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Seeking Optimal Means to Address Micronutrient Deficiencies in Food Supplements: A Case Study from the Bangladesh Integrated Nutrition Project

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ABSTRACT

In seeking to improve the micronutrient contents of a food supplement used in a major community-based nutrition project in Bangladesh, operations research was conducted to compare the provision of needed micronutrients through additional food sources (fresh or dried fruits or vegetables), a micronutrient multi-mix, and a combination of the two. Micronutrient gaps (the difference between micronutrient requirements and actual micronutrient intake) were estimated for four groups of project beneficiaries, with target intakes defined as requirements for iron, calcium, zinc, vitamin A, vitamin C, riboflavin, niacin, and vitamin B12 recommended by the Food and Agriculture Organization/World Health Organization. Primary focus was placed on iron and vitamin A. Cost and bulk constraint analyses, based on cost of supplement, feasibility of delivery, and serving volume needed to achieve micronutrient targets, were used for comparing the supplement options. In terms of these analyses, the micronutrient multi-mix proved, by far, to be the most advantageous. Food options, however, are arguably desirable in that they provide dietary benefits additional to that of known micronutrients and may increase demand to boost production of domestic fruits and vegetables for the population as a whole. The study concludes that it is cost-effective to use powdered micronutrient mixes for such specific purposes as enrichment of supplementary food and food fortification, but encourages production and consumption of micronutrient-rich foods through programme messages and activities.

Key words: Micronutrients; Food supplementation; Food fortification; Nutrition disorders; Nutrition; Operations research; Fruits; Vegetables; Bangladesh

INTRODUCTION

There has been considerable debate over whether food or non-food approaches are preferable in addressing micronutrient deficiencies. The issue is highlighted when efforts are made to enhance the micronutrient content of a locally-produced food supplement used in a community-based nutrition project. This analysis was carried out to contribute empirical evidence to the debate and, at the same time, to contribute to practical problem-solving relating to the food supplement used in the Bangladesh Integrated Nutrition Project (BINP).

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BINP, initiated in 1995, has since been incorporated into the National Nutrition Programme which, in turn, will become part of the country's integrated health services. One of the BINP components involved daily on-site supplementary feeding for four beneficiary groups: (a) children aged 6-24 months who are growth-faltering (age <1 year gaining <200 g per month, age >1 year gaining <150 g per month), (b) children aged 6-24 months who are severely malnourished (weight-for-age <60% of median of the National Center for Health Statistics/ 1990 reference population of World Health Organization), (c) pregnant girls and women who were determined to be suffering from chronic energy deficiency at the time they are identified as pregnant (body mass index [BMI] <18.5), and (d) lactating girls and women who were determined to be chronic energy-deficient at the identification of pregnancy (BMI <18.5).

The BINP food supplement consisted of 20 g roasted rice powder, 10 g roasted pulse, 5 g molasses (sugar cane molasses), and 3 g soybean oil (unfortified) and was packaged in individual-serving units called '*pushti*' (nutrition) packets. Each packet provided 150 kcal of energy. Growth-faltering children received a single packet daily six days a week, severely-malnourished children received two packets daily, and chronically energy-deficient pregnant and lactating women received four packets daily. Unlike food supplements in many other such projects in developing countries, the purpose of the BINP food supplement was primarily educational rather than therapeutic: the project provided the supplement to demonstrate to mothers the importance of complementary food as an easy way to feed their children to promote growth. The BINP supplement was processed locally by women's groups for purpose of local ownership and income-generation instead of having it centrally processed by a food company.

The BINP food supplement, however, was deficient in micronutrients. Since supplement recipients, by definition, suffer from protein-energy malnutrition, they are virtually certain in rural Bangladesh, also to be micronutrient-malnourished (1). The provision of a supplement lacking adequate micronutrient contents also raises ethical concerns over the failure to address a known deficiency, especially in a situation where participants may substitute project food for other foods that may contain these needed micronutrients. This would be particularly true in the case of breastfeeding children for whom the food supplement would likely displace a portion of their breastmilk intake. The purpose of this research was to identify the optimal means of increasing the micronutrient contents of the BINP food supplement to make it more appropriate to the needs of the beneficiaries.

