Review Article

National food fortification: a dialogue with reference to Asia: balanced advocacy

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The vulnerability of large segments of Asia's population to micronutrient deficiency is more a consequence of cultural evolution and demography than of economic inequities. We evolved in a hunter-gatherer lifestyle with vigorous energy expenditure, wide dietary variety and a nutrient-dense diet (meat, viscera), and wound up 10,000 years ago as agriculturalists cultivating cereal and tuber crops for 70% of our dietary calories. Obtaining rice, maize and wheat is less energy intensive than needed for hunters' fare, while grains are distinctly less rich in available vitamins and minerals. Recurrent infectious episodes, transmitted in crowded societies, further deplete micronutrient nutriture. A fast-track option to address historically unprecedented life conditions includes chemical- or bio-fortification of ubiquitous condiments or widely consumed staples. With little or no change in habitual eating individuals will consume recommended micronutrient intakes and uptakes. Generous intakes of nutrients such as vitamin A and zinc counteract the adverse environmental effects on quality of life and survival in poverty situations. One size may not fit all, and over-consumption of certain micronutrients in heterogeneous societies is to be avoided. For the rice bowl to support the descendants of the caveman in the third millennium requires both imagination and technological ingenuity.

Key Words: micronutrient deficiency, staple grains, food fortification, nutrient excess, Asia

INTRODUCTION

One of the ways to deliver more vitamins and minerals to the population is through fortification of foods. In an era that makes addition of micronutrients to foods (condiments, staples) technically feasible, it has become an issue of public policy in Asia and around the world. For example, salt fortification, at a national level is either mandated or encouraged in almost all Asian nations. Scott[1] has documented the legal mandating of folic acid addition to foods in 42 nations worldwide; in Asia, these include: Bahrain; Indonesia; Kazakhstan; Kyrgyzstan; Omar; Qatar; Saudi Arabia; and Yemen. Edible oil is fortified in four countries: Bangladesh; *China*; Pakistan; and Philippines. India's only mandated fortification is vitamin A in margarine and vanaspati. Flour or rice is enriched, variously, with B-vitamins and iron in 19 nations: Azerbaijan; Bahrain; *Bangladesh*; China; *Indonesia*; Iran; Iraq; *Jordan*; *Kazakhstan*; Kuwait; *Kyrgyzstan*; *Mongolia*; Oman; *Palestine*; Philippines; Saudi Arabia; U.A.E.; and *Uzbekistan*; the 10 countries in Italics are fortifying with zinc, as well. On the one hand, Cambodia currently has no mandated fortification; on the other hand, the Philippines has been the most energetic in the breadth of mandated and optional fortification.

So, there is a broad reality to fortification programs in the region. As this dialogue illustrates, there is a contrary and a positive stance to be taken to "national food fortification" programs. These pages present an argument of advocacy, balanced by the need for selective application and cognizant of potential scenarios in which adverse consequences can ensue for some.

Why human populations experience micronutrient malnutrition

The existence of endemic micronutrient malnutrition is a consequence of two components of human evolution: hominid biological evolution over millions of years, and human cultural evolution to depend on agriculture for sustenance. The ancestors of the modern human were hunter-gatherers who consumed large amounts of a diverse, nutrient-dense diet, perhaps inclining more toward animal sources of foods.[2] The nutrient demands stamped into the human genome are the product of this high throughput of micronutrients. Without any change in physiological requirements, the mode of supplying food to the diet underwent an transformation 10,000 years ago with the advent of the Agricultural Era.[3] From that time to the present, up to 70% of dietary calories have come from cultivation of staple grains and tubers such as rice, wheat, maize, sorghum, millet, potatoes, cassava and yams. A common feature of these staples is their low content (and occasional poor bioavailability) of micronutrients. The Table illustrates the nutrient density (units per 1000 kcal) for selected vitamin and minerals for unrefined forms of the three cereal grains most relevant to Asia: rice, wheat and maize. It further illustrates how much of the U.N. System's Recommended Nutrient Intake (RNI).[4]

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value would be obtained from a 2000 kcal daily diet in which the staple of interest constituted 70% of energy (1400 kcal). This information provides a quantitative appraisal of why and how human populations' dependence on agriculture exposed us to a vulnerability to micronutrient malnutrition.

