All That Glitters is Not Gold: The False Hope of "Golden Rice"

(short version)

Summary

Five years after the media hyped announcement of the development of genetically engineered (GE) "Golden Rice", this icon of the global GE industry is still surrounded by scientific uncertainty and worse, it is distracting attention and funding from real solutions to malnutrition and Vitamin A deficiencies (VAD). It seems like Golden Rice was designed more to help industry overcome the widespread consumer rejection of GE crops than to help overcome a vitamin deficiency.

The GE rice will be no real solution for vitamin A deficiency, no matter how much extra beta-carotene is in it. There is substantial progress and many existing, proven solutions for vitamin A deficiencies. Some of these are short term and immediate, while others provide longer term solutions. There is growing evidence that the use of existing biodiversity, especially in rice, could be far more beneficial for achievin a full and healthy diet than the illusory Golden Rice ever could do.

On the contrary, the GE Rice could, if introduced on a large scale, exacerbate malnutrition and undermine food security because it encourages a diet based on one staple food rather than the re-introduction of the many vitamin-rich food plants that were once cheap and readily available. These plants could address a wide variety of micronutrient deficiencies, not just VAD.

There have been suggestions that in 2005, Syngenta and its co-operating scientists will announce a new version of Golden Rice that will claim to have a tenfold higher content of beta-carotene. However, there is a very real risk that renewed hype surrounding Golden Rice will distract attention away from other more effective, reliable and sustainable solutions to vitamin A deficiency. Given the known environmental and human health risks of GE crops, it is neither desirable nor necessary to introduce Golden Rice.

A big promise?

Vitamin A is an essential vitamin for humans. It has several functions in the human body and is important for eyesight. Vitamin-A deficiency (VAD) can lead to blindness and even death. VAD poses a severe threat to millions of children worldwide, predominantly in the Global South.

In 2000, it was reported that rice had been genetically engineered (GE) to contain beta-carotene (pro-vitamin A) in the laboratory (Ye et al., 2000). The developers called it "Golden Rice" because the beta-carotene gave it a yellow colour. When the intention to commercialise Golden Rice was announced, it was accompanied by a strident media campaign asserting that Golden Rice could save millions of lives: the headline *"This rice could save a million kids a year"* appeared on the front page of Time magazine (2000). The developer of Golden Rice even placed moral pressure on any organisations or institutions opposed to the cultivation of GE crops: *"The consequences will be millions of unnecessary blind children and vitamin-A deficiency related deaths."* (Potrykus, 2001).

Despite this, in October 2004, Syngenta (Syngenta, 2004) announced the harvest of the first ever field trial of Golden Rice in the US, claiming there were "*new lines containing significantly higher levels of beta-carotene*", although no concentration was given and the full trial results have not been made public. In addition, it has been reported that "*new material is in the pipeline that is said to contain more than 10 times the level of pro-Vitamin A compared to the original material*" (Coffman et al., 2004).

Technical problems with Golden Rice

Beta-carotene needs to be taken up and converted into vitamin A within the human body before it can be utilised. However, this is more complex than the proponents of Golden Rice have admitted.

- Careful reading of the publications reveals inaccuracies in the reporting of the beta-carotene concentration in Golden rice. It is commonly assumed (e.g. Potrykus, 2004) that the amount of beta-carotene present in Golden Rice is 1.6 µg/g. But actually, this figure refers not to beta-carotene, but to a to a group of compounds, carotenoids (Ye et al., 2000). This carotenoid group is a mixture of beta-carotene, with other, less efficient pro-vitamin A compounds and even non pro-vitamin A carotenoids, which are not easily converted into vitamin A by the human body. Similarly, another publication (Datta et al., 2003) gave the only total amount of carotenoids, not the amount of beta-carotene. Therefore, the amount of beta-carotene, and the potential for vitamin A formation, is likely to be significantly less than commonly assumed.

- Further, there are different types of beta-carotene itself in Golden Rice which have differences in their nutritional value. It is not clear from the existing publications which type of beta-carotene is produced to which extent in the GE rice grains.

- There are many other questions that have not been answered. The rate of absorption of beta-carotene and its conversion to vitamin A is dependent on many factors such as the biochemical quality of the compounds or the occurrence of other components in the diet such as oil and zinc (Castenmiller & West, 1998). Because of these factors, the conversion ratio ranges from less than 12:1 up to 2:1 (IOM, 2002, IVACG, 2004, Potrykus, 2004). The actual conversion rate for beta-carotene in Golden Rice still not known. Losses of beta-carotene during cooking have already been reported and losses during storage are expected – both of which can severely undermine the effectiveness of Golden Rice.

All-in–all, the estimate that a person might have to eat several kilogrammes of GR to get the necessary amount of pro-vitamin A is still valid (see Greenpeace, 2001).

Health and Environmental Risks

There are several unexpected effects in Golden Rice, which raise important questions concerning human health safety and nutritional quality. From the GE inserts, Golden Rice should have been red (due to the presence of lycopene) but to the surprise of the scientists, it turned out yellow (due to the presence of beta-carotene). The question why exactly the GE rice is yellow and not red cannot be explained with current scientific knowledge (Beyer et al., 2002). In addition, unexpected compounds such as lutein and zeaxanthin were formed. (Ye et al., 2000 and Kuiper et al., 2001). In the light of this, any risk assessment of the Golden Rice would have to deal with the possibility of these and any other unexpected compounds which may lead to anti-nutritional, allergenic or even toxic effects in humans.