The BINP operations research committee requested an exploration of alternative possibilities of meeting the 'micronutrient gap' between actual vitamin and mineral intake of supplement recipients and recommended daily intake, especially for iron and vitamin A. The alternatives considered to go along with the existing supplement were: (a) vegetables or fruits (fresh or dried), (b) a micronutrient multi-mix, and (c) some combination of the two. The food options had the advantage of promoting the local economy and serving as a valuable education and demonstration tool. Yet, feasibility was uncertain because of the large quantity of fruits and vegetables that would be needed to provide adequate amounts of micronutrients, particularly vitamin A and iron—two of the deficiencies considered public-health problems in most developing countries. The multi-mix had the expected advantages of low volume and cost, but questions were raised about the practicality, acceptability, and sustainability of using the powdered multi-mix at the local level.

This paper reports the results of the first phase of operations research and focuses on the review of options to increase the micronutrient contents of the food supplement. A second phase, carried out subsequently, involved the feasibility testing of the option selected. A report of this work was submitted to BINP (unpublished).

MATERIALS AND METHODS

Phase 1 of the study is presented here and divided into two parts: (a) analysis of micronutrient gap and (b) cost and bulk constraint analyses based on the cost of the supplement, logistics of delivery, acceptability to BINP participants, and serving volume needed to achieve micronutrient targets.

Analysis of micronutrient gap

Micronutrient gaps for the four BINP beneficiary groups were determined using a methodology developed specifically for this project by Beaton, modelled after Beaton's earlier work (2,3). In this methodology, nutrient intake is assumed to be normally distributed in the target population, and published dietary intake data are assumed to represent individuals in the target group. The 'micronutrient gap' in intake for a hypothetical individual participating in BINP feeding is the difference between the recommended daily intake of a nutrient and the estimated individual intake, calculated as the published mean intake plus the amount of that nutrient available from the standard food supplement, minus the amount of nutrient that would be lost from the diet due to substitution of the BINP supplement for other foods. The micronutrients found to be lacking in the diets of target groups include iron, calcium, zinc, vitamin A, vitamin C, riboflavin, niacin, and vitamin B12; no significant gaps were found for thiamine, vitamin B6, and folic acid.

Tabular data from the Bangladesh National Nutrition Surveys (4) and other published data (5) were used for estimating average intake and standard deviations

Table 1. Micronutrient gaps and suggested addition of nutrients to food supplement

Nutrient	Micronutrient gaps*				Estimated additions per 100 g of food supplement by target group				Suggested addition per 100 g of food supplement	Addition per *pushti* packet (38 g)
	Growth faltering	Severely malnourished	Pregnant women	Lactating women	Growth faltering	Severely malnourished	Pregnant women	Lactating women		
Iron (mg)	1	0.3	7.6	0	2.7	0.5	5	0.2	2.1	0.8
Calcium (mg)	145	216	801	813	381.4	284.3	526.7	534.7	300	114
Zinc (mg)	2.43	2.75	5.7	5.7	6.4	3.6	3.8	3.8	4.4	1.67
Vitamin A (RE)	201	259	686	392	528.4	340.3	451.1	258.1	394.5	149.9
Vitamin C (mg)	9	13	40	2.3	24	17	26.1	14.9	20.5	7.78
Riboflavin (mg)	0.22	0.31	0.68	0.68	0.6	0.4	0.4	0.4	0.5	0.18
Niacin (NE)	0.3	0.6	11.8	-1.1	0.8	0.8	7.8	-0.7	2.2	0.83
Vitamin B12 (µg)	0	0	1.03	1.11	1.1	0.6	0.7	0.7	0.8	0.29

*Micronutrient gap is the difference between the recommended daily intake of a nutrient and the estimated individual intake; they represent the gap to be filled by the *pushti* packets (1 per day for growth-faltering children, 2 per day for severely-malnourished children, and 4 per day for pregnant and lactating women). Values assume 75 kcal displaced for children (50 kcal rice and 25 kcal breastmilk) and 400 kcal displaced for pregnant and lactating women (400 kcal of rice)

NE=Niacin equivalents; RE=Retinol equivalents

for the four BINP target groups (growth-faltering and severely-malnourished children, pregnant and lactating women). The micronutrient-enhanced food supplement, in addition to estimated dietary intake from food, was expected to meet the US-recommended dietary allowances (RDAs) for iron, calcium, zinc, vitamin A, vitamin C, riboflavin, niacin, vitamin B12 (6) for a fixed percentage of each beneficiary group (99% of children and 95% of mothers). Based on international data from supplementary feeding programmes, it was estimated that beneficiary women would substitute the supplement (which provides 600 kcal for pregnant and lactating women) for 400 kcal at home (7). Since 80% of adult Bangladeshi energy intake consists of rice (4), rice was assumed to be the only displaced food for women. For children, it was assumed that 75 kcal would be displaced from home food: 50 kcal of rice and 25 kcal of breastmilk. The calculated micronutrient gaps were used for determining the levels of nutrients that should be added to the existing supplement (Table 1).

