

Golden rice

From Wikipedia, the free encyclopedia

Golden rice is a variety of *Oryza sativa* rice produced through genetic engineering to biosynthesize beta-carotene, a precursor of vitamin A, in the edible parts of rice.^[1] The research was conducted with the goal of producing a fortified food to be grown and consumed in areas with a shortage of dietary vitamin A,^[2] a deficiency which is estimated to kill 670,000 children under 5 each year.^[3]

Golden rice differs from its parental strain by the addition of three beta-carotene biosynthesis genes. The scientific details of the rice were first published in *Science* in 2000,^[1] the product of an eight-year project by Ingo Potrykus of the Swiss Federal Institute of Technology and Peter Beyer of the University of Freiburg. At the time of publication, golden rice was considered a significant breakthrough in biotechnology, as the researchers had engineered an entire biosynthetic pathway.

In 2005, a new variety called *Golden Rice 2*, which produces up to 23 times more beta-carotene than the original golden rice, was announced.^[4] Although golden rice was developed as a humanitarian tool, it has met with significant opposition from environmental and anti-globalization activists.

Golden Rice has undergone two years of field testing in the Philippines.^[5]



Golden rice (right) compared to white rice (left)

Contents

- 1 Creation
 - 1.1 Subsequent development
- 2 Potential use to combat vitamin A deficiency
- 3 Research
 - 3.1 Clinical trials / food safety and nutrition research