GM Nutritionally Enhanced and Altered Crops

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This briefing examines the claims made about GM nutrient enhanced and altered crops (the so-called second generation GM crops) and whether the hyperbole about them matches up with their reality, given that no such crops have been grown commercially anywhere. It also looks at alternative solutions to malnourishment or diet deficiency that offer a more equitable and sustainable way forward.

Introduction

One of the main claims of the biotechnology industry since genetically modified crops were first commercialized in the USA in 1996 has been that a "second generation" of GM will bring real consumer benefits, for example by improving nutritional value of foods. First generation GM crops are aimed at farmers by inserting genes for herbicide tolerance and insect resistance, which were sold by the biotechnology companies as a way to cut inputs and labour (which is disputed[i]). Consumers in the UK, the rest of the EU and around the world rejected them. Their main use is therefore in animal feed and, more recently, in biofuels, neither of which are obvious or labelled at the point of sale[ii].

The biotech industry now hopes to boost their market with second generation nutritionally enhanced GM crops, which it is claimed will alleviate malnutrition and improve health. Many biotech proponents go even further and claim that consumers will be able to obtain foods specifically developed to prevent common diet-related diseases such as heart conditions, cancer and diabetes. They also claim that the increasing knowledge of the human genome will enable individuals who are genetically predisposed to these diseases to be identified and to tailor their diet accordingly[iii].

However, no nutritionally enhanced crops are so far commercially available despite over a decade of such promises and hyperbole, and better approaches to such conditions are cheaper and already available for use.

What are Genetically Modified Crops?

Most genetically modified crops are genetically engineered to include a gene construct from other plants, viruses or microbes. Genes from plants frequently come from completely unrelated species.

Two methods have been developed to force novel genes into the chromosomes of the receiving crop plant:

- using a bacterium called *Agrobacterium tumefaciens* (which causes crown galls in some tree species) to insert genes into the plant genome;
- and using a small ballistic object to fire the novel gene into the host.

Both methods have a high failure rate and are imprecise in terms of where the novel gene will be located in the host's chromosome. This random insertion of novel genes can disrupt the functions of the host plant's genes and disrupt DNA, producing unpredictable outcomes that can have implications for human and animal health if consumed.

The GM genes are designed to cause the host plant to produce novel chemicals or proteins (to resist herbicides or insects, etc), many of which have not been consumed by people or animals before and may be toxic, or changing the nutritional value of the crop. These chemicals have to be screened to see if they are allergenic, but this process is far from foolproof. It is not safe to assume that a protein that was non-allergenic in its natural species will behave the same when it is produced by a GM plant. For instance, a harmless bean protein produced an allergenic protein when genetically engineered into a pea[iv].

Does GM Nutrient Enhancement Solve Problems of Malnutrition?

Many people in the Global South depend of a single crop for the bulk of their calorific and nutrient intake, for instance, rice in the Indian sub continent and Far East, maize in Zambia and cooking bananas in Uganda. No one food provides all the nutrients required to allow the human body to grow and be healthy. Therefore enhancing individual foods with single vitamins and minerals only tackles one symptom of malnutrition – it does not address the causes of poor diets and malnutrition.

Research by Save the Children shows how malnutrition is rooted in poverty[v]:

> *"In 2007, Save the Children published research that estimated how much it would cost a typical family in a number of poor countries to buy a diet that would meet their minimum nutritional requirements. This means a diet that gives them enough calories, but also provides 15 different key nutrients necessary for good health and cognitive and physical development. Our analysis showed that, even before the recent price rises, poor people were generally not able to afford all the different types of food needed for a nutritious diet. In Kurigram district in Bangladesh, for instance, a staggering 80% of the households studied could not afford such a balanced diet."*

The long-term solution is for everyone to have a balanced diet that contains sufficient protein, vitamins and minerals, as well as the fats and carbohydrates essential to provide the energy the body requires to perform all its healthy functions. In northern industrialised countries, few people have difficulty in accessing a balanced diet and nutrient or mineral deficiencies are comparatively rare occurrences.

People in the northern industrialised world who are overweight may be malnourished in that they are consuming the wrong foods, which may also be deficient in some way and therefore do not meat all their needs. This usually arises from a lack of balance in the diet rather than the lack of access to a balanced diet.