Identification and development of supplement options

After establishing the levels of nutrients required in the supplement to meet the micronutrient gaps in the diet, supplement options were identified and compared based on their ability to provide the required nutrient density, cost, feasibility of delivery, acceptability, and serving volume.

Formulation of a micronutrient pre-mix containing the required amount of each nutrient was needed to achieve the required nutrient density to fill the 'micronutrient gaps' using chemical nutrients. The mix formulation provided for 'overages' of certain nutrients, as recommended by the suppliers, to cover losses during storage. Table 2 shows the multi-mix content.

Achieving the required nutrient density using food products was more complicated because of the varying

Table 2. Composition of multi-mix*

Vitamin/mineral	Amount per 100 g†
Vitamin A (IU)	2,660,000
Vitamin C (g)	40
Riboflavin (g)	1
Niacin (g)	4.4
Vitamin B12 (g)	1.6
Reduced iron (g)	0.25
Calcium carbonate (g)	93.75
Zinc sulphate (g)	1.38

*Dextrose monohydrous was used as a filler to increase the pre-mix to a manageable bulk

†Nutrient levels were adjusted to allow for losses prior to consumption

Table 3. Provision of iron from fresh/cooked fruits and vegetables: amount and cost (recommendation: 2 mg of iron per 100 g of BINP food supplement)

Fruit and vegetable	Iron content in 100 g of edible portion (8) (mg)	Iron bio-available in 100 g of edible portion (10%) (mg)	Fresh edible amount to provide 2 mg of iron (g)	Edible portion of raw food (11) (%)	Raw amount of produce purchased to provide fresh edible amount (g)	Average market price per kg of raw produce (11) (Tk)	Cost of purchased produce for 100 g of food supplement (Tk)	Cost of purchased produce per *pushti* packet (Tk)
Leafy vegetables								
Data shak (green amaranth leaves, *Amaranthus lividus*)	1.80	0.180	1,111.1	40	2,777.8	5.00	13.89	5.28
Pui shak (Indian spinach, *Basella alba*)	1.14	0.114	1,754.4	40	4,386.0	6.00	26.32	10.00
Helencha shak (marsh herb, *Enhydra fluctuans*)	--	--	--	40	--	9.00	--	--
Lal shak (red amaranth leaves, *Amaranthus gangeticus*)	1.80	0.180	1,111.1	40	2,777.8	6.50	18.06	6.86
Legumes								
Borboti (cow pea, *Vigna sesquipedalis*)	5.90	0.590	339.0	100	339.0	17.50	5.93	2.25
Other								
Gajor (carrot, *Daucus carota*)	2.20	0.220	909.1	100	909.1	17.50	15.91	6.05
Mishti kumra (pumpkin, *Cucurbita maxima*)	0.70	0.070	2,857.1	80	3,571.4	11.00	39.29	14.93
Paka pepe (ripe papaya, *Carica papaya*)	0.50	0.050	4,000.0	80	5,000.0		--	--
Amra (hog plum, *Spondias dulcis*)	3.90	0.390	512.8	80	641.0	27.50	17.63	6.70

densities of the desired nutrients in available foods. To simplify the task, assessment of the food-based option was carried out only for vitamin A and iron, with the rationale that the supplement must, at a minimum, provide these nutrients given the high prevalence of the associated deficiencies and their consequences. Content of other nutrients would be assessed following identification of a viable food for iron and vitamin A.

To meet the vitamin A and iron gaps identified, a list was compiled of locally-available fruits and vegetables with high iron and/or vitamin A contents. Each identified fruit and vegetable was then assessed in terms of cultural acceptance, market price, and seasonal availability. This yielded a practical list of nine readily-available, accessible and acceptable fruits and vegetables. For the short-listed nine fruits and vegetables, cost and amount of food required to meet the required vitamin A and iron nutrient densities per *pushti* packet were calculated using five parameters: vitamin A and iron contents of the raw food (8), bioavailability of the micronutrient, vitamin A and iron loss during processing (9,10), edible portion of the raw food (11), percentage of dried matter (11), and average market price between peak and lean season (11) (Tables 3 and 4).

