Golden Rice

Matthias Sivarajah, Siddharth Kumar & Daniel Gaus

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Dr. Patrick Ruggle

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Preface

For numerous decades scores of institutions of public and private sectors worldwide have been consecrating themselves to research and development in the range of genetically engineered agricultural crop and food. In the mid nineties the first genetically engineered agricultural products and groceries came to the market and promised a successful future in the industry which has been growing ever since. But since the appearance of green biotechnology the development of introducing and distributing their products has led to a controversial public guided debate which has obtained a global nature and elicited strong opposition in several countries. We want to analyse the possibility to curtail the widespread vitamin A deficiency with the aid of a genetically modified rice and include different opinions on the assets and problems of this potential solution. An estimated 250'000 to 500'000 vitamin A-deficient children become blind every year, half of them dying within 12 months of losing their eyesight (WHO 2016). Actually many growing children especially in African and Asian countries, where rice is the staple food, suffer from vitamin A deficiency. Ordinary rice hardly contains provitamin A and can't cover the daily demand of nutrients for a human. The question is why can't we counteract the deficiency symptoms of the affected population in times of genetic engineering. Indeed green biotechnology is used in agriculture and in food production and is a controversial topic. There has been the approach to introduce genes of plants in different species in order to achieve agronomic characteristics such as stress resistance or modify other characteristics such material or nutritional compositions. The rice was enriched with beta-carotene, a precursor of vitamin A and the so-called Golden rice originated. We would like to investigate this more closely and try to answer the following question: Shall Golden Rice have a share in covering the world-wide vitamin deficiency? Our topic of research has a lot to do with serious global issues regarding basic human rights with makes it so special. What fascinates us is that even in a world like ours which is so developed and advanced with the latest of technologies in genetic engineering for example, there is an equal amount of malnutrition, underdevelopment and lack of human rights. If we have what we need to exterminate these fundamental problems, how come these issues are still present and so abundant? The global relevance makes our subject special.

Introduction

Many regions in south east Asia, especially those influenced by Thai-Buddhism, have rice as their staple food besides milk-products. Problems come in the kind of rice they are eating. The so-called polished white rice is favoured by a majority of the population but isn't as rich in nutrients as its unpolished brown rice counterpart (Penny Van Esterik 1984). The disadvantage of white rice is that a very important nutrient, provitamin A otherwise known as carotenes, is present only in small quantities, which in case of an insufficient diet can lead to serious bodily dysfunctions. A lack of carotenes can cause a weakened immune system, the loss of eyesight and in many cases even death. This is why scientists have been trying to find a way to increase the amount of carotenes in polished rice to alleviate the number of new occurring provitamin A related illnesses (Murray W. Nabors 2007, Kathrin Mehner 2015).

Ingo Potrykus form the ETH Zürich and Peter Bayer from the Albert-Ludwigs-University of Freiburg successfully introduced a gene that triggers the lycopene production from phytoenes into the DNA of rice. After a seven-year researching period the "Proof of concept" was published in 1999 and the newly created golden rice patented. But the invention still wasn't a product that could be sold on the market and the public support was lacking so the inventors sold their patent to Syngenta who started testing and improving the golden rice as well as commencing field studies in the USA, Vietnam, India and the Philippines (Science 2000, Ingo Potrykus 2010). These field studies have been going on ever since and a legalization of golden rice still seems improbable. So it seems that this project has reached a dead end, although the golden rice has won the Patents for Humanity award of 2015 (Golden Rice Humanitarian Board 2015).

There is a diversity of ancient rice varieties which naturally contain a lot of the beta-carotene and are, in contrast to genetic engineered rice, adapted to the local circumstances (Konrad Biesalski 2013). Other crops such as maize and cassava have a naturally high content of provitamin A and can ensure a sufficient and natural vitamin A intake (Harvest Plus 2012). The distribution of vitamin A supplements has also proven itself as a possible solution. Further available treatment are the enrichment of vitamin A in staple foods such as flour and sugar or the supply of diversified food with the help of fruit and vegetable production in home gardens. The latter particulary achieved great success in Africa (Greenpeace). A combination of these strategies is also possible. A longterm and sustainable reduction of the problem would be an ecological agriculture that produces good-quality food in locally adapted systems and thus guarantees a varied, vitamin and mineral-rich diet.

All the proven and cost-effective strategies that take a more overall approach could help to tackle the problem successfully and without risk to health and the environment. A side-oriented solution as envisaged by the Golden Rice, on the other hand, only enriches the genetic engineering industry. For the agro-genetic engineering companies the profit is the focus, but not the fight against global hunger. This is reflected, for example, by the fact that

the farmers must purchases new licenses for the gene-seed every year as well as the gene-seeds itself. This results in the peasants getting more and more dependent on large cooperations and falling in to a debt spiral.

