market today and each is specifically suited for use in particular food products (Appendix 2) The form of vitamin A most commonly used in fortifying wheat flour is a fine, dry, light yellow powder containing stabilized vitamin A palmitate with a potency of 250,000 IU/g The active ingredient is retinyl palmitate dispersed in a water miscible matrix of acacia gum, lactose, and coconut oil, plus BHT, sorbic acid, and sodium benzoate as antioxidant preservatives The particle size of this type of retinyl palmitate is similar to that of wheat flour, which facilitates mixing and minimizes segregation during shipping and storage

To compensate for vitamin A losses in storage and handling, additional vitamin A is added to wheat flour, and this is often referred to as the "overage " Vitamin losses are estimated by testing at both factory and household level, taking into account losses during processing, distribution, storage, and food preparation Other additional losses until the time of consumption must also be considered when

[3] F Hoffmann La Roche Ltd and BASF Inc are the two producers of synthetic vitamin A

determining overages The total amount of vitamin to be added can be calculated given the RDI, estimated consumption, and estimated percent loss For example, if RDI is 400 RE/day (the value frequently used for children between 1 and 6 years old), estimated consumption of wheat flour is 120 g/d, and losses are estimated at 40 percent, the following calculations can be done to determine fortification levels

RDI for vitamin A

400 RE per day

Consumption of flour

120 g per day

To provide 100% of RDI, target level of vitamin A

400/1 2 = 333 RE per 100 g flour

Target level of vitamin A

333 RE per 100 g flour

Estimated losses (storage, processing, etc)

40 percent

Estimated amount remaining

60 percent

Total amount to be added

333/0 6

Total amount to be added

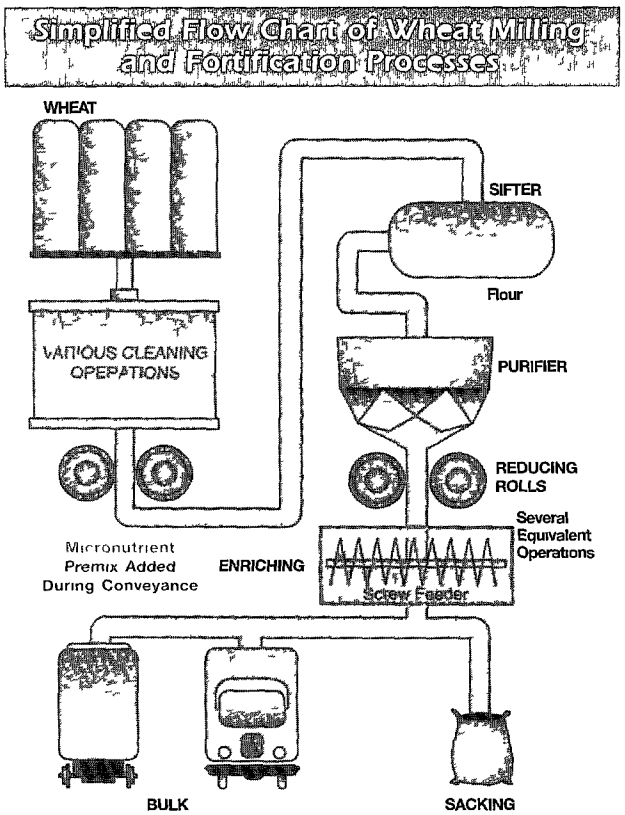
555 RE (1,850 IU) per 100 g flour

The amount of overage required has important cost implications Overages up to 50 percent have been considered acceptable and used in different fortification programs

Stability

Heat, light, air (oxygen), moisture, and an acid pH all reduce the stability of vitamin A Heated to moderate temperatures, vitamin A is reasonably stable in the absence of water, air (oxygen) and light Oxygen and light can result in an extensive