Given the limited consumption capacity of young children and, therefore, the necessity of feeding them smaller portions of foods with high nutrient and energy density, it was assumed that the large bulk of food required to provide adequate vitamin A and iron would pose a constraint. The team, therefore, explored means of reducing the bulk of these fruits and vegetables. Drying was the most promising option, since it improves the storage quality of fruits and vegetables in addition to increasing their nutrient density. Solar drying with dryers made from locally-available materials, a low-cost technology developed by the Mennonite Central Committee, a prominent local NGO, was considered for its capability for rapid drying during the rainy season.

Since the precise bioavailability of iron in particular foods is uncertain, a sensitivity analysis with a range of values was conducted. The assumption was made that the bioavailability of iron varied from 10% to 50%. Considering the absence of an iron-absorption enhancer, such as vitamin C, in the Bangladeshi diet, and the presence of inhibitors, such as tannins and phytates, even absorption of 10% iron may be unrealistic. Higher estimates were used, however, for giving the benefit of doubt to the food-based option, since a higher-estimated iron-absorption percentage reduces the amount of food needed to provide the required iron density. One hundred percent of iron was assumed to be retained following drying and cooking.

Likewise, the team considered all vitamin A (converted from beta-carotene using a 6:1 conversion factor) to be bioavailable. The conversion factor specified by the US National Academy of Sciences is 12:1 (6), but halving that again gave the benefit of doubt to the food option. Estimates used for retention of vitamin A during cooking and drying were 63% and 84% respectively (9,10).

After assessing the cost and bulk necessary to provide adequate vitamin A and iron for each of the nine selected foods, the BINP senior management concluded that only fresh and dried *lal shak* (red amaranth, *Amaranthus gangeticus*) had sufficient availability and nutrient density to warrant further analysis. The BINP officers also suggested eggs as a potentially-appropriate supplement because poultry-rearing was already a BINP food-security initiative.

To provide useful estimates for the BINP planners, costs were calculated per 1,000 Community Nutrition Centres (CNCs) per year (Table 5). The existing BINP monitoring data indicated that, on average, a CNC fed two severely-malnourished children, 10 growth-faltering children, and 20 pregnant or lactating women each day, requiring a total of 94 *pushti* packets per day for the 25 feeding days per month. Calculations were made in Bangladeshi taka and converted to US dollar using the rate of Tk 48 to US$ 1 (Spring 1999). The cost of the multi-micronutrient mix, taken from estimates provided by Indian suppliers, was US$ 3 per 1,000 *pushti* packets. One-time capital costs (fortification equipment for the micronutrient pre-mix and drying equipment for vegetables) and processing costs (fortification with the micronutrient pre-mix, drying and mixing of vegetables) were not considered.

RESULTS

Micronutrient gap

Estimates of age-specific nutrient consumption in Bangladesh were taken from two sources (4,5). The micronutrient contents of the BINP food supplement were analyzed by the laboratory of the Institute of Nutrition and Food Science (INFS) of University of Dhaka. For nutrients in the BINP supplement that the INFS was unable to test, the content was estimated from the literature (8,12,13).

Estimated micronutrient gaps for all the four target groups for iron, calcium, zinc, vitamin A, vitamin C, riboflavin, niacin, and vitamin B12 are presented in Table 1.

Cost and bulk constraint analyses

As indicated in Table 5, the cost of the multi-mix, meeting all major micronutrient requirements, was a fraction

Table 4. Provision of vitamin A from freshly-cooked fruits and vegetables: amount and cost (recommendation: 400 RE per 100 g of BINP food supplement)

Fruit and vegetable	Vitamin A content in 100 g of edible portion (8) (RE)*	Vitamin A available after retention during cooking (9) (RE)	Fresh edible amount of produce to provide 400 RE of vit A (g)	Edible portion of raw food (11) (%)	Raw amount of produce purchased to provide fresh edible amount (g)	Average market price per kg of raw produce (11) (Tk)	Cost of purchased produce for 100 g of food supplement (Tk)	Cost of purchased produce per *pushti* packet (Tk)
Leafy vegetables								
Data shak (green amaranth leaves, *Amaranthus lividus*)	1,000	630.0	63.5	40	158.7	5.00	0.79	0.30
Pui shak (Indian spinach, *Basella alba*)	1,240	781.2	51.2	40	128.0	6.00	0.77	0.29
Helencha shak (marsh herb, *Enhydra fluctuans*)	2,283	1,438.3	27.8	40	69.5	9.00	0.63	0.24
Lal shak (red amaranth leaves, *Amaranthus gangeticus*)	1,990	1,253.7	31.9	40	79.8	6.50	0.52	0.20
Legumes								
Borboti (cow pea, *Vigna sesquipedalis*)	94	59.2	675.4	100	675.4	17.50	11.82	4.49
Other								
Gajor (carrot, *Daucus carota*)	315	198.5	201.6	100	201.6	17.50	3.53	1.34
Mishti kumra (pumpkin, *Cucurbita maxima*)	1,200	756.0	52.9	80	66.1	11.00	0.73	0.28
Paka pepe (ripe papaya, *Carica papaya*)	170	170.0	235.3	80	294.1	--	--	--
Amra (hog plum, *Spondias dulcis*)	45	45.0	888.9	80	1,111.1	27.50	30.56	11.61