Functionality and Description of engineering modification technique

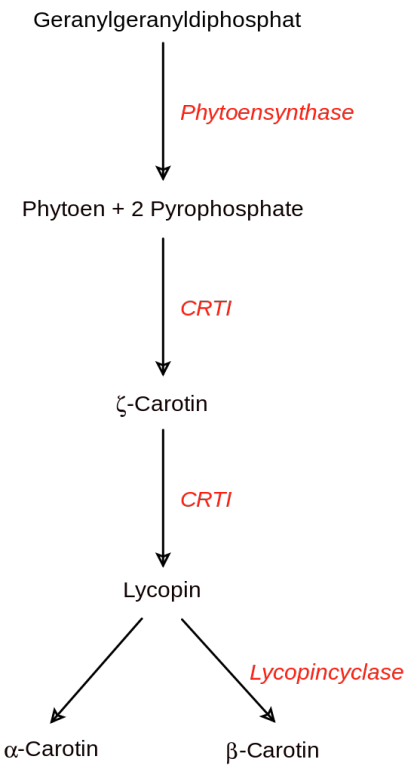

Fig.1: Reaction chain

Multiple genes are necessary to cause this chain of reactions(Fig.1) NpPSY, NpLCY and crtl. The geranylgeranyldiphosphat (GGPP) stands at the beginning of the carotene synthesis. The enzyme phytoensynthase (psy) produced by the gene NpPSY combines two GGPP molecules to a phytoen and two Pyrophosphate molecules. The phytoen is then further processed into all-trans-Lycopin when Carotenedesaturase (CRTI) is present. Carotenedesaturase is produced by the gene crtl is in the DNA. When the gene NpLCY is present the all-trans-lycopin is changed into Beta-Carotene, which is then stored in the outer layers of the rice corn.

The NpPSY and NpLCY are isolated and extracted from the daffodil plant (Narcissus pseudonarcissus (which is why the genes have a Np- prefix)). From the Bacteria sharing the genus Erwinia the crtl genes are extracted (TillF; 7 Feb. 2016 (last updated), McGeddon; 16 April 2016 (last updated)).

There are many possible ways to extract the wanted genes, but it always follows a certain guideline:

- Cell disruption or cell lysis. Breaking the cell open to expose the DNA within.

- Removing the disturbing cell parts including proteins and RNA by adding a detergent, a protease and RNase.

- DNA purification by...

1)… adding ice cold ethanol to the DNA containing solution and using centrifugation to separate it.

2)…adding phenol that denatures the proteins and after centrifugation nucleic acid swims on top. Putting chloroform into the nucleic acid will lead to a remaining purified form of DNA.

3)… using the nucleic acid as a binder to the solid phase, by providing the right pH and salt content.

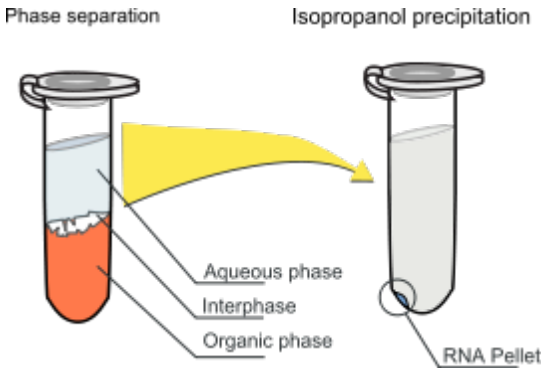

Fig.2: Separation of DNA from the aqueous phase

- Separating the wanted genetic part with the help of DNA specific glycosylase enzymes for example.

- Using a method (like centrifugation) to separate required gene sequence from the rest.

- Insert the gene sequence (ThermoFisher Scientific 1990).

Documentation and pictures of research institutions

Unfortunately, our request for an interview with Syngenta got declined but we still got a chance to visit one of their research facilities in Stein.

Dr. Jürg Oetiker, a researcher from the departement of life sciences at the university of Basel was kind enough to take time to share some of his knowledge on the topic of golden rice specifically and its correlation with biotechnology and genetic engineering in general.

1.) Are the possibilities of application of gene technology limited?

Yes, gene technology has a lot of limits. If you wanted to, you could incorporate any gene into a plant. But not every gene of a monkey may be useful in a plant. There are limitations. Furthermore there are laws which we humans have to accept. Take a book for example. If you were to pick any two random words from the book and put them together, they would not form a meaningful sentence.