The derivative point made is in the third column of each set, in which the nutrient-density of the residual 600 kcal of dietary fare would have to have, in order to achieve the gender-specific RNI. If we assume no change in their dependence on the traditional staple, a Herculean adjustment in the rest of the diet would be needed to meet recommended intakes.

The micronutrient intake balance sheet in the region

Survey data on micronutrient intakes from almost every corner of the region documents the failure to achieve recommended daily intakes of at least some micronutrients.[5,6] The deficits in nutrient intakes most commonly observed in Asian populations were vitamin A, iron, calcium, riboflavin, and iodine, with an occasional mention of folate and zinc. The actual findings from Asia confirm the quantitative prediction implicit in the Table.

The conformation and costs of the nutrient-adequate diet

The counter-proposition for correcting micronutrient deficiency and preventing its future occurrence is centered around a strategy of consuming an array of nutrient-dense animal foods, such as meats, especially organ meats, as well as eggs and dairy items. Legumes, fruits, and green leafy vegetables are variously rich in certain vitamins or minerals, but must be consumed in artful combination to provide the balance of the nutrients in appropriate balance.

Monetary expense is the first cost consideration. Those with scarce resources buy the least expensive foods. Purchase price is directly related to nutrient density. To meet the recommended intakes from an array of meats, fish, seafood, beans, fruits and vegetables, requires more than an average income in almost any society in Asia, or around the world.

Adverse effects on the environment of obtaining nutrient-rich foods from the animal kingdom represent additional costs. Depletion of fish and seafood stocks could be the result of increased demand for marine and aquatic species for foods. Pressure on terrestrial fauna, and their depletion or extinction, could result from the Asian population's turning to free-living mammals, birds and reptiles and wild eggs as a source of nutrient-dense fare. Raising domestic poultry and livestock poses issues of the nitrogenous waste in their excreta is an environmental issue at the site. For ruminant animals, the expulsion of methane from their rumen stomachs contributes greenhouse gases in the atmosphere. Clearing forest or savanna lands, or draining of wetlands is destructive of the environment.

Finally, there are health costs to be paid in obtaining the recommended micronutrient intake from a diet that relies on animal sources of nutrients. In the most general sense of preventing chronic diseases, consuming a plant-based diet is the single most universal guideline.[7,8] Detrimental effects attributed to exposure to specific animal foods primarily drive this. Red meat is associated with excess risk of colorectal cancer, and the mechanism of carcinogenesis are being recognized. Organ meats, whole milk and eggs are laden with cholesterol. The sodium and nitrite- and nitrate-based carcinogens in salted and cured meats predisposed to alimentary tract tumors. Charred foods and meats cooked at high temperatures have similar effects due to the generation of endogenous cancer-causing compounds.[9] Marine fish is rich in nutrients, but can be a source of methylmercury.[10]

Fortification: moving empty calories to nutritive calories

The physiological needs of humans have a hierarchy of priorities. Hydration is the most compelling. The need for energy to fuel essential functions and proteins for renovation of tissues follow this. Given the hierarchy, we are driven to fill our mouths and stomachs with the edible flora and fauna to slake our thirsts and assuage our hunger. When the major substances of our diet are grains (Table 1), tubers or roots, less than the required vitamins and minerals will be consumed. Adding these nutrients back by fortifying or enriching foods or condiments is an opportune way to overcome a low nutrient diet, as long as certain norms are respected.[11] Its primary advantage is that it does not require a change in behavior.

Table 1. Consequences of nutrient density of three staple grains for meeting average nutrient requirements of adult men

	Rice			**Wheat**			**Maize**		
Nutrient	Density[1]	% EAR at 70 en%[2]	Residual density[3]	Density[1]	% EAR at 70 en%[2]	Residual density[3]	Density[1]	% EAR at 70 en%[2]	Residual density[3]
Vitamin A	0	0%	715	0	0%	715	30	10%	645
Thiamin	0.49	69%	0.52	0.54	76%	0.40	0.68	95%	0.08
Riboflavin	0.15	19%	1.48	0.20	25%	1.37	0.22	28%	1.32
Niacin	5.8	68%	6.5	3.3	38%	12.3	5.2	61%	7.8
Folate	19	8%	488	86	38%	333	69	30%	133
Calcium	30	5%	1320	47	8%	1278	19	3%	1343
Iron	4.3	56%	8.0	3.5	45%	9.8	6.6	85%	2.6
Zinc	3.2	78%	2.1	3.2	78%	2.1	4.8	116%	--

