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Estimating the impact of vitamin A-fortified vegetable oil in Bangladesh in the absence of dietary assessment data

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Abstract

Objective: Vitamin A deficiency is a serious health problem in Bangladesh. The 2011–12 Bangladesh Micronutrient Survey found 76·8 % of children of pre-school age were vitamin A deficient. In the absence of nationally representative, individual dietary assessment data, we use an alternative – household income and expenditure survey data – to estimate the potential impact of the introduction of vitamin A-fortified vegetable oil in Bangladesh.
Design: Items in the household income and expenditure survey were matched to food composition tables to estimate households' usual vitamin A intakes. Then, assuming (i) the intra-household distribution of food is in direct proportion to household members' share of the household's total adult male consumption equivalents, (ii) all vegetable oil that is made from other-than mustard seed and that is purchased is fortifiable and (iii) oil fortification standards are implemented, we modelled the additional vitamin A intake due to the new fortification initiative.
Setting: Nationwide in Bangladesh.
Subjects: A weighted sample of 12 240 households comprised of 55 580 individuals.
Results: Ninety-nine per cent of the Bangladesh population consumes vegetable oil. The quantities consumed are sufficiently large and, varying little by socio-economic status, are able to provide an important, large-scale impact. At full implementation, vegetable oil fortification will reduce the number of persons with inadequate vitamin A intake from 115 million to 86 million and decrease the prevalence of inadequate vitamin A intake from 80 % to 60 %.
Conclusions: Vegetable oil is an ideal fortification vehicle in Bangladesh. Its fortification with vitamin A is an important public health intervention.

Keywords
Fortification
Nutrition
Policy
Household surveys
Bangladesh
Micronutrients
Vitamin A
Vegetable oil

Bangladesh is an international health success story. In the past three decades, it has made enormous strides in reducing population growth, mortality and morbidity. It is one of the few countries that will achieve Millennium Development Goal 4, a two-thirds reduction in the under-five mortality rate by 2015. In contrast to the impressive advances that have been made in general health status, nutritional deficiencies remain high and have proven more intractable. Anthropometric measures, for instance, only began to improve in the mid-1990s and nutritional deficiencies remain higher than would be predicted by the country's income level alone[1]. Despite having what many regard as one of the most successful vitamin A supplementation programmes in the world, with nearly three decades of high and sustained coverage rates, vitamin A deficiency remains at 76·9 % among pre-school children[2]. Moreover, evidence from the 2011 Demographic and Health Survey suggests that the programme's performance has begun to slip[3]. Bangladesh needs to examine other options for accelerating its progress in improving nutrition.

Major characteristics of the vegetable oil market in Bangladesh

Traditionally, the main source of vegetable oil in Bangladesh was home-grown and home-processed mustard-seed. That market has changed dramatically in recent years with rapid growth in low-priced imports of soya and especially palm oil (refined palm olein)[4,5]. Bangladesh's total vegetable oil market is 1·3 million Mt of which about 55 % is food. Of the vegetable oil that is consumed as food, mustard-seed-based oil now comprises only 15 % of the total market, while soya constitutes about 35 %, palm 45 % and all other sources account for the residual 5 %[5]. The sixteen companies that are now fortifying have a

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combined output that is estimated at 85–90 % of Bangladesh's total palm- and soya-based vegetable oil market (P Randall, consultant to the Bangladesh National Fortification Alliance, personal communication, 2013).

Vitamin A fortification in Bangladesh

The introduction of vitamin A fortification in Bangladesh has been actively considered for decades. The Bangladesh Standards and Testing Institute (BSTI) of the Ministry of Industries established fortification standards in 2006, and fortification feasibility studies – primarily of wheat flour – have been conducted in Bangladesh starting at least 30 years ago[6–8]. The current oil fortification initiative dates from 2008. In June of that year, UNICEF, the BSTI, the Bangladesh Vegetable Oil Refiners Association (BVOA) and the Global Alliance for Improved Nutrition (GAIN) formed a partnership and signed an agreement to implement a 3-year project that would culminate with the introduction of vegetable oil fortification. GAIN provided $US 3 million that was used to pay for the development of fortification quality assurance and control protocols, oil refinery recruitment and premix (which were provided to participating companies), fortification training of both public and private stakeholders, and a consumer awareness campaign.