2.) Can gene technology have harmful consequences regarding the consumers health?

No. The possibility that plants which have been modified with a poison-gene also produce this poison. Consuming it would definitely be harmful for humans. Genetically modified plants are harmless. It is like eating DNA of cells. Let us contemplate the Fugu fish in Sushi. The fish contains highly poisonous organs such as the intestine, roe and liver. That's why it is important to consume Sushi made by a professional who is aware of the risks of poisoning. We humans can eat the fish's flesh without problems though. Eating DNA is harmless. And also by eating the flesh one would be consuming its heritage.

3.) Golden rice has been modified in a way that it produces vitamin A. Would it also be possible to simultaneously activate the synthesis of any other vitamin? If so, would this entail biological drawbacks? Greenpeace states that the lack of vitamin A can be resolved with vitamin supplements. Do you think that would be possible?

Yes, it works in theory. I knew Ingo Potrykus quite well and also worked with him. His idea was to resolve world food problems with gene technology. Most types of rice hardly not contain vitamin A. We also have to take into regard of course that nutrition can vary strongly from region to region and between cultures. It is clear for us that we would take a bite of a vitamin A rich carrot against this deficiency. And thus, it would already be done for us. Today is possible to produce varieties of rice containing vitamin A without genetically modifying them. Then the question is if anyone is interested in rice which has been genetically modified with various vitamins. To thoroughly study the matter would mean around 20 years of research and would also cost quite a bit. A multivitamin tablet doesn't solve any world food problem. Also the countries which consume a lot of rice don't want to live solely on rice but also have a varied diet. Like this the food problem would not be solved. This whole discussion is a philosophical question. A genetically modified plant can cause problems in a new ecosystem. But the same problems have also been displayed by neophytes. A genetically modified plant would introduce around 1-10 genes into the new ecosystem. Neophytes on the other hand could bring in up to 30’000 genes into the new ecosystem. One case where I support the view of Greenpeace refers to the dangers of genetically modified, weed resistant plants. Golden rice is something good. Ordinary wheat has been crossbred for centuries. And the farmers passed on their knowledge to each following generation. The depth of the intervention of gene technology has been larger. Switzerland does not need gene technology. We are a rich country. Our agriculture depends on subsidies. Our smallholders are dying out. Many of these

farmers are discovering bio-niche which are competitive, marketable and exportable. These farmers are strictly against gene modified plants because they could potentially contaminate the non-modified plants. Here we speak of the problem of coexistence. This of course is also an economic argument of the farmers.

4.) Is the sterilization of male GMOs just a business strategy developed by large corporations to gain more profit with the seeds or does is have additional reasons?

The rice is sterilized and no longer produces pollen. This method has been used for over 100 years. It is the same thing with corn. 95% of the corn has been produced with this method without the use of gene technology. Selected males and females have been crossed in a way that hybrid seeds emerge. This doesn't have anything to do with gene technology. One asset is that the consumer receives a better product. You need the producer and you need the seeds and due to this, the cultivator is protected and earns money. The situation is the same with genetically modified plants. The consumer buys them and the producer is protected. This way the modified plants cannot pollinate the biological plants. Corporations certainly have financial interests too but it also has a positive impact on the consumer.

5.) If, for example, a growth-promoting gene runs wild, is there a possibility that species turns invasive?

In every ecosystem which undergoes a change, unexpected consequences can always take place. If an extremely resistant species of bamboo from Asia would be planted in our forests it would repress our the existing plants and trees and change our whole ecosystem. Invasive plants in Switzerland are an example of serious changes which can happen. Another example is goat grass. It is an ancestor of our wheat and belongs to the plants which display weed resistance. It has been been planted on golf courses in the US. The goat grass had been genetically modified bred with other species of grass. In both cases an ecosystem is interfered with and both cases bear massive aftermath.

6.) What is your opinion regarding the conflict of green gene technology? What are your assumptions about its development in the future?

My opinion is simple. It is the same opinion as with a knife. A knife can be something good. It is the same with gene technology. It depends on how we use it. What does a member of Greenpeace do if he is diagnosed with diabetes? Nowadays insulin is only produced through gene technology. Doctors sell it and consumers buy it. In gene technology we distinguish between output traits and and input traits. Only the producer benefits from input traits. It doesn't provide any advantages for the plants. An example are the weed resistant plants. Output traits directly serve the consumer. Here the example would be golden rice. Most genetically modified plants are input traits. Today we still don't have sufficient knowledge concerning all the functions of plant genes. I think that plant genetics need more output traits. Along with rising the consumer's tolerance for gene technology the interest and amount of conducted research would also in the field of output traits. Switzerland doesn't need green gene technology. There is no economic urgency.