[1]The amount of the micronutrient in question per 1000 kcal of the cereal grain of interest, expressed in its conventional unit. [2]The percentage of the Estimated Average Requirement (EAR) that would be obtained consuming 1400 kcal of the cereal grain of interest. [3]The micronutrient density needed in the remaining 600 kcal of intake to meet the full, daily EAR

Better living through chemistry, of agricultural science

A new format to increase the vitamin and mineral content or availability in plants is emerging. This is termed biofortification.[13] It involves developing improved varieties of crops and plants through breeding. High carotene rice and sweet potato and high iron rice are examples. The latter has shown nutritional efficacy in human trials.

Home fortification of complementary foods

Home fortification of complementary foods with iron is neither mandatory nor national in scope in any region. However, the development of foodlets, Sprinkles, and high-nutrient density spreads, concentrated nutrient sources that can be mixed into the foods of infants and toddlers show promise as a solution for micronutrient malnutrition in children aged 6 to 18 mo.[14]

The right to an adequate diet

The United Nations has supported the notion that "the right of everyone to an adequate standard of living for himself and his family, including adequate food".[15] This could be interpreted as to guaranteeing the requisite intake of micronutrients as set for the world's population by the FAO/WHO.[4] Considerations in the Table confirm the need to intervene. A benign and uncomplicated justification that a State could embrace is to intervene to improve the quality of the diet, supporting intakes of the vitamins and minerals to the Estimated Average Requirement.[11]

The right to health

The U.N. has also projected the right to health, per se, as a human right. Many studies related to provision of nutrients and health outcomes (positive and negative) exist to allow for evidence-based development of public policy.

The fortificant nutrients that counteract environmental stress and protect life and health at the population level

For a series of nutrients, large and well-conducted field trials with supplementation levels of nutrient provide evidence of going beyond normative nutrition; they correct extant health problems. Vitamin A interventions reduce child death from childhood infections.[16] Zinc supplementation also reduces child morbidity.[17] Peri-conceptional folic acid supplementation reduces the incidence of neural tube defects.[18] Providing these in fortification programs could produce similar results for a society.

The fortificant nutrients that may be detrimental to some members of the population

Subsumed within the right to health is the right not to be made ill by public health initiatives. There are a certain nutrients that can be beneficial when fortified to the foods of deficient individuals and potentially detrimental as fortificants in the diets of nutrient-replete individuals. The ironic problem is that the heterogeneity of status across individuals finds persons of both categories coexisting in the same societies. Three often-fortified nutrients of note are: folic acid; vitamin A; and iron. Recent evidence for adverse consequences at or close to recommended intakes have been offered for folic acid,[19] vitamin A,[20] and iron.[21] These, along with iodine, are the nutrients of primary public health interest in fortification programs.

CONCLUSIONS

We humans were set into our genetic constitution through an evolutionary process that involved high outputs of energy and consumption of a varied, micronutrient-dense diet. Today, we are increasingly sedentary and consumers of a diet with a much lower content of vitamins and bioavailable minerals. Those who replicate the caveman's nutrient density and adequacy from natural foods do it at unsustainable costs. Such an approach is beyond the means of most Asians and outside of the religious tenets of some. It also has adverse effects on the environment and long-term health. Fortification, in its best sense, should aspire to be better living through chemistry; it offers the path of least resistance to re-balancing the micronutrient intake toward the state of the evolutionary human diet. It is a matter of putting scarce micronutrients into the foods that provide the most energy and protein through addition at milling or processing or plant genetics. Asian fortification programs should be: orderly and well administered; if not national in scope, then targeted to those most vulnerable; and monitored to avoid unintended consequences of excessive exposures.

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AUTHOR DISCLOSURES

Noel W. Solomons serves as an Editorial Advisor to Nutriview and a Contributing Editor for Sight and Life Magazine. CeSSIAM has received research contributions from Sight and Life, Akzo Nobel, and the Malaysian Palm Oil Board.

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