Figure 3



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loss of vitamin A activity due to oxidation reactions that are accelerated in the presence of trace metals, such as iron The stability of vitamin A in flour and wheat products varies depending on the physical and chemical factors in effect during storage, distribution, and food preparation

Stability in Fortified Flour

Vitamin A losses of about 7 percent were reported for fortified wheat milled at temperatures up to 130°F (Barrett and Murphy 1989), while treatment of fortified bread flour with various maturing, bleaching, and oxidizing agents did not result in a significant loss of vitamin A (Ranum et al 1981) Vitamin A in fortified wheat flour was found to be distributed evenly exhibiting resistance to segregation during pneumatic handling and shipping (Parrish et al 1980a) Storage of fortified flour at

Table 2

Vitamin A Retention in Wheat Flour With 9% Humidity Stored at Room Temperature or 45°C

	IU/Kg	Retention (%)
Label Claim	16 534	
Initial	18 078	
Room Temperature		
2 months	18 078	100 0
4 months	17 681	97 8
6 months	17 526	97 0
45°C		
1 month	16 534	91 5
2 months	14 175	78 4
3 months	12 919	71 5

Cort W M B Borenstein B , J H Harley M Osadca and J Scheiner 1976 Nutrient stability of fortified cereal products *Food Technology* 30 52 81

room temperature for six months induced negligible (3 to 11 percent) vitamin A losses (Bauernfeind and Arroyave 1986, Parrish et al 1980a, Rubin et al 1977, Cort et al 1976 (Table 2)) In contrast, storage at elevated temperatures of *40 to 45* °C resulted in dramatic losses, loss of vitamin A was 28 percent after three months (Cort et al 1976), and 50 percent after six months (Parrish et al 1980a) Although there was a gradual loss of vitamin A during storage, the estimated biopotency (biological activity) of vitamin A that remains in the stored flour remained unchanged (Liu and Parrish 1979)

The results of these experiments, however, may not reflect the extent of storage losses that would occur in practice in developing countries These experiments were carried out under controlled storage conditions, where the moisture content of flour ranged from 8 to 11 percent Storage conditions in many developing countries are not controlled and flour is generally stored at ambient conditions that are naturally hot and humid, thus, the moisture content of flour may be higher depending on the relative humidity to which the flour is exposed Consequently, losses of vitamin A may be higher than projected

The extreme losses of vitamin A observed, in the above experiments, during high temperature and prolonged storage periods underscore the importance of optimum storage conditions to ensure the stability of the added nutrient High temperature and humidity conditions in warehouses where flour is stored are typical of many developing countries In such instances, particular attention should be paid to the rotation period of flour to minimize the storage period Vitamin A losses may be also associated with other quality parameters, such as rancidity, during storage and distribution

Stability in Processed Foods

Further losses of vitamin A during food processing form an additional concern, because the fortification level should be based on the vitamin A level in the food at the time of consumption Retention varies according to the food processed with lower losses from bread, spaghetti, cakes, and pancakes than from pasta Parrish et al (1980b) reported that 90 percent of vitamin A was retained in processed foods (bread, spaghetti, cakes, and pancakes) made from fortified wheat flour stored less than six months Vitamin A losses in pasta products made from fortified durum wheat flour amount to 13 percent during drying at 75°C and 17 percent during cooking Minimal vitamin A losses of 12 percent were observed during baking of *chapati* from fortified wheat flour (Barrett and Murphy 1989)

Double Fortification with Vitamin A and Iron

Double fortification of wheat flour with vitamin A and iron is techno logically feasible, and may be an economical and biologically effective intervention

When the NAS/NRC proposed the enrichment of wheat flour with several vitamins and minerals, includ ing vitamin A and iron, in 1974, numerous researchers investigated the technical possibility of such an enrichment regimen These studies demonstrated the feasibility of adding 4 333 IU/lb (9,533 IU/kg) of stabilized vitamin A (type 250 SD) and 11 5-40 mg/lb (25 2-88 0 mg/kg) of reduced iron to wheat flour, along with the other proposed vitamins and minerals, with no significant deleterious effects on the stability of vitamin A, or the sensory and storage properties of the fortified flour or bread (Emodi and Scialpi 1980, Parrish et al 1980a, Cort et al 1976)