GM Promises

So far no GM nutritionally enhanced foods have been developed for commercial cultivation anywhere in the world.

However claims about nutritionally enhanced foods fall into several categories:

- Enhanced vitamins (eg higher levels of beta carotene the precursor of Vitamin A).
- Enhanced minerals (eg higher levels of iron).
- Enhanced healthy fatty acids content (eg omega 3 unsaturated fatty acids).
- Enhanced amino acid (eg tryptophan).
- Enhanced protein (eg in potatoes).
- Enhanced levels of antioxidants to help fight cancer.
- Reduced risk of allergic reactions (eg by silencing or removing genes in food such as wheat and peanuts).

Examining some of these claims in detail, we find:

1. GM and vitamin A deficiency

Vitamin A deficiency (VAD) is a major health problem in SE Asia and Africa. WHO estimate that it causes 250-500,000 children to become blind every year, with half dying within 12 months of becoming blind[vi].

"Golden Rice" has been the biotech industry's proposed solution to VAD since 2000. Golden Rice was genetically modified to produce beta carotene (used by the body to make Vitamin A) using a gene from the daffodil in the first instance, and later on a gene from maize. The latter modification using maize genes increased the amount of beta carotene produced by the rice after the daffodil version was heavily criticised because of the large amounts of rice required to be consumed to achieve the recommended intake of beta carotene.

However, even the researchers who developed the maize modified version of the Golden Rice concede that more research is required on the uptake of beta carotene from the rice to demonstrate that it is an effective solution:

> *"Definitive statements on the benefits of Golden Rice for the alleviation of Vitamin A deficiency cannot be made. The vitamin A delivered and the impact on the body depends on several unquantified factors, including β-carotene uptake and conversion to vitamin A, as well as the amount of rice consumed by the individual. These factors are under rigorous investigation at present but for the time being only estimates are available[vii]."*

Other commentators have emphasised what we don't know about Golden Rice:

"Until today, no research has been published indicating the nutritional benefit of this new rice whether alone or integrated in meals or consumed for a short or long time. What we also do not know is whether this much touted transgenic biofortified rice approach is superior to other conventional strategies for preventing and overcoming vitamin A deficiency[viii]."

Doubts about the effectiveness of Golden Rice in supplying the required level of vitamin A to under-nourished people come from the lack of information on:

- The bioavailability and bioconversion of beta carotenes in Golden Rice (especially in sick people).
- The rate of decay of beta carotene in stored rice.
- The rate of decay of beta carotene during cooking.
- The cultural acceptability of "golden" rice in societies where yellow rice is new and only white rice is normally available.
- Safety of the rice following genetic modification (ie does it contain new allergens and toxins and have nutritional changes occurred?).

According to a recent review of progress towards the marketing of Golden Rice[ix] no data covering these concerns is yet available despite nearly a decade of research.

Another significant concern is to ensure that people who do not have a deficiency of vitamin A do not receive too much from consuming Golden Rice because:

"While in general the body absorbs retinoids and vitamin A very efficiently, it lacks the mechanisms to destroy excessive loads. Thus, the possibility of toxicity exists unless intake is carefully regulated. Revision of earlier estimates of daily human requirements of vitamin A has been suggested; the suggestion is that estimates ought to be revised downwards. Concerns exist about the teratogenicity of vitamin A[x]."

What's the solution?

The solution is to provide a balanced diet with sufficient vitamins, minerals, proteins and carbohydrates. This can be achieved by:

- Promoting breast feeding.
- Increasing availability of orange, yellow or dark green vegetables through local gardens and allotments.
- Introducing meat, eggs or dairy products to the diet.
- Improving sanitation and clean water supplies to reduce diarrhoea and increase the up take of beta carotene.
- Food fortification.
- Vitamin A supplementation.

Even proponents of Golden Rice concede that diet diversification is the best solution:

"Dietary diversification is generally considered the most desirable and sustainable solution in the long run, because it improves overall dietary quality instead of addressing single micronutrient deficiencies only[xi]."

Diet diversification can start now and is known to be safe, neither of which can be said for Golden Rice, which has recently been hit by new controversy when it was discovered that children had been used in feeding trials[xii].