The original project was delayed and revamped several times as a result of recurrent food price crises, which dampened industry's enthusiasm to participate. The initial intention was to introduce fortification in seven of Bangladesh's twenty-two refineries, with the longer-term goal of expanding participation to twelve companies. The first fortified oil was produced in February 2012 and was accompanied by a bandwagon effect: within 6 months, the number of participating companies jumped to sixteen (Mr B Kar, GAIN Bangladesh Country Director, personal communication, 16 August 2012).

Use of household income and expenditure surveys for dietary assessment

Designing and assessing micronutrient programmes requires an understanding of the magnitude, distribution and causes of the deficiencies in the population, as well as knowledge about other existing interventions that affect the same deficiency[9]. Only a handful of countries, however, have food consumption data from what nutritionists generally regard as the preferred food consumption methodologies, i.e. observed-weighed food records or 24 h recall surveys, because such surveys are expensive and difficult to conduct[9–11]. The lack of evidence on the nature and magnitude of nutritional deficiencies has slowed the development of nutrition policies and programmes, and has probably contributed to the design and implementation of suboptimal programmes. The present paper addresses this lack of food and nutrition information by using an alternative, less precise, but more affordable and readily available data set – the Bangladesh 2010 Household Income and Expenditure Survey (HIES) – to estimate the prevalence of inadequate vitamin A intake and the impact of the recent introduction of vitamin A-fortified vegetable oil. We follow the assumptions and methodologies already applied to estimate food consumption from HIES for estimating nutrient intakes and selecting food fortification vehicles for Bangladesh[12], India[13], Guatemala[14], Zambia[15] and, more generally, designing food fortification programmes and providing a proxy measure for food and nutrition information[10,16].

Methods

Data source

Bangladesh began conducting HIES in 1972. The particular survey analysed here, which is the fifteenth HIES round, incorporated a two-stage stratified sampling design using probability proportional to size based on the 2001 population census[17,18]. A total of 12 240 households were included in the sample. Demographic information was collected on each household member.

Sample weights, adjusted for non-response, were included in the database and were used to determine total population estimates of households and individual household members (Table 1). The Institutional Review Board at Tufts Medical Center/Tufts University gave an exemption for the present study because it was based on secondary analysis of a publicly available data set without personal identifiers.

Estimating usual intakes

The 2010 HIES Daily Consumption Module contains 134 food items. Households reported their food consumption and acquisition using a 14 d diary. Households identified the quantity, value and source (i.e. purchases, in-kind wage, own production, gifted and other) of each food item for each day during the 14 d reporting period. We combined these data with energy and nutrient information from food composition tables created for this analysis[12] to estimate the household's intakes of total energy and the micronutrients vitamin A, Fe, Zn and Ca. In addition to the specific foods identified in the 134-item food list, each of the thirteen general food categories contained an entry called 'Other'. For these 'other' categories (e.g. 'other fruits', 'other vegetables'), energy and nutrient values were estimated by taking the food composition tables' average of all other items within the general food category. The HIES also included several 'dining out' meals and differentiated them by their primary ingredient (e.g. rice). Typical recipes were used to estimate the energy and nutrient composition of these meals[12]. For the study reported here, we included only energy and vitamin A results.

In analysing the HIES we assumed that food that was purchased during the 14 d reference period was entirely consumed during that period and no other food was consumed (e.g. from food stores purchased in an

Table 1 Weighted numbers and percentages of households and individuals, by division, in the Bangladesh 2010 Household Income and Expenditure Survey

	Households		Individuals		
Division	*n*	%	*n*	%	Average number of persons per household
Barisal	2 048 252	6·2	8 325 666	5·8	4·06
Chittagong	5 687 580	17·2	28 423 019	19·7	5·00
Dhaka	11 079 903	33·5	47 424 418	32·9	4·28
Khulna	4 147 217	12·6	15 687 759	10·9	3·78
Rajashahi	4 487 863	13·6	18 484 858	12·8	4·12
Rangpur	3 906 236	11·8	15 787 758	11·0	4·04
Sylhet	1 670 963	5·1	9 910 219	6·9	5·93
Total	33 028 014	100·0	144 043 697	100·0	4·36

earlier period). Adjustments were made for the edible portion of foods, but no additional account was made for waste or loss. To remind the reader of these assumptions and limitations we refer to the HIES-based estimate of food consumed as 'apparent food consumption'.

