FORTIFICATION AND FORMULATION OF NEW DIETS

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Throughout these sessions we have been looking for realistic approaches to the goal of achieving adequate nutrition for all the world's people. The very complexity of the processes by which food moves from fields through commercial channels onto the world's tables dictates that there are numerous approaches to a more adequate world food supply that are not necessarily mutually exclusive but rather complementary. Some are of short-range value; others of long-range utility. Some are very costly; others are not.

To a considerable extent our wisdom as participants in the drive to achieve a satisfactory food supply will depend on our ability to identify the economically, culturally, and politically practical approaches in a particular country or region and on our persistence in seeing that the practical innovations come about rather than the politically attractive but economically unsound alternatives.

Eradicating world's food deficits

Drawing on technological developments of the last 50 years we have at present a considerable list of largely new ways of getting at eradicating the world's food deficit:

Significant increases in production of the traditional cereal grains, particularly rice and wheat, have already been achieved, although full world-wide application of new breeds and the accompanying agronomic practices is still years off. Clearly the improved cultivars have a major role to play that will not be fully felt for many years because of the unsettling adjustments of marketing, storage, and distribution which the green revolution necessitates.

Less emphasis has so far been placed on the stimulation of production of specific crops that are rich sources of particular nutrients. The major exception is the relatively recent effort to treat oil seed and legume production somewhat as rice, wheat, and corn have been handled. In the case of the legumes the attempt is an overt one to bolster the protein supply.

Clearly effective management of man's proliferation as a species has a great deal to contribute, for up to now the past decade's encouraging progress in expanding food production has been nearly wiped out by a concurrent increase in the number of mouths to be fed.

In contrast to the long-range and economically sound nature of the previous three approaches, free distribution of large quantities of food produced in the industrialized nations to recipients in the emerging nations has proven to be of limited value except as a short-term humanitarian measure in times of disaster.

The fifth approach, practical education of mothers in basic sanitation and least-cost feeding of their children using local foods, has been shown recently to be a very effective long-term approach to the particularly acute problems of the pre-school child.

An important role is being played by introduction of new foods such as INCAPARINA which are blends of low-cost plant foods of high nutritive value when mixed.

In the future it is to be anticipated that useful new foods derived from unconventional sources such as single cell protein will find a place, though their significance in the immediate future looks to be limited.

It is also generally held that an inevitable consequence of the general economic development of the world's resources will lead to a better food supply as the productivity, and therefore the earning capacity and purchasing power, of people as a whole increases.

Opportunities through the last approach, fortification of the food supply with factory-produced vitamins, minerals, and amino acids, are now quite real. Through fortification it is now possible to eradicate many forms of malnutrition which were completely beyond control as little as 25 years ago. Fortification is a relatively high cost but also immediate high impact technique which I would like to discuss with you because it seems to me that no nation has ever exploited the fortification approach to anything like its full potential.

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Fortification programs

Like furniture, the goals of fortification programs come in about any size you want. The one nutrient "milking stool" program is represented by fortification of table salt to prevent goiter. We also have "love seat" programs like the addition of vitamins A and D to margarine or milk products. The most ambitious we've been in a national program is the "sofa size" program in which 3 or 4 nutrients are added to a ubiquitously consumed food. The B-vitamin enrichment of wheat is a typical example.

What I want to lay out in rough plan today is the design of a fortification plan more on the scale of a "church pew." We are ready, I believe, to attempt fortifying national food supplies with all nutrients except calories that are deficient in the national diet. It is at last reasonable for the first time to consider fortification of national food supplies with any nutrient of which there is widespread deficiency in amounts designed to meet the public need. It may seem strange that this has not been attempted, but I think we will see that the task is one of considerable complexity and that the cost though low, less than $1.00 per person per year, is still enough that few governments see fit to attempt it.

A plan of attack on the problem of designing a comprehensive national fortification program is outlined below:

Major steps toward comprehensive fortification

1. Selection of Public Health Goals
2. Determination of Actual Nutrient Intakes
3. Calculation of Actual Deviation From RDAs
4. Identification of Carriers
5. Design of Fortification Formulas
6. Planning for Cost Assumption
7. Provision for Evaluation and Monitoring

In considering the plan I will draw on data from a nation-wide nutrition survey of middle- and low-income groups in the Dominican Republic in 1969.

As a test case, suppose we establish as our objective the eradication of clinically significant deficiencies of vitamins, minerals, and amino acids by fortification of one or more carrier foods with those nutrients that have been demonstrated to be in short supply.