2. Enhanced mineral content

Malnutrition can be caused and made worse by deficiencies of key minerals such as iron, iodine and zinc. These minerals are vital in controlling growth, overall health and oxygen uptake. Some proponents of GM crops claim that genetic engineering will produce crops containing enhanced minerals[xiii and xiv].

Some plants take up essential minerals from the soil more efficiently than others, and food plants can contain very different levels of minerals. For instance, kidney beans contain around 2.5 times as much iron as soya beans, nine times as much as sweet corn, and 13 times as much as rice[xv]. The same principle applies to other nutrients and other food plants.

What's the solution?
Once again a diversified diet is the answer. Trying to solve malnutrition by genetic modifying one crop for one trait will not provide a long-term solution. Even if GM is successful the accessibility and affordability of seeds to the poor who need them most remains to be seen.

3. Omega 3 enhancement
Some nutritionists have highlighted the health-enhancing properties of a diet with a higher intake of omega 3 poly-unsaturated fatty acids, particularly in the prevention of cardiovascular disease. The only direct sources of omega 3s are oily fish (such as mackerel) and other sea life, which takes them up from marine algae. This has led the Food Standards Agency to recommend minimum weekly intake of one portion of oily fish per week (less for pregnant and breast feeding mothers and girls because of the presence of dioxins and PCBs)[xvi]. Farming marine algae has been considered, but so far this has not taken off commercially on a large scale. Some animal feed is enhanced with fish oil, and the resulting animal products are marketed as high in omega 3.

The body can form omega 3s from omega 6 fatty acids, but only slowly. Several foods contain omega 6s, for instance, sunflower seeds, walnuts and linseed. Meat from grass-fed lamb and beef[xvii] has been shown to contain higher levels of omega 3 fatty acids than grain-fed. Organic milk produced from forage-fed cows has higher levels of omega 3s than intensively produced milk [xviii] and [xix], although the Food Standards Agency says that oily fish are a better source of long chain fatty acids[xx]. Research has also shown that it is the total amount of omega 3 and omega 6s, rather than the ratio, that influences the conversion[xxi].

Genetic engineers have taken genes from marine algae and inserted them in oil-bearing plants such as soya[xxii] and oilseed rape[xxiii]. These crops are claimed to be close to commercialisation, although there have been no test sites in the EU or applications for marketing or cultivation.

What is the solution?
Although oily fish can help to prevent cardiovascular diseases, it is only one factor in a range of other important preventative measures, which include:

- Stopping smoking.
- Taking regular exercise.
- Eating a healthy diet, including 5 portions of fresh fruit and vegetables, more wholegrain starchy foods, and less saturated fat and total fat and salt.
- Limiting alcohol intake.
- Maintaining a health body weight.
- Having regular health checks, including for cholesterol and blood pressure, particularly for those 40 years old, or with a family history of heart disease.

3. Increased amino acids
Another claim of GM proponents is that GM crops can be engineered to produce enhanced levels of amino acids, such as Tryptophan, in crops like rice. Tryptophan is said to have calming properties and is used to treat depression. It could be added to food up until 1990 when it was banned[xxiv] following the occurrence of Eosinophilia-Myalgia Syndrome (EMS) in people taking dietary supplements containing tryptophan in the US and UK. During the 1989 epidemic of EMS in the US, more than 1500 cases were reported and 37 deaths occurred. The probable cause of EMS was never proven, but the source of the L Trytophan responsible was traced to a US factory that subsequently burned down. The L tryptophan produced at the Showa Denko factory was produced using genetically modified microorganism in contained vessels and was reported to contain "one or more contaminants" [xxv]. Whether or not these contaminants were the cause of the illness, and whether they arose from poor quality controls or as a result of using genetically modified micro-organisms to produce the L tryptophan, will never be known.

Any food that had been genetically modified to produce tryptophan would have to be assessed very carefully for its safety in view of the past history. There are plenty of natural sources of tryptophan including nuts, seeds and dairy products, so there is no need for GM crops to produce it.