Discussion:

The topic golden rice has always been a subject of high tension. Ever since the publication of its scientific papers it has been praised as the solution for stopping malnutrition due to insufficient food supply by one side but also as another danger to the environment and health by the others. This has lead to some quite aggressive discussions on whether the risk should be taken and if 15 years of experimenting are enough to finally legalize this GMO. Here are a few more Pros and Cons:

Pros

- A huge advantage and basically the main reason behind the concept and development of Golden rice is its richness in vitamin A which normal white rice lacks. Many people in countries where rice is the staple food suffer from vitamin A deficiency. The most effective way of tackling this problem is by providing the nutrients which the people require through the item which accounts for the biggest part of their diet. This is the precise function and purpose of Golden rice.
- The countries affected by vitamin A shortage suffer heavy financial losses due to the health issues caused by the deficiency. This is another obstacle which could be avoided with the use of Golden rice.
- Some studies conducted in the USA have found out that has positive side effects including higher yields and a lower requirement of pesticide use (OccupyTheory; 2015).
- As the primary food source, rice should offer sufficient nutrients which it doesn't. Golden rice is being developed so that it can potentially also provide more essential nutrients such as vitamin C, zinc, iron and even protein (NLCATP; 2015).

Cons

- The last point mentioned in the pros of Golden rice bears a significant drawback though. One should not rely on a single food as the source of all needed nutrients and should rather have a balanced diet including different foods which offer all the necessary nutrients.
- As it is the case with all genetically modified foods, Golden rice can cause allergies. Normally these foods are modified in a way that they contain additional nutrients. These nutrients have to be derived from somewhere, in most cases from plants or animals and since people have allergies to plants and animals, they will also be allergic the genetically modified item.

- Most GMOs have the antibiotic feature that they are resistant to insects and other germs. This feature could hamper with how our body reacts to antibiotics.

- The possibility of Golden rice spreading out in the wild. The consequence of this would be some sort of highly resistant organism which would be nearly impossible to eliminate (NLCATP; 2015). Golden rice has not officially been released yet since it still today is a very controversial topic. There are plenty of disagreements over Golden rice mainly between scientists and environmental activists. These political conflicts and the increasing environmental awareness are the main reason Golden rice hasn't been implemented yet. The whole situation of Golden rice is currently at a stand still (Weekly; Date Unknown). Greenpeace, a non-governmental organization of environmental activists who are in general against the use of GMOs has released multiple reports on golden rice and why they oppose it. They state that instead of technically getting rid of vitamin A deficiency with a genetically modified food which may bring along new problems such as the consumption of the rice being against the beliefs of some people or environmental contamination risks, first the more fundamental reasons behind malnutrition such as poverty and lack of access to a healthy and varied diet should be given more thought. Alternatives which they suggest include vitamin supplements for example (Greenpeace International; 2012).

Even though Syngenta ceased to make any profit from this product. In fact, they planned to offer it to farmers in critical regions for free. They continued to improve and modify the Golden Rice. The creatively named Golden Rice 2 is modified with a psy gene from maize, that increases the production of carotenoids up to 23-fold compared to the original version (Nature Biotechnology; 2005). Unfortunately, there haven't been any reports from new golden rice modifications and Syngenta didn't publish any plans to further do research on it.

Summary

What we can deduct from our research, is that golden rice which was invented by Ingo Potrykus and Peter Bayer is that from the scientific perspective it is a relatively simple but effective product to end Provitamin A and Vitamin A related illnesses due to insufficient nutrition although it is still unclear if there are any long-term health related effects on people who eat the golden rice. This question has led to the project coming to a standstill. This however hasn't stopped industry from doing further research and modifications on golden rice. The newer golden rice 2 has a much higher Provitamin A content. But it will still do no good for all the ill-nourished people in the third world because it hasn't been approved for farmers to use yet. Even though there are a lot of drawbacks and room for improvement the concept itself could go a very long way in terms of eradicating world food problems if implemented correctly. But it all comes down to us. The only way to make a difference is if we stop quarrelling with each other and all together take a step in the right direction.

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Image Pictures:

Pic.1: https://de.wikipedia.org/wiki/Goldener_Reis#/media/File:Carotinsynthesen.svg

Pic.2: https://de.wikipedia.org/wiki/DNA-Extraktion#/media/File:PhOH-CHCl3_extraction.svg

Pic.3: http://www.goldenrice.org/image/how_GR2.jpg