Vitamin A added to wheat flour along with reduced iron was found to be stable through shipping and distribution, and during storage at room temperature, although storage at a higher tempera ture of 45°C caused a significant loss (28 to 50 percent) of the vitamin (Ranum et al 1981, Parrish et al 1980a, Cort et al 1976 (Table 2)) Processing losses amounted to 10 to 17 percent in breads, cakes, or pasta made from fortified flour (Parrish et al 1980b) Iron added to flour as ferrous sulfate, or reduced iron, had no significant effect on the stability of vitamin A in white bread (Parrish et al 1980a) It must be pointed out, however, that these results may not reflect actual losses in developing countries, where conditions of storage widely differ from those used in the experiments

Table 3

Current Costs of Different Types of Vitamin A Fortificants[1]

Type (potency)	Cost (U S $/kg)
Vitamin A Palmitate 250 SD (250 000 IU/g)	46 00
Vitamin A Palmitate 250 CWS (250 000 IU/g)	46 00
Oily Vitamin A Palmitate (1 0 million IU/g)	56 00
Water-miscible Vitamin A (100 000 IU/g)	20 50
Vitamin A Acetate 325 CWS/F (325 000 IU/g)	49 50

[1] Personal communications F Hoffmann La Roche Ltd Chile 1997 these are reference values only and may vary

A commercial rusk (made of wheat flour, sugar, and vegetable oil), intended as a complementary food for young children, fortified with ten micronutrients, including vitamin A (13,200 RE/g or 44,000 IU/kg as retinyl acetate), and iron (290 mg/kg, as ferric ammonium citrate) was found to be palatable and may have improved iron status in young children in rural Beijing, thus promising to be an effective food fortification vehicle (Liu et al 1993)

Several studies have shown the beneficial effects of vitamin A supplementation, alone or in combina tion with iron, on iron status of animals and humans A recent study of double fortification of pre-cooked maize flour with 9,500 IU/kg of vitamin A and 50 mg/kg of iron (as ferrous fumarate) suggested that vitamin A forms a soluble complex with iron and may enhance the absorption of iron (Layrisse et al 1997) More research is needed to substantiate this hypothesis Considering such beneficial vitamin A iron interactions, the potential of adding these two nutrients together to wheat flour must be explored in national fortification programs

Other Nutrient Interactions

When more than one fortificant is being added to a particular food vehicle, consideration must be given to nutrient interactions that may take place For example, calcium and magnesium adversely affect vitamin A retention during the baking process (415°F, 20 minutes, 38 percent moisture level) Bread fortified with a premix containing calcium and magnesium[4] (along with vitamin A, thiamin, riboflavin, pyridoxine, niacin, folic acid, iron, and zinc) retained only 83 percent of vitamin A, while that fortified with the same premix without calcium and magnesium retained 95 percent of the added vitamin A (Rubin et al 1977)

Sensory Characteristics

Results from studies on the NAS-NRC proposed levels of added nutrients (vitamin A, thiamin, riboflavin, pyridoxine, niacin, folic acid, iron, calcium, magnesium, and zinc) to wheat flour found that the combination of these nutrients did not discolor flour or contribute to an undesirable taste or odor (Cort et al 1976) Also, no off flavors were noticed in breads fortified with the ten nutrients, including vitamin A added at a level of 992 IU/lb or 2,182 IU/kg (Emodi and Scialpi 1980, Rubin et al 1977)