The environmental risks inherent in GE organisms apply to Golden Rice. Rice is known to cross-pollinate (outcross) and wild and weedy relatives grow in close proximity to rice cultivation (Lu et al., 2003; Chen et al., 2004). Thus, the spread of genes to conventional and wild varieties of rice is likely to happen over time. This could lead to contamination of wild population and cultivated seed supply. If a hazardous unexpected effect arises with the GE rice, e.g. increased toxicity or susceptibility to disease, there could be no withdrawal of the gene because of contamination. It is conceivable that this could undermine the food security of a region if the problem became widespread. The case of Golden Rice is a typical example of how little is actually known about the complexity of plant physiology – it would not be surprising if additional unexpected changes in the plant would occur, posing new risks to the environment or human health. Indeed, some unexpected effects in Golden Rice have already been reported. Some of the GE Golden Rice plants showed unexplained differences to the respective non-GE control plants: "*shorter stature, dark and stay-green nature, and late flowering, and some of them had a much smaller number of seeds*" (Datta et al., 2003).

Golden Rice is not necessary

Existing solutions - Options exist to defeat vitamin A deficiency. There are many food sources that contain naturally a high amount of beta-carotene. Examples include refined red palm oil, carrots, leafy green vegetables, sweet potato, cassava, mango, papaya and watermelon (Greenpeace, 2001). Existing options to defeat vitamin A deficiencies are detailed in a report, commissioned by Greenpeace: "Vitamin A deficiency: diverse causes, diverse solutions" (Lorch, 2005).

Although VAD is still a problem, aid agencies state that "*very significant progress has been made over the last 15 years"* with regard to VAD (MI & UNICEF 2004). There is a real chance to combat VAD using existing methods, without needing to resort to the high risk strategy of GE crops. In general, it is acknowledged that VAD is not so much a problem lacking in solutions, but the problem is whether VAD is given enough priority by international, regional and national politicians and policy makers. Combating VAD requires action at several different levels: on individual/household and on population level; on daily and on long-term basis; with preventative and with remedial treatment. The factors that contribute to VAD are as diverse as the solutions. There are two basic strategies to reduce VAD, medicine-based strategies and food-based strategies.

Medicine-based strategies include supplementation with vitamin A tablets. The Micronutrient Initiative and UNICEF (MI & UNICEF, 2004) state that 43 countries now have formal supplementation programmes reaching at least two-thirds of all young children, and that 10 have virtually eliminated VAD (see Lorch, 2005 for further details).

Food-based strategies include "home gardens", where vegetables are grown in household gardens (HKI, 2003b). The strategy of home gardens is a quite promising because an estimated 50% of the undernourished are small scale farmers and only 20 % are urban poor who may not have access to a garden (FAO, 2004). For example, a study in Bangladesh showed that 75g of Indian Spinach, a low-cost green leafy vegetable available all year round in Bangladesh, provides enough pro-vitamin A on a daily basis (Haskell et al., 2004).

The current successful approaches to combating VAD should be supported on all possible levels. The Golden Rice project does not look to be very promising in this context. GE rice is an unnecessary high-tech solution with too many open questions and severe potential to endanger the environment.

Beta-carotene occurs naturally in some rice varieties - Whole grain rice is a high value component of daily diet, supporting people with starch, protein, minerals and oil. This is not the case with a GE rice enriched in one isolated nutrient such as Golden Rice. A number of regional varieties of rice have been identified so far, which naturally contain a certain amount of beta-carotene. Recent findings are about 0.13 µg/g in the Philippines (Frei & Becker, 2004) with new analyses of up to 0.38 µg/g (Frei & Becker, 2005). Unlike Golden Rice, the beta-carotene resides in the outer layers of rice. This means it is lost on milling but the outer layers are also rich in lipids including unsaturated fatty acids, which would aid the bioavailability of beta-carotene (Frei & Becker, 2005). Thus the use of current biodiversity looks much more promising than the use of biotechnology derived GE rice.

Conclusion

There are many unanswered questions and known problems concerning Golden Rice:

- Golden Rice suffers from several technical failures (e.g. a range of unexpected compounds are produced).
- Even the occurrence of beta-carotene (and the yellow colour of the rice) cannot be fully explained by current scientific knowledge.
- The conversion ratio of beta-carotene in Golden Rice to vitamin A is not known.
- The complexity of the genetic engineering and the extent to which the metabolic pathways in the plant were changed increase the potential for unexpected and unpredictable effects, thus raising severe concerns concerning the human food safety.
- It is known that GE rice can outcross to wild and weedy relatives, raising cultural, agronomic and environmental problems.

The Golden Rice project lacks a coherent idea of how the VAD syndrome could be fought in a convincing and efficient way. The high risks of growing and using GE Golden Rice as food to alleviate vitamin A deficiency is not at all justified by the theoretical benefits. Other approaches to combat vitamin A deficiency, such as home gardening, that are successful, effective, and improve nutrition in general are available. Golden Rice is distracting attention and funding from real solutions to tackle VAD. Not all that glitters is gold!

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