The HIES reports food consumption data for the entire household, not for individual members. Given the lack of information about the intra-household distribution of food, to make inferences about individual household members' nutrient intake requires making an assumption about the intra-household distribution of the household's food. We assumed that all household food was distributed among its members in direct proportion to each member's share of the household's total adult male consumption equivalents (ACE)[19]. ACE values were calculated as the ratio of the energy requirement of an individual of a particular age and gender with a medium physical activity level, to the energy requirement of an adult male age 18–30 years. The HIES lacked details about pregnant or lactating women. Therefore, in our analysis, all women were treated as non-pregnant, non-lactating women.

The cut-point method was used to evaluate the prevalence of inadequate intakes of vitamin A[20]. We quantified each individual's 'usual daily intake' of dietary energy and vitamin A from the household's total food intake over the 14 d diary period, and compared the individual vitamin A intake levels with their age- and sex-specific Estimated Average Requirements (EAR) to characterize the individual's vitamin intake level as 'adequate' (for levels equal to or greater than the EAR) or 'inadequate' (for levels less than the EAR). We assumed the bioavailability of vitamin A was 100 %.

Simulation of fortification interventions

We simulated vitamin A fortification of vegetable oil assuming the vitamin A levels were equal to those established in the BSTI's 2006 standards for cooking oil in the retail marketplace, i.e. 10 mg/kg. To take into account vitamin A degradation from the time the vegetable oil is manufactured to the time it is sold at retail, it was assumed that a vitamin A overage of 5 mg/kg, and thus a total of 15 mg/kg, is added at the factory. We also assumed an additional 20 % of the vitamin A added to the vegetable oil is lost between the time the oil is sold at retail and when it is consumed. Thus we assumed that the vitamin A content of ingested vegetable oil was 8 mg/kg, implying total vitamin A losses from the point of fortification to ingestion to be 47 %. Using this information, we calculated the daily additional intake of vitamin A (measured in μg of retinol activity equivalents, or RAE) by households consuming fortifiable vegetable oil.

Results and discussion

Consumption of fortifiable vegetable oil

In our modelling, we assumed that mustard-seed-based oil, which is generally home-produced or produced in artisan-scaled plants, is not fortifiable because of (i) the inherent difficulties of small, technologically simple plants adhering to quality assurance standards necessary to ensure the regulatory requirements are strictly adhered to and (ii) the difficulties of monitoring compliance in a large number of plants in what is often a largely informal sector. We assumed that only the other-than mustard vegetable oil and only that portion of it that is purchased is likely to be produced in larger-scale plants and is amenable to being fortified.

Table 2 shows the number and percentage (i.e. coverage) of persons consuming fortifiable vegetable oil and the average (mean and median) quantities consumed, per ACE, by place of residence, poverty status and division. Two sets of averages are presented: (i) those calculated for the entire population (referred to as the 'unconditional' averages), which include vegetable oil consumers and non-consumers alike; and (ii) those calculated using only the portion of the population that purchases some fortifiable vegetable oil (referred to as the 'conditional' averages). Figures 1 and 2 detail the percentage contribution of vitamin A, at baseline, from fortifiable oil by poverty groups and administrative divisions, respectively. The coverage of the fortification vehicle is consistently

Table 2 Estimates of coverage and consumption of fortifiable vegetable oil in Bangladesh (g/adult consumption equivalent per d) based on the Bangladesh 2010 Household Income and Expenditure Survey

	Total population (unconditional averages*)			Consumers only (conditional averages†)			
	No. of persons	Mean	Median	No. of persons	% of population	Mean	Median
Place of residence							
Urban	37 657 231	33	30	37 160 378	98·7	34	30
Rural	106 021 111	21	20	93 007 785	87·7	24	21
Total	143 678 341	24	22	130 168 162	90·6	27	24
Poverty status							
Non poor	72 719 516	27	25	67 086 796	92·3	29	26
Absolute poverty	35 036 305	23	21	31 347 806	89·5	25	23
Hard-core poverty	17 298 840	21	20	15 188 397	87·8	24	22
Hard-ultra poverty	18 623 680	18	17	16 545 164	88·8	20	18
Total	143 678 341	24	22	130 168 162	90·6	27	24
Division							
Barisal	8 830 638	27	25	8 662 668	98·1	28	25
Chittagong	27 223 210	26	24	25 802 079	94·8	27	25
Dhaka	47 009 024	27	26	40 305 535	85·7	31	28
Khulna	17 093 960	26	24	16 503 468	96·5	27	24
Rajshahi	18 138 784	20	19	16 948 835	93·4	21	19
Rangpur	16 408 304	17	16	14 305 965	87·2	20	17
Sylhet	8 974 423	17	15	7 639 612	85·1	20	17
Total	143 678 341	24	22	130 168 162	90·6	27	24

*Unconditional averages: calculates averages based on the number of persons in the entire population, those apparently consuming vegetable oil and those not consuming vegetable oil.
†Conditional averages: calculates averages based only on the number of persons who consume vegetable oil, excludes those not consuming vegetable oil.