*Conversion factor: 6 mg beta-carotene: 1 RE
RE=Retinol equivalents

of the cost of the fresh or dried *lal shak* (red amaranth) required to meet requirements of vitamin A and iron. Compared to the multi-mix, the cost of providing vitamin A at 100% absorption was 1.4 times higher for fresh *lal shak*, 1.65 times higher for dried *lal shak*, and nearly 15 times higher for eggs. For providing iron at 50% absorption, *lal shak* (fresh or dried) was 9.5 times more expensive than the multi-mix, and eggs were over 25 times more expensive. For iron at a more realistic 10% absorption, *lal shak* (fresh or dried) was 50 times more costly than the multi-mix; eggs were over 125 times more expensive.

Table 5. Annual costs needed to meet vitamin A and iron gaps for 1,000 community nutrition centres and quantities of food added per *pushti* packet

Source of micronutrients	Total cost per 1,000 CNCs (US$)	Cost relative to multi-mix	Quantity added per *pushti* packet(s)*		
			1 packet (growth-faltering children)	2 packets (severely-malnourished children)	4 packets (pregnant and lactating women)
Multi-mix	84,600	1.0	Negligible	Negligible	Negligible
Fresh *lal shak*					
Vitamin A†	117,500	1.4	12 g	24 g	48 g
Iron 50%¶	804,875	9.5	84 g	168 g	336 g
Iron 10%§	4,212,542	49.8	422 g	844 g	1,688 g
Dried *lal shak*					
Vitamin A†,‡	139,881	1.65	2.3 g	4.6 g	9.1 g
Iron 50%¶	804,875	9.5	16 g	32 g	64 g
Iron 10%§	4,212,542	49.8	80 g	160 g	320 g
Egg					
Vitamin A†	1,239,625	14.7	0.7 egg	1 egg	2.8 eggs
Iron 50%¶	2,150,250	25.4	1.2 eggs	2 eggs	4.8 eggs
Iron 10%§	10,633,750	125.7	2 eggs	4 eggs	8 eggs

*Assumes % dry material in *lal shak*=19% ; †If bioavailability=100%; ‡Loss of vitamin A during drying=84% (10); ¶If iron bioavailability=50%; §If iron bioavailability=10% CNCs=Community Nutrition Centres

The volume of fresh foods needed to reach nutrient needs, or bulk constraint, is as much a concern as cost. At the 50% iron-absorption level, growth-faltering children (who were given 1 *pushti* packet per day) would need to consume about 84 g per day of fresh *lal shak* or 1.2 eggs to get the same level of iron as the multi-mix; at the 10% iron-absorption level, they would have to consume 422 g per day (about 1 lb) of fresh *lal shak* or two eggs per day. Severely-malnourished children (who were given 2 *pushti* packets per day) would need to consume about 168 g per day of fresh *lal shak* or 2.4 eggs per day to meet iron requirements at 50% absorption; they would have to consume 844 g per day (about 2 lb) of *lal shak* or four eggs per day to meet requirements at 10% absorption. Pregnant and lactating women (who were given 4 *pushti* packets per day) would need to consume 336 g of *lal shak* per day or 4.8 eggs to get enough iron at 50% absorption; they would have to consume 1.7 kg of *lal shak* per day or eight eggs per day to get enough iron at the 10% absorption level.

For only meeting needs of vitamin A at 100% absorption, serving size is less of a constraint. Growth-faltering children would have to eat just 12 g of *lal shak*; severely-malnourished children would eat 24 g, and pregnant and lactating women would eat 48 g. Growth-faltering children would need to eat 0.7 egg per day, severely-malnourished would need 1.4 eggs per day, and pregnant and lactating women would need 2.8 eggs per day to meet requirements of vitamin A via eggs.