Quality Assurance and Control

Quality assurance and control ensures that the manufactured food is safe, unadulterated, properly labeled, and meets all company as well as government regulations It also helps ensure that the fortified flour contains vitamin A at the level stated on the label, and provides the intended level of vitamin A at the time of consumption Quality assurance covers a wide range of activities, including inspection of all ingredients against reference standards, testing the product for contaminants, micronutrient content, and spoilage at different critical points during manufacturing (e g , after adding premix, after packaging), and distribution (e g , wholesale and retail levels)

The development and implementation of a sound quality assurance system is crucial to developing an effective, practical, and economical fortification program Manufacturing companies and government agencies involved in food regulation must commit to monitoring and evaluating the quality of the fortified food for any fortification program to be successful

Monitoring the vitamin and mineral content of the premix and fortified flour is an important aspect of food fortification quality control programs Appropriate analytical methods should be based on the accuracy and precision of a given method, available facilities and equipment, and the need for simple and rapid tests

The retinol content of wheat flour can be determined semiquantitatively using a colorimetric method that was primarily developed for measuring vitamin A added to sugar (Dary and Arroyave 1996) It is based on a chromogenic reaction and the intensity of the blue color is measured semiquantitatively by visual comparison against a reference scale of copper sulfate solutions This method is simple and rapid, and does not require a spectrophotometer However, it is a semiquantitative method providing only an approximate estimate of the vitamin A content in a sample, making it unsuitable for premix analysis It may be used for monitoring the vitamin A content of flour at the production level, but the results should be verified using quantitative methods

Quantitative determinations of vitamin A in premixes or wheat flour can be made using spectrophotometric or high pressure liquid chromatography (HPLC) methods In the spectrophotometric method, vitamin A is saponified by refluxing with

[4] 558 mg/lb (1 227 mg/kg) of calcium and 124 mg/lb (272 8 mg/kg) of magnesium

alcoholic potassium hydroxide (KOH) and then extracted with hexane Retinol in solution then reacts with chloroform saturated with antimony trichloride (Carr-Price reagent) resulting in a transient, blue-colored compound whose absorbance is measured at 620 nm In the HPLC method, vitamin A is saponified with ethanolic KOH and extracted into an organic solvent Subsequently, retinol and its isomers are separated by liquid chromatography on a silica column and quantified by measuring their absorbance at 325 nm

Cost

The estimated cost of a metric ton of wheat flour in the U S PL 480 Title II program in 1993 was U S $203 00, of which $3 79 was attributed to the cost of the added vitamin A (Combs et al 1994) Vitamin A is the most expensive nutrient added to the PL 480 commodities Liquid vitamin A palmitate (1 0 million IU vitamin A/g) and dry vitamin A palmitate (0 5 million IU vitamin A/g) currently cost U S $46 00 and U S $47 00 per kg, respectively Using an RDI of 2,830 IU of vitamin A/day, this is equivalent to U S $130 00 per one million people for liquid vitamin A palmitate and U S $266 00 for dry vitamin A palmitate Table 3 presents the costs of different types of vitamin A fortificants

The cost of vitamin A fortification may increase the cost of the final product by an estimated two percent, not accounting for the costs of quality control and monitoring Indeed, cost is one of the major deterrents of wheat flour fortification with vitamin A

Table 4

Foods Considered in Vitamin A Fortification Programs in Developing Countries

Food	Intervention	Countries
Sugar	Program	Guatemala Honduras Panama
MSG	Experimental	Philippines Indonesia
Corn Flour	Program	Venezuela
Wheat Flour	Program	U S PL 480 Title II
	Experimental	Jordan Tunisia India Pakistan Philippines Sri Lanka
Whole Wheat	Experimental	Bangladesh
Milk	Program	Argentina Brazil Mexico
Milk Powder	Program	Venezuela
Margarine	Program	Brazil Chile Colombia Mexico Honduras El Salvador Peru Panama Ecuador Guatemala India Indonesia Malaysia Philippines
Oil	Program	Chile
	Experimental	Brazil