To achieve this it will be necessary to establish first which deficiencies are of enough public health significance to warrant attack, to calculate what levels of fortification of each will be needed to correct the deficiency, to identify the potential foods that can serve as carriers of the fortificant, and to design the appropriate fortifying formula. Since the cost will be substantial on a national scale, provision for its assumption will have to be made, and procedures will be needed to monitor and evaluate the program.

In establishing the goal we are working against the general background of nutritional fact (Fig. 1). Starting at the bottom there is a range of nutrient intake below which survival is impossible. In general, above this range is one in which one sees reduced resistance to disease, impaired growth, reproductive failures, and any of a variety of lesions specific for the nutrient in question. As the intake rises first the lesions disappear, then reproduction and finally growth become normal, and lastly disease resistance becomes optimal. Somewhere above these levels the Recommended Dietary Allowance (RDA) is set; this RDA is a level of intake selected to protect essentially all of a population from deficiency of the nutrient. As intakes are raised well above the RDA levels indicating toxicity are usually seen.

The fortification goal, then, will be to raise the intake of the average person close to the Recommended Dietary Allowance and at the same time make sure that no one's intake rises into the toxic range.

An aspect of the problem here appears in Fig. 2. If the frequency plot of present intake is represented by the solid line, the fortification program would seek to move the curve to the middle one because in arriving at the RDA a margin of safety is already built in to cover individual variations in need. To move to the right hand curve would not only add considerably to the cost at no benefit; it would also increase the danger of creating toxicities.

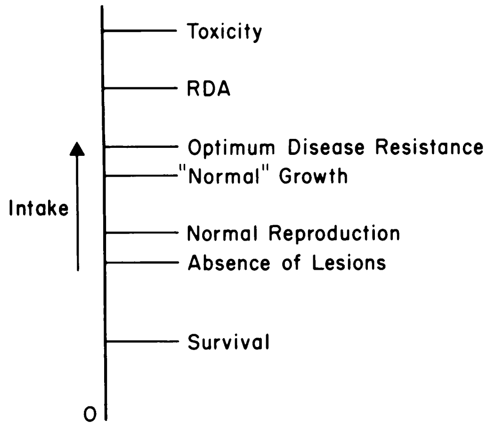

Fig. 1. Relation between level of nutrient and response.

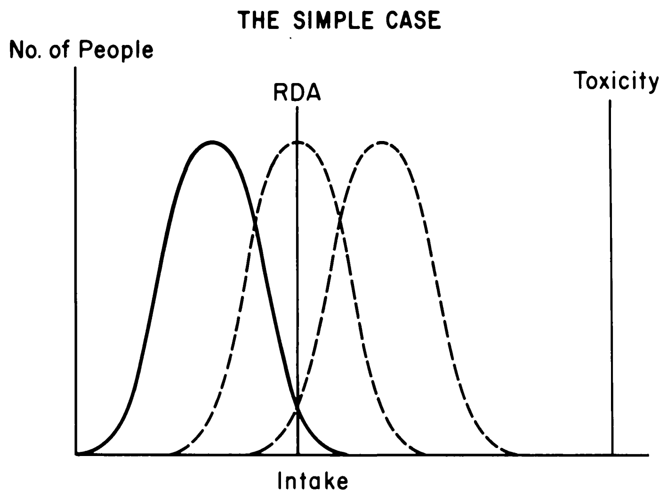

Fig. 2. Hypothetical frequency distributions of nutrient intake in relation to Recommended Dietary Allowance.

Estimating fortification needs

In determining what the present levels of nutrient consumption are, we have several techinques:

Approaches to determination
of actual intakes

FAO Food Balance Sheet
Classical Dietary Survey
 24-hr recall
 3 to 7-day weighed intake
Dietary Survey – Composite Analysis

One choice is the *FAO Food Balance Sheet.* Here agricultural census data, export data, and import data are compiled on all foods. Wastage and loss factors are applied. Then from tables of food composition the national supply of all nutrients can be calculated. I am not impressed with the results because in most developing countries agricultural census data are horseback guesses at best; and losses caused by insect infestation and spoilage are crude estimates. In the Dominican Republic, for example, the FAO Food Balance Sheet failed to reveal caloric, protein, and other deficiencies that were conspicuous from clinical, anthropometric, biochemical, and dietary survey data.

Dietary survey data are considerably more accurate provided the sampling is carefully done and the data are carefully processed. There are 2 types of data frequently sought. One, the simplest, relies on interviews in which the interviewee recalls the kinds and amounts of food he ate during the previous 24 hr. Even more reliable is the survey in which over several days everything prepared and eaten in the home is carefully weighed and food eaten outside the home is documented. From either the 24-hr recall or the weighed intake data the surveyor then refers to standard tables of the nutrients in the various foods to calculate the total daily intake of each nutrient.