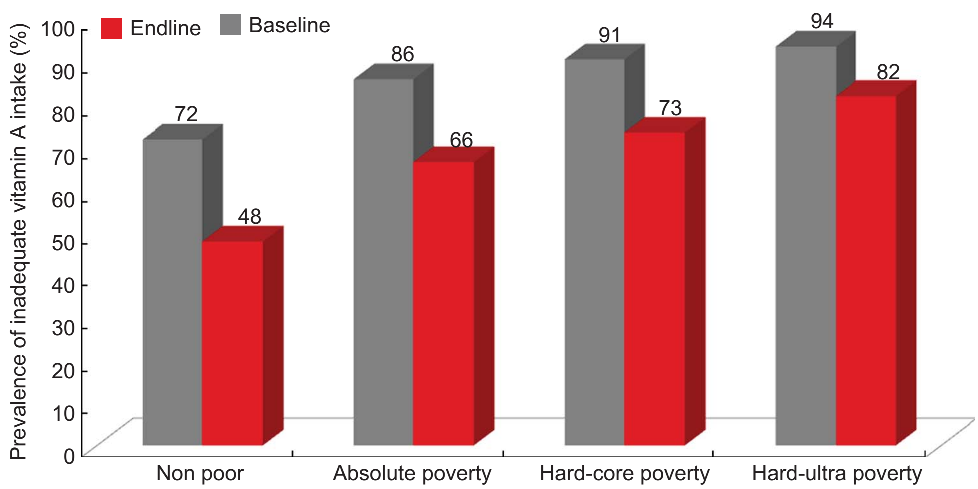

Fig. 1 (colour online) Prevalence of inadequate vitamin A intake in Bangladesh (percentage of persons with vitamin A intake less than their Estimated Average Requirement) before (baseline) and after (endline) introduction of fortified vegetable oil, by poverty status. Weighted sample of 12 240 households comprised of 55 580 individuals from the Bangladesh 2010 Household Income and Expenditure Survey

high across the three sets of characteristics analysed. While both the coverage and the quantities purchased vary across households in ways that one would anticipate, i.e. larger percentages and quantities being purchased by urban and wealthier households, the differences are not extreme.

Not having any information about the brand-names consumed or the geographic dimensions of the market of the companies that are fortifying and those that are not, we have no way of adjusting our household-level based data to identify the 10–15 % of the palm- and soya-based vegetable oil that is not fortified. Our approach, therefore, results in an overestimation of the consumption and probably of the impact of vitamin A-fortified vegetable oil.

Table 3 shows three measures of average vitamin A intake levels: at baseline (i.e. prior to the introduction of fortification), the additional intake due to fortification and intake at endline (i.e. after the introduction of fortification). Table 3 also reports the percentage of the EAR that the mean intake level represents, thereby providing an age- and sex-adjusted reference point for better understanding

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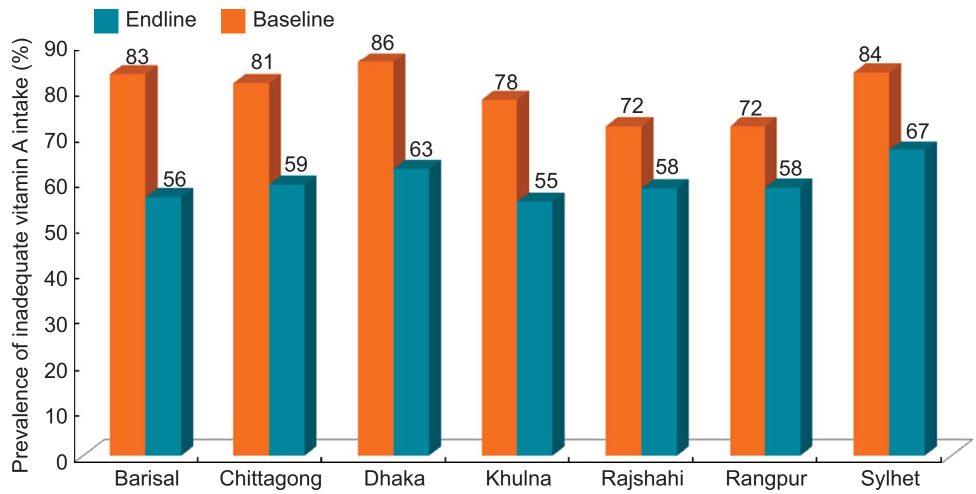