International Trade

A recent review of the effects of enrichment on international trade illustrated some of the concerns for countries exporting wheat flour to other countries, where enrichment standards vary (Ranum and Trood 1995), because they are designed to fulfill local nutrition needs Enrichment standards can create barriers to trade For example, differences in wheat flour enrichment standards between the United States and Canada make flour that meets U S standards unacceptable for sale in

Canada because it would contain too much iron and folic acid However, this may not be of concern in many developing countries where whole wheat is imported and milled within the country

Other Food Vehicles

Foods other than wheat flour have been considered and are used in vitamin A fortification programs in a number of developing countries (Table 4) In Venezuela, *precooked corn flour* i e , flour which is steamed and then dried, is successfully used as a vehicle for fortifying with vitamin A, as well as with thiamin, riboflavin, niacin, and iron This flour is used to make "arepas," a staple food in the Venezuelan diet, making it an important and viable source of the added micronutrients *Sugar* fortification with vitamin A is legislated in Guatemala, Honduras, and Panama, although programs have not been fully effective due to weak enforcement

Alternately, high fat and fat-based foods such as milk, margarine, and vegetable oils may form better vehicles considering that vitamin A is fat soluble, not only is the nutrient more compatible, but its absorption may also be enhanced Vitamin A addition to *milk* is legislated in the United States, Argentina, Brazil, and Mexico, while mandatory fortification of *margarine* with vitamin A is practiced in numerous developing countries Other potential food vehicles that have been experimented upon include *monosodium glutamate*, *vegetable oil*, *rice*, *tea*, and *salt*

V. Further Research

Although fortification of wheat flour with vitamin A appears to be technically feasible and promising according to field trials, there are a number of limitations to it being widely implemented The following are some of the programmatic issues that need further consideration

- The development of a simple, quantitative test for the determination of vitamin A in fortified wheat flour and other foods would help reduce the costs of a fortification program
- Information on nutrient stability, shelf-life, and sensory properties of flour double-fortified with vitamin A and iron under climatic conditions found in developing countries is lacking Also, the biological efficacy and cost effectiveness of adding these two nutrients together needs to be studied
- Studies on the efficacy and economic aspects of previously conducted or ongoing vitamin A fortification (of wheat flour) programs are needed to convince governments and food companies of the cost-effectiveness of food fortification
- Information on consumer behavior regarding acceptable price levels of wheat flour, especially in countries where fortified wheat flour pilot trials were promising Such information will indicate if social marketing is necessary or helpful in implementing fortification programs

VI References

Arroyave, G 1992 "Food Nutrification with Emphasis on the Addition of Micronutrients to Wheat Flour" Paper prepared for USAID Office of Nutrition by VITAL/ISTI project Report No TA 9 June Washington, DC

Barrett, F and P Murphy 1989 *Stability of Vitamin A in Fortified Wheat Products in Bangladesh* Office of International Cooperation and Development, USDA

Bauernfeind, J C and G Arroyave 1986 "Control of Vitamin A Deficiency by Nutrification of Food Approach Cereal Grain Products" In *Vitamin A Deficiency and Its Control*, edited by J C Bauernfeind, Nutrition Basic and Applied Science A Series of Monographs pp 372 388 Orlando, FL

Bauernfeind, J C 1980 *Safe Uses of Vitamin A International Vitamin A Consultative Group The Nutrition Foundation* Washington, DC

Clarke, R 1995 "Impact of Legislation on Food Fortification Practices" Paper prepared for the FAO Technical Consultation on Food Fortifica tion Technology and Quality Control Novem ber FAO, Rome

Combs, G F, P B Dexter, abd S Horton 1994 *Micronutrient Fortification and Enrichment of P L 480 Title II Commodities Recommendations for Improvement* Report submitted to USAID/BHR by OMNI/JSI project November Arlington, VA

Cort, W M, B Borenstein, J H Harley, M Osadca, and J Scheiner 1976 Nutrient stability of fortified cereal products *Food Technology* April Vol 30 pp 52 81