One problem with these particular survey techniques is that the values in the tables represent the nutrients in raw foods. Cooking losses are therefore unaccounted for. These cooking loss errors can be eliminated if from the dietary survey data accurate representative daily composite diets are prepared from the local foods cooked in the traditional way and then analyzed for all of the vitamins, minerals, and amino acids and subjected to proximate analysis. In the Dominican Republic survey, for example, the simple dietary survey data indicated very adequate consumption of Vitamin C, but the clinical and biochemical data both pointed to quite common Vitamin C deficiency. Analysis of composite diets documented about a 75% cooking loss of the vitamin, thus resolving the paradox.

From that survey the average data describing the diets of middle- and low-income groups are described (Fig. 3). Here each bar represents the intake of a different nutrient as labeled at its outer end. A bar touching the 100 circle represents a nutrient for which the intake was 100% of that recommended. A bar reaching the 75 circle, like ascorbic acid or iron, represents a nutrient for which the average intake is only 3/4 of that recommended.

These data show adequate or even generous intakes of leucine, phenylalanine, tyrosine, threonine, valine, lysine, isoleucine, and phosphorus. Thiamine and tryptophan intakes are in excess of 90% of the recommended amounts. Crude protein and calories lie outside the scope of the kind of fortification we are considering.

That leaves us with iron, ascorbic acid, methionine, folic acid, niacin, calcium, riboflavin, zinc, magnesium, pyridoxine, retinol, α-tocopherol, vitamin B_{12}, and copper to consider as ingredients of the fortification formula.

The amounts of each to be put into the fortification formula are then established by subtracting the actual intakes seen here from the amounts recommended.

That even this approach does not assure absolutely complete protection can be seen from looking at the data in Table 1. We have been looking at average data for the most part up to now – average data describing middle- and low-income groups. But even within this

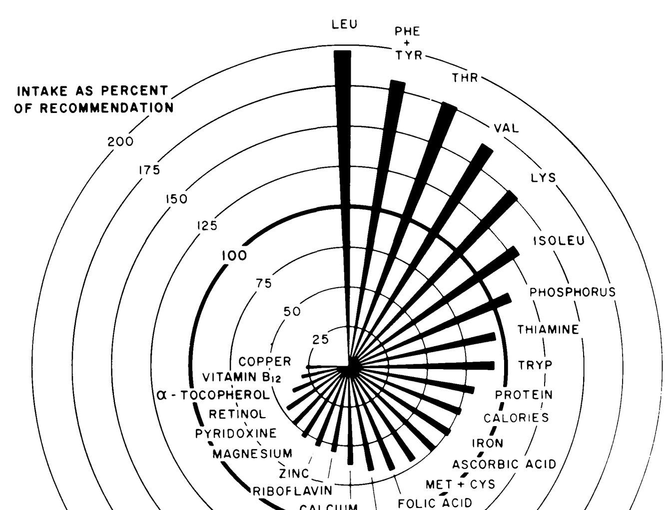

Fig. 3. Intake of nutrients as % of recommended levels, middle and low-income groups, Dominican Republic, 1969.

group the range of nutrient intake is very wide depending on family size. In general households of four people or less are reasonably well nourished. But as family size increases there is a striking deterioration in dietary adequacy.

Table 2 further emphasizes the point by summarizing the highest, lowest, and average nutrient intakes of the households surveyed. It is clear that a fortification program designed to raise the average intake to 100% of the recommended intake will still leave about half of the citizenry shy of the target though probably protected from deficiencies of clinical significance.

At this point, the calculations follow for each nutrient the general scheme outlined below:

A. Development of recommended annual dietary allowance (RADA)
   1. For each demographic group: No x RDA = RDA_{group}
   2. Total these = national RDA
   3. x 365 = $RADA_{national}$

B. Development of estimated national intakes
   1. Calculate total household units in country
   2. Measure actual intake per unit
   3. #1 x #2 = total daily intake
   4. #3 x 365 = total annual intake

C. A - B = annual fortification need

The first step is to establish for each nutrient the national recommended annual dietary allowance. To do this the daily allowance of each group, for example, adult women, is multiplied by the number of people in that group. Totalling these group allowances yields the national recommended daily allowance, and this figure multiplied by 365 yields the national recommended annual dietary allowance.