4. Increased Protein
In 2003 some media outlets announced that the Indian Government would approve the release "within six months[xxvi]" of a GM potato with 30% more protein than normal. The potato was genetically modified with a gene from the Amaranth, a grain crop, which has a higher protein content than potatoes (12-18% compared to 2-2.1%). One Indian commentator put this claimed GM development into context:

"What this country needs, and which it has in abundance, is pulses. Now the pulses contain 20-26% proteins. This potato they talk about has 2.5% protein. Please tell me which one is better? [xxvii]*"*

Indeed, GM potatoes with, say, 3% protein would only have a fraction more protein than boiled Brussels sprouts[xxviii] and would probably be more expensive to grow and buy. Even by 2009 (six years on from the reported Indian announcement) no GM potatoes have been grown commercially in India. Once again GM hyperbole appears to have overtaken reality.

5. Increased antioxidants

The genetic modification of common foods to increase levels of antioxidants (which are believed to reduce the risks of cancer) has been given a good deal of publicity. Most recently "purple tomatoes", developed by the John Innes Centre (JIC), are said to be high in anthocyanins, said by JIC to:

"…offer protection against certain cancers, cardiovascular disease and age-related degenerative diseases. There is evidence that anthocyanins also have anti-inflammatory activity, promote visual acuity and hinder obesity and diabetes[xxix]*."*

Commenting on the a JIC feeding study using the GM tomatoes, Dr Andrew Wadge, Chief Scientist at the Food Standards Agency wrote:

"Sorry to pour cold water on the news splashed across the papers today, but I don't think the new purple tomato is going to protect us all from cancer. The research conducted by a team of researchers at the John Innes Centre and published in Nature Biotechnology *looks interesting, but let's not get carried away with newspaper hyperbole. First, the biotechnology industry has been promising products that will bring real benefits to consumers for a long time, but they have yet to materialise, at least in the UK. Second, any new product will need to go through a comprehensive approvals process to assure independent scientists and regulators that it is as safe as any conventional counterpart. And third, even if we do have a new tomato stuffed full of lots of antioxidants, can we confidently predict that these will protect us from cancer?.....*

"The evidence for any possible anti-cancer effects of anthocyanins in humans is very limited and has not yet been systematically reviewed – for example, in the World Cancer Research Fund's cancer report[xxx]*."*

What's the Solution?

There are a large numbers of conventionally-bred purple tomatoes already available (eg Black Cherry and Black Russian, both available in UK seed catalogues in January 2009). The newly-developed Sun Black[xxxi] has a "high content of anthocyanins, the same pigments which are present in some healthy fruits as black grapes and blueberry."

There is no shortage of foods high in anthocynans that can already form part of a balanced diet. Major sources are berries (such as blackcurrants, blackberries, grapes, and blueberries) and some vegetables (such as egg-plants/aubergine and avocado). In fact, "The natural production of anthocyanins in nature is estimated to be 10^9 tonnes/year![xxxii]" Over 500 anthocyanins have been isolated from plants, but there is still much research to be done on which are likely to bring health benefits and how much needs to be consumed. GM is not required to introduce this element to a healthy diet.

6. Removing Allergens

Another claim by the biotechnology lobby is that GM will make food safer by removing allergen-causing proteins[xxxiii and xxxiv]. Ironically, one of the main safety concerns about genetic modification is that it allows novel proteins to be introduced into diets which may themselves be allergenic – genetic engineering has been shown to alter the allergenicity of proteins (see above). Testing proteins for allergenicity is not straightforward and there is no foolproof methodology.

The chances of removing peanut allergens using genetic engineering were dismissed by the UK GM Science Review:

"Efforts to remove the allergen from peanuts would be beneficial to a substantial fraction of the population whose sensitivity to the protein can expose them to life threatening situations and work to this end is underway (Bannon et al.2001). Although this would be beneficial, it is not simple to achieve. Peanut contains potentially more than 20 allergenic proteins. The removal of one or two of them are unlikely to make the peanut safe to eat for all peanut allergy sufferers."[xxxv]

Even if peanuts could be changed by genetic engineering, the remaining product many not resemble the peanut we know today very closely. Similarly, removal of gluten from wheat may help allergen suffers but would not be good for bread making.

Another important consideration is whether or not GM allergen removal would actually help allergen sufferers. GM non-allergenic crops would not completely replace non-GM allergenic crops on the market, so allergen suffers would still have to take care to avoid peanuts and wheat in case there had been labelling mistakes or contamination had taken place in processing. Contamination could occur at any part of the food chain as the crops are shipped around the world. The recent removal of scores of peanut products from US shelves due to contamination in the one processing plant that made hundreds ill and killed several shows just how vulnerable such chains are. [xxxvi]

A new technique for dealing with allergies to peanuts has been developed at Addenbrooke's Hospital Cambridge which may prove to be more effective than genetic engineering. This is based on exposing sensitive children to tiny amounts of peanut in powder form and slowly increasing the dose. So far this has proved to be successful in preventing anaphylactic shock with an intake of 12 peanuts per day[xxxvii].