Crowley, P R, F F Barrett, R P Weil, D A Fellers, and N M Blocker 1989 Final Report Food Technol ogy for Development project OICD/USDA, Washington, DC

Dary, O and Arroyave, G "Analytical Methods for the Control and Evaluation of Sugar Fortification of Vitamin A" In *Manual for Sugar Fortification with Vitamin A* Part 3 OMNI/USAID/INCAP, March, 1996

Dexter, P B 1995 "Requirements for Effective Fortification in Food Aid Program" Paper prepared for the FAO Technical Consultation on Food Fortification Technology and Quality Control November FAO, Rome

Emodi, A S and L Scialpi 1980 Quality of bread fortified with ten micronutrients *Cereal Chemistry* 57(1) 1 3

FAO/WHO 1994 "Codex General Principles for the Addition of Essential Nutrients to Foods CAC/GL 09 1987 (as amended 1989, 1991)" In *Codex Alimentarius*, Volume 4 Second Edition Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission, FAO, Rome

Gershoff, S 1978 "Evaluation of Cereal Enrichment Programs" In *Nutrition in Transition Proceedings Western Hemisphere Nutrition Congress V* Edited by Philip White and Nancy Selvey, AMA, Chicago, IL

Layrisse, M, M N Garcia Casal, L Solano, M A Barorl, F Arguello, D Llovera, J Ramirez, I Leets, and E Tropper 1997 The role of vitamin A on the inhibitors of nonheme iron absorption Preliminary results *Nutritional Biochemistry* 8 61 67

Liu, D S, C J Bates, T A Yin, X B Wang, and C Q Lu 1993 Nutritional efficacy of a fortified weaning rusk in a rural area near Beijing *Ameri can Journal of Clinical Nutrition* 57 506 511

Liu, L I and D B Parrish 1979 Biopotency of vitamin A in fortified flour after accelerated storage *Journal of Agricultural and Food Chemistry* 27 1134 36

National Research Council (NRC) 1984 *The Results and Interpretation of Three Field Trials of Lysine Fortification of Cereals* Task Force on Amino Acid Fortification of Cereals Food and Nutrition Board National Academy Press Washington, D C

Parrish, D B, W D Eustace, J G Ponte, Jr, and L Herod 1980a Distribution of vitamin A in fortified flours and effect of processing, simulated shipping, and storage *Cereal Chemistry* 57(4) 284 287

Parrish, D B, L Herod, J G Ponte, Jr, P A Seib, C C Tsen, and K A Adams 1980b Recovery of vitamin A in processed foods made from fortified flours *Journal of Food Science* 45(5) 1438 1439

Ranhotra, G S 1979 Bread industry in India production and nutritional considerations *Bakers Digest* October, 20 22

Ranum P and I S V Trood 1995 Effects of enrichment on international trade *Cereal Foods World* 40(2) 77 82

Ranum, P M , R J Loewe, and H T Gordon 1981 Effect of bleaching, maturing, and oxidizing agents on vitamins added to wheat flour *Cereal Chemistry* 58(1) 32 35

Raunhardt, O and A Bowley 1996 Mandatory food enrichment *Nutriview* Supplement to issue 1/1996

Rubin, S H , A Emodi and L Scialpi 1977 Micronutrient additions to cereal grain products *Cereal Chemistry* 54 895 904

Solon F S , M A Solon T Nano 1996 *Fortification of Wheat Flour with Vitamin A A Preliminary Report* Nutrition Center of the Philippines, Manila

USDA, ASCS 1994 *Commodity Specifications Product specification Wheat Flour* Announcement WFSF4 February 1

USAID 1988 *Report of a Technical Review Meeting of Appropriate Levels of Vitamin A in P L 480 Title II Commodities* August 18 Rosslyn, VA pg 9