Fig. 2 (colour online) Prevalence of inadequate vitamin A intake in Bangladesh (percentage of persons with vitamin A intake less than their Estimated Average Requirement) before (baseline) and after (endline) introduction of fortified vegetable oil, by division. Weighted sample of 12 240 households comprised of 55 580 individuals from the Bangladesh 2010 Household Income and Expenditure Survey

Table 3 Estimates of vitamin A intakes in Bangladesh – baseline intakes, additional intakes due to fortifiable oil and endline intakes (reported as vitamin A in μg of RAE, unless otherwise indicated) – based on the Bangladesh 2010 Household Income and Expenditure Survey

	Baseline			Additional intake			Endline		
	Mean	Median	% EAR at mean	Mean	Median	% EAR at mean	Mean	Median	% EAR at mean
Place of residence									
Urban	420	364	66	257	236	41	677	620	107
Rural	437	361	69	155	149	24	592	524	93
Total	433	362	68	182	170	29	614	552	97
Poverty status									
Non poor	511	439	80	206	191	32	717	653	113
Absolute poverty	384	334	61	170	162	27	554	514	88
Hard-core poverty	344	301	54	157	151	25	500	468	79
Hard-ultra poverty	302	259	48	132	129	21	434	393	68
Total	433	362	68	182	170	29	614	552	97
Division									
Barisal	442	393	69	208	195	33	650	595	102
Chittagong	433	372	68	195	184	31	629	576	99
Dhaka	377	317	59	206	197	32	582	527	92
Khulna	479	383	75	196	187	31	674	596	106
Rajshahi	490	398	77	147	143	23	637	529	100
Rangpur	484	431	76	126	118	20	610	560	96
Sylhet	416	365	66	136	121	21	551	515	87
Total	433	362	68	182	170	29	614	552	97

RAE, retinol activity equivalents; EAR, Estimated Average Requirement.

the significance of the mean value relative to physiological requirements. While the urban and wealthier populations attain larger absolute quantities of additional intake, the proportion and relative importance of the additional vitamin A obtained by the rural and poorer populations are greater. For instance, while the non-poor have a mean additional intake of 206 μg of RAE, compared with the ultra-poor's 132 μg of RAE, these quantities constitute 40 % and 43 % of the baseline intakes of the two groups, respectively.

Table 4 shows the number and percentage of persons with inadequate vitamin A intake at baseline and endline, together with the changes in these measures due to oil fortification. At baseline, the national prevalence of inadequate vitamin A intake is 80·3 %. Oil fortification results in more than 29 million of the 115 million Bangladeshis with inadequate vitamin A intake at baseline achieving adequate vitamin A intake levels. In other words, as a result of oil fortification, 20 % of all Bangladeshis go from having inadequate to adequate vitamin A intakes and another 86 million with inadequate VA intakes at baseline benefit from increased vitamin A intakes but continue to have inadequate vitamin A intakes at endline.

The benefits of oil fortification are not only significant, they are also widespread. Even among the ultra-poor there

Table 4 Estimates of baseline and endline prevalences of inadequate vitamin A intakes based on the Bangladesh 2010 Household Income and Expenditure Survey