Alternative Paths to Healthy Food

Very few people in rich Northern countries suffer from chronic malnutrition. The majority of under nourished people are in the Global South, and this hunger and malnutrition are not caused by global food shortages but by poverty, economic collapse, civil unrest, war and severe weather events (droughts or floods) causing crop failure. None of these problems are tackled by introducing GM crops.

In addition, most people suffering from malnutrition are usually lacking more than one nutrient or vital trace element. Thus single gene solutions in single crops will not tackle the whole problem. A diet based largely on rice would be lacking in iron, riboflavin, vitamin C as well as vitamin A. Dietary diversification provides a sustainable, effective and affordable solution to dietary deficiencies.

There are many examples of where this has been effectively applied at community level in the Global South. For example the Sodo project in Ethiopia included diet diversity as ones of its means to tackle hunger and poverty:

> *"Farmers report that the introduction of improved, early maturing varieties has increased the yield of maize and wheat by 50-95%. Improvement of agricultural practices (planting in rows etc), greater use of irrigation, introduction of 'new' drought-resistant crops and of agroforestry have further increased crop production. In a 2007 evaluation, families involved in the Sodo Project (130km south of Addis Ababa) said the 6-month hungry season had virtually been eliminated and that they were eating 3 meals/day compared to 1 previously. The use of improved practices is high (85%), and diversification allows production both for consumption and for the market, which then helps to create capacity to reinvest (eg in a rainwater harvesting pond, or a rope and washer pump).*
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> *"Improved natural resource management activities include 49 rainwater harvesting ponds in Sodo, 550 agroforestry plots and a watershed management project protecting almost 600ha of crops. Here, as elsewhere, the scene from vantage points is one of clumps of green dotting the otherwise brown landscape. At Sodo, 10 individual and community nurseries are producing and selling around 400,000 fruit, coffee and other tree seedlings annually. Women are gradually becoming more involved in growing their own crops and other activities. At Sodo, 15% of recipients of improved maize and wheat seed are women, while women received 13% of the inputs for vegetable production. Other projects aim to increase this to at least 25%.[xxxviii]"*

Projects aimed at introducing vegetables into the diets of children through the establishment of home gardens combined with the homestead production meat and eggs in Nepal, Cambodia and Bangladesh showed that:

> *"The increased availability of home-produced foods and income enables households to increase their consumption of micronutrient-rich foods from both animal and plant sources and to diversify their diet, and thus lower the risk of micronutrient deficiencies[xxxix]."*

Conclusion

The hyperbole surrounding the genetic modification of crops to make them healthier has not been matched by results. Even the Golden Rice, which has received a lot of research investment, is still not proven or available. Other GM "solutions" remain inside greenhouses, in laboratories or are theoretical. Adding essential amino acids and removing genes for allergens appear to have advanced very little despite the promises of the 1990s.

Better, cheaper and more sustainable options are available to the Global South. Research into and dissemination of these methods should be a high priority over further investment in GM.