Vaghefi, S B and M Delgosha 1975 Fortification of Persian type bread with vitamin A *Cereal Chemistry* 52 753 756

World Bank 1994 *Enriching Lives Overcoming Vitamin and Mineral Malnutrition in Developing Countries* The World Bank, Washington D C

VII Appendices

Appendix 1— Specifications for Vitamin A Added to PL 480 Title II Wheat Flour[5]

Form Requirements

Vitamin A palmitate (stabilized) must be added in encapsulated form containing 250,000 IU vitamin A palmitate/g Particle size must comply with the requirement that at least 98 percent will pass through a U S Standard No 50 sieve, at least 90 percent through a U S Standard No 60 sieve and at least 45 percent through a U S Standard 100 sieve The product must not be less than 95 percent of the all-trans isomer as determined by the USP assay procedure Flour must not be sifted through a cloth after vitamin supplementation which could remove vitamin A palmitate

Stability Requirements

Vitamin A palmitate must have storage stability such that no more than 20 percent of its original activity will be lost when stored for 21 days at 45°C in a sealed container at a level of 10,000-12,000 IU/lb (22,000-26,400/kg) in wheat flour, having a moisture content in the range of 13 5-14 5 percent In addition the vitamin A palmitate must contribute no off-flavor or odor to the dry mix or the cooked products prepared from fortified flour

Level

Vitamin A palmitate added to allow for a minimum of 10,000 IU/lb (22,000 IU/kg) and a maximum of 12,000 IU/lb (26,400 IU/kg) of wheat flour

[5] Specifications defined in product announcement by USDA for wheat flour WFSF4 February 1, 1994

Appendix 2 — Forms of Vitamin A Used in the Fortification of Foods

Form	Potency (*million IU/g*)	Other Ingredients	Usage
Liquid Products			
Vitamin A palmitate	1 65 1 8	Edible antioxidant, no oil diluent	Where maximum concentration is required with stabilizers
Vitamin A palmitate	1 65 1 8	No antioxidants, no oil diluent	Where maximum concentration is required, no stabilizers
Vitamin A palmitate Type PIMO/BH	1 0	Edible oil diluent, edible antioxidant	Recommended for general use, with stabilizers
Vitamin A acetate or vitamin A palmitate	1 0	Edible oil diluent, no antioxidant	For specific uses
Vitamin A palmitate emulsion	0 5	Emulsifiers, antioxidants preservatives	Fortification of cereals, milk products, potato flakes and food products that require specific processing techniques
Dry Products			
Vitamin A palmitate beadlets, Type 500	0 5	Gelatin, carbohydrate, tricalcium phosphate, antioxidants preservatives	For products not dispersed in cold water where high resistance to moisture and heat required, e g , extruded foods
Vitamin A palmitate beadlets, Type 250 CWS	0 25	Modified food starch, carbohydrates, gum acacia, antioxidants	Water dispersable, for dry products to be reconstituted before use, e g , sugar
Vitamin A palmitate beadlets, Type 250 S	0 25	Gelatin, dextrose, modified food starch, sodium citrate, sorbitol, coconut oil, antioxidants	Water dispersable, free flowing beadlets to help meet the stringent flavor needs of milk based products and other beverages
Vitamin A palmitate beadlets, Type 250 T	0 25	Acacia, carbohydrate, modified starch, alpha tocopherol, preservative	Water dispersable fine beadlet product for pre mixes
Vitamin A palmitate Type 250 SD	0 25	Acacia, lactose, coconut oil, preservatives	For use where very fine particle size is desired, i e flour, corn meal, vitamin pre mixes, dry milk, sugar, beverage powders

Bauernfeind J C and G Arroyave 1986 Control of Vitamin A Deficiency by Nutrification of Food Approach Cereal Grain Products in *Vitamin A Deficiency and Its Control* edited by J C Bauernfeind Nutrition Basic and Applied Science A Series of Monographs Orlando FL 1986 pp 372 388