DISCUSSION

In terms of cost and feasibility, the multi-mix approach to the provision of micronutrients in the BINP food supplement is clearly superior to dried or fresh food. Even when targeting only vitamin A and iron, instead of the wide range of nutrients contained in a micronutrient multi-mix and using generously high estimates of their bioavailability, the food-based approach is far more expensive and increases the volume of the food supplement beyond the capacity of participants to consume. Drying the *shak* diminishes the problem of bulk constraint, yet there are problems with the dried food as well: beyond the high cost involved, drying with solar dryers would require the installation of multiple dryers at each site, involving the expenses of training in their use, and the cost of maintenance. Further, only freshly-cooked vegetables are culturally acceptable in Bangladesh—it would be exceedingly difficult to successfully promote dried vegetables as foods. Contrary to popular assumption, the multi-mix has great promise for acceptability and sustainability. Although an imported multi-mix was used in this operations research, large-scale requirements for a national programme would almost certainly generate local production within Bangladesh.

After reviewing the findings presented here, the BINP management requested feasibility trials, under Phase 2 of this project, to address the unique logistical challenges of adding a micronutrient pre-mix to ingredients of the existing food supplement at the community level. [The Phase 2 feasibility study subsequently carried out and reported to the BINP management indeed found that local addition of the micronutrient pre-mix was feasible and practical. At this writing, plans are being developed to initiate such community-based micronutrient enhancement or 'fortification' of the supplement in the National Nutrition Programme. A similar community-level procedure is underway in parts of India under the Integrated Child Development Service (ICDS)].

Although the results of the cost and bulk constraint analyses indicate that the multi-mix was superior for the purpose of enhancing the micronutrient contents of the BINP food supplement, the broader benefits of fruits and vegetables, coupled with the sustainability of food-based options, argue for creative ideas to bolster such approaches. Foods contain a host of components beyond the macronutrients and established micronutrients, such as phytochemicals and fibre, which are beginning to be characterized and recognized as having major importance to health. Food options are also important in maintaining or enhancing the acceptability of the supplement and the pleasure of eating. Furthermore, food-based solutions may increase the likelihood of longer-run sustainability by increasing local demand for such foods and, in response, boosting production.

Delivery of food supplements as part of a large-scale nutrition programme is, by definition, an imperfect intervention. Ideally, participants would be encouraged to consume a varied diet, including many vegetable- and animal-source foods. A varied diet would doubtlessly provide more nutrients than attempting to find a single 'superfood' to contribute all of the needed nutrients to the diet. Dietary diversity rather than consumption of one specific food is indeed associated with decreased stunting rates in children (14). Simply encouraging such a diet may not be effective because of socioeconomic constraints, but seeking to provide such a varied diet to beneficiaries would raise a host of logistical problems relating to supply and transportation, market availability, food preparation, and prevention of food spoilage. A home-gardens programme would be a better way to promote dietary diversity. Given the value of food-based approaches, national governments should take all possible steps to encourage the production and consumption of micronutrient-rich foods through combinations of behaviour-change communications and sustainable home-gardening activities.

There may be ways to incorporate the advantages of both food and multi-mix-based solutions into a food supplement. For example, an alternative to the multi-mix alone might be the use of fresh *lal shak* to meet the vitamin A gap (increasing the cost of meeting this gap by only 40% while increasing supplement weight by less than a third), in addition to using the multi-mix to address the iron and other gaps. Research and programme efforts to make these food-based options viable sources of micronutrients for even the poorest households should be encouraged.

The results of this operations research indicate a distinct advantage to providing the needed micronutrients in the BINP food supplement through a powdered multi-mix or through some combination of a multi-mix and fresh foods. Meeting the micronutrient need through the addition of food alone would be unrealistic. In addition to the major cost differential, the amount of fresh food necessary to meet these micronutrient gaps would far exceed the capacity of young children to consume such bulk. The expense, cultural unacceptability, and logistics of drying vegetables to reduce their bulk for addition to the BINP food supplement also rendered the dried *shak* option impractical. While Bangladesh should continue to promote intensively the consumption of micronutrient-rich foods and to encourage home-garden production of micronutrient-rich foods, it would be unrealistic to use fruits and vegetables exclusively for this narrower purpose of enriching the food supplement.

Accordingly, it is our conclusion that the use of powered micronutrient mixes for such specific purposes as supplementary food-enrichment and food-fortification is fully justified. In resource-scarce developing economies, it would be foolhardy to bypass such an attractive and cost-effective opportunity.

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