The second step is to determine the actual national intake of each nutrient. Census data provide the total household units in the country, and the dietary survey data describe the actual daily intake per household unit. The product of these two figures multiplied by 365 gives the actual national annual intake of each nutrient.

The amount of nutrient to be included in the national fortification formula is then obtained by subtracting the actual annual intake from the national recommended allowance.

Limitations and costs

At this point decisions have to be made on what foods will serve as carriers for the added nutrients. The 6 basic characteristics of a useful carrier are as follows: 1) It must be a food eaten regularly throughout the year by the target groups of people. 2) A narrow range (maximum 5x) of intakes among people is essential to avoid both possible toxicities and insufficient supplementation. 3) Essentially all of the food must pass through some central facility where fortificant can be added under controlled conditions. 4) Obviously the food must be amenable to fortification in the technical sense, and 5) the added nutrient must have a reasonable shelf life. 6) Finally, the fortified food must be one that will be acceptable on the market. For example, riboflavin fortification of rice in the Dominican Republic failed many years ago because the vitamin gave the rice a yellow cast which people would not accept. The dietary survey data from the Dominican Republic revealed that country's potential carriers to be sugar, salt, coffee, corn, rice, and tomato paste.

Calculation of costs of overcoming nutrient deficits are summarized in terms of actual data from the Dominican Republic in Table 3. Several points are worth noting here. One is that fortification completely ignores the very sizable caloric deficit. Another is that the protein deficit is only dealt with in terms of the improvement in quality as a result of the methionine added in the bottom row.

The annual cost of ingredients totals nearly $3,000,000 per year which would constitute a very major investment for so small a country. Should the fiscal decision require that the methionine be deleted, and should the alpha-tocopherol be omitted on the grounds that there is no evidence of clinical deficiency in the field, then the cost would be reduced to about $340,000 per year.

In actuality experience has been that the shipping and processing costs of fortification about equal the cost of the ingredients so that a best estimate of this vitamin-mineral fortification program would be approx $700,000 per year or 18¢ per citizen per year. Estimates of current food expenses in the Dominican Republic are very approximate, but assuming them to run about 20¢/day this fortification aimed at eradicating vitamin and mineral deficiencies would raise the national food bill by approx 0.3%.

Table 1. Nutrient intake as affected by family size, middle- and low-income groups, Dominican Republic, 1969.

People per household	Intake as % RDA					
	Calories	Protein	Ca	Fe	B_1	B_2
1–4	103	93	79	104	120	73
4.1–7	88	90	64	84	93	64
7.1–10	69	74	53	73	86	49
>10	61	60	42	61	74	35

Table 2. Range and average nutrient intake of middle- and low-income households, Dominican Republic, 1969.

Nutrient	Intake as % RDA		
	Lowest	Average	Highest
Calories	50	76	108
Protein	50	81	124
Calcium	22	62	105
Riboflavin	22	55	87
B_{12}	14	30	62
S-Amino acids	42	72	113
Tryptophan	50	93	132
Isoleucine	76	130	193
Lysine	92	151	217

Table 3. Calculated costs of nutrients to overcome deficiencies in a fortification program, Dominican Republic, 1969.

Nutrient	Annual deficit (kg)	Annual cost
Calories	$737 \times 10^{9*}$	--------
Protein	15,200,000	--------
Calcium	291,000	400
Iron	4,990	9,980
Retinol	477	57,240
Riboflavin	793	19,230
Niacin	6,770	18,143
Ascorbic acid	17,600	68,640
Folic acid	65	78,000
Pyridoxine	1,470	46,187
Vitamin B_{12}	5+	35,800
α-tocopherol	9,110	455,500
Copper	2,160	1,620
Magnesium	226,000	158
Zinc	6,770	1,489
Methionine	489,000	2,200,000
Total Annual Materials Cost		$2,992,387 (60¢/capita/yr)

*Equivalent to 200,000 Tons of Cereal.

Summing up

In opening this discussion we looked at a number of alternate approaches to closing the world-wide food gap, some of them long-range, others short-term by nature. Comprehensive fortification programs of the kind we have just been examining seem to me to have real merit as immediate impact short-term measures. We need to remember, however, that factory-made vitamin and mineral supplements are quite costly compared to those produced by traditional agriculture. In the Caribbean today, for example, a 10¢ lb. of dry beans contains nutrients worth 25¢ if they were purchased individually at wholesale prices. Because of this it seems only prudent to me to attempt fortification on this scale only as a short-term program planned from the beginning to be eventually abandoned when traditional agriculture has caught up with a nation's food needs. In the interim fortification has a great deal to offer.