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[i] See www.gmfreeze.org/page.asp?ID=340&iType=1079 and www.gmfreeze.org/page.asp?ID=337&iType=1079
[ii] Although under EU Regulation 1830/2003 animal feed must be labelled if any ingredient is more than 0.9% GM, the dairy products, meat and eggs produced by the animals it feed do not require a GM label. Bioethanol or biodiesel produced from GM crops do not have to be labelled as such.
[iii] Wallace H, 2006. *Your Diet Tailored to Your Genes.* GeneWatch UK see www.genewatch.org/uploads/f03c6d66a9b354535738483c1c3d49e4/Nutrigenomics.pdf
[iv] See www.pi.csiro.au/GMpeas/GMpeas.htm
[v] Save the Children, undated, *Rising Food Prices. Implications for children and recommendations.* www.savethechildren.org.uk/en/docs/Rising_Food_Prices.pdf
[vi] See www.who.int/nutrition/topics/vad/en/index.html
[vii] Paine JA, et al, 2005. "Improving the nutritional value of golden rice through increase pro-vitamin A content". Letter to *Nature Biotechnology*.
[viii] Krankwinkel M, 2007. "What we know and what we don't know about Golden Rice". Letter to the editor, *Nature Biotechnology* Vol 25.
[ix] Then C, 2009. *The campaign for genetically modified rice is at the crossroads A critical look at Golden Rice after nearly 10 years of development,* see www.foodwatch.de/foodwatch/content/e6380/e23456/e23458/GoldenRice_english_final_ger.pdf
[x] See http://emedicine.medscape.com/article/126104-overview
[xi] Stein AJ, et al, 2006. "Supplementary Discussion Potential Impact and Cost Effectiveness of golden rice", available on Nature Biotechnology Website
[xii] Open Letter from 22 scientists to Tufts Medical School. See www.gmfreecymru.org/
[xiii] See www.abcinformation.org/library/files/Microsoft%20Word%20-%20abc%20developing%20world%20briefing%20FINAL.pdf
[xiv] See www.nuffieldbioethics.org/go/browseablepublications/gmcropsdevcountries/report_209.html
[xv] MAFF, 1985, HMSO.
[xvi] See www.food.gov.uk/news/pressreleases/2004/jun/oilyfishadvice0604press
[xvii] See www.bristol.ac.uk/news/2004/1113907771
[xviii] Goyens PLL, *et al*, 2006. *Conversion of α-linolenic acid in humans is influenced by the absolute amounts of α-linolenic acid and linoleic acid in the diet and not by their ratio*. American Journal of Clinical Nutrition 84 44-53.
[xix] Butler G, Nielsen JH, Slots T, *et al. Fatty acid and fat-soluble antioxidant concentrations in milk from high- and low-input conventional and organic systems: seasonal variation. J Sci Food Agric* 2008; 88:1431-1441.
[xx] See www.food.gov.uk/news/newsarchive/2006/sep/organicmilkresponse
[xxi] Goyens PLL, *et al*, 2006. *Conversion of α-linolenic acid in humans is influenced by the absolute amounts of α-linolenic acid and linoleic acid in the diet and not by their ratio*. American Journal of Clinical Nutrition 84 44-53.
[xxii] See www.foodnavigator-usa.com/Financial-Industry/Monsanto-Solae-joint-forces-for-omega-3-from-GM-soy
[xxiii] See http://britishnutrition.org.uk/upload/J%20Napier.pdf
[xxiv] See www.opsi.gov.uk/si/em2005/uksiem_20052630_en.pdf
[xxv] *Ibid*
[xxvi] See http://news.bbc.co.uk/1/hi/sci/tech/2980338.stm
[xxvii] *Ibid*, Quote from Davinder Sharma
[xxviii] MAAF,1985. *Manual of Nutrition,* HMSO.
[xxix] See www.jic.ac.uk/corporate/media-and-public/current-releases/081026martin.htm
[xxx] See www.fsascience.net/2008/10/27/purple_haze
[xxxi] See www.freshplaza.com/news_detail.asp?id=26245
[xxxii] See www.food-info.net/uk/colour/anthocyanin.htm
[xxxiii] "Non-allergenic peanuts under development", see www.agrow.com/biotech_news10.shtml
[xxxiv] Interview with Professor David King, *Today Programme*, BBC Radio 4, 27 November 2007.
[xxxv] *GM Science Review*, 2003. See www.gmsciencedebate.org.uk/report/pdf/gmsci-report1-pt3.pdf
[xxxvi] See http://uk.reuters.com/article/marketsNewsUS/idUKN1141386520090211
[xxxvii] See www.cuh.org.uk/addenbrookes/news/2009/feb/peanut_allergy.html
[xxxviii] Wardle C, 2008. "Community Area Based Development Approach (CABDA) Programme: An alternative way to address the current African food crisis?" *Natural Resource Perspectives 119.* Overseas Development Institute.
[xxxix] Helen Keller International, 2003 (Special Issue). *Integration of Animal husbandry into Home gardening Programsto Increase the Vitamin A Intake from Foods: Bangladesh, Cambodia and Nepal.* See www.hki.org/research/pdf_zip_docs/APRO%20Special%20issue%20Jan%202003.pdf