		Persons with inadequate intake at baseline						
		Baseline		Endline: still inadequte		Endline: achieved adequacy		
	Total population	No. of persons	% of population	No. of persons	% of population	No. of persons	% of population	Endline as % of baseline
Place of residence								
Urban	37 657 231	31 020 762	82·4	19 369 812	51·4	11 650 949	30·9	62·4
Rural	106 021 111	84 413 094	79·6	66 778 260	63·0	17 634 834	16·6	79·1
Total	143 678 341	115 433 856	80·3	86 148 073	60·0	29 285 783	20·4	74·6
Poverty status								
Non poor	72 719 516	52 227 712	71·8	34 865 755	47·9	17 361 958	23·9	66·8
Absolute poverty	35 036 305	30 102 052	85·9	23 297 092	66·5	6 804 960	19·4	77·4
Hard-core poverty	17 298 840	15 673 657	90·6	12 705 794	73·4	2 967 863	17·2	81·1
Hard-ultra poverty	18 623 680	17 430 435	93·6	15 279 432	82·0	2 151 002	11·5	87·7
Total	143 678 341	115 433 856	80·3	86 148 073	60·0	29 285 783	20·4	74·6
Division								
Barisal	8 830 638	7 349 523	83·2	4 985 407	56·5	2 364 117	26·8	67·8
Chittagong	27 223 210	22 144 331	81·3	16 090 302	59·1	6 054 029	22·2	72·7
Dhaka	47 009 024	40 365 163	85·9	29 441 956	62·6	10 923 207	23·2	72·9
Khulna	17 093 960	13 257 988	77·6	9 485 883	55·5	3 772 105	22·1	71·5
Rajshahi	18 138 784	13 025 679	71·8	10 571 338	58·3	2 454 341	13·5	81·2
Rangpur	16 408 304	11 788 729	71·8	9 587 378	58·4	2 201 351	13·4	81·3
Sylhet	8 974 423	7 502 442	83·6	5 985 809	66·7	1 516 633	16·9	79·8
Total	143 678 341	115 433 856	80·3	86 148 073	60·0	29 285 783	20·4	74·6

are substantial gains in the percentage of the population that achieves adequate vitamin A intake with the introduction of fortification, as the prevalence of inadequate vitamin A intake falls from 80·3 % to 60·0 % (Table 4). Seventeen million rural residents achieve adequate vitamin A intake. Three of the four divisions that had the highest baseline prevalence rates of inadequate vitamin A intake – Barisal, Chittagong and Dhaka – experience the largest reductions in prevalence; while Sylhet, the division with next to highest baseline prevalence of inadequate vitamin A intake (84 %), achieved an important reduction of 17 percentage points (Fig. 2).

Limitations of the study

There are several limitations of the present study, which stem primarily from our use of a household-based survey to estimate the vitamin A intake adequacy of individuals: (i) the lack of information about the intra-household distribution of foods; (ii) the extent to which the assumption holds that foods containing vitamin A are distributed among household members in direct proportion to the energy requirements; (iii) our use of 'apparent' consumption to estimate consumption; (iv) seasonality might affect the types and quantities of foods apparently consumed; and (v) our inability to identify the portion of palm- or soya-based vegetable oil that is not fortified, which results in overestimation of the consumption of fortified oil by 15–20 % and an overestimation of the impact of fortified by oil by perhaps as much as that as well.

The price elasticity of demand for a particular good is a measure of the responsiveness of a change in demand for a good to a change in its price, other things held constant. Ganesh-Kumar *et al.* estimate the price elasticity of demand for vegetable oil in Bangladesh (using the 2006 Bangladesh HIES) at –0·697[21]. This indicates that the demand for vegetable oil is relatively price inelastic (i.e. relatively insensitive to changes in price). The incremental cost of vegetable oil fortification across a number of countries has consistently been found to be <1 % of the pre-fortification retail price of oil[22–24]. If it is assumed that all incremental costs of vegetable oil fortification in Bangladesh are passed on to the consumer, the price of vegetable oil would increase by <1 %. Thus, the introduction of vegetable oil fortification in Bangladesh would be expected to have less than a 1 % increase in its price and less than a 0·697 % decrease in the quantity of it demanded. While the impact would be somewhat higher among the poor (who have a larger, but un-quantified, price elasticity), the impact would still be minor.

Conclusion

The results of the present study indicate that palm- and soya-based vegetable oil in Bangladesh has the characteristics of an ideal vitamin A fortification vehicle: (i) it covers a high proportion of the population; (ii) the quantities in which it is consumed are relatively uniform across both the divisions and socio-economic levels; and (iii) the quantities in which it is consumed are adequately large to have a significant impact on vitamin A deficiency. The fortification of vegetable oil will reduce the prevalence of inadequate vitamin A intake in Bangladesh by 20 percentage points, a reduction of one-quarter. Vitamin A fortification of vegetable oil in Bangladesh is an important public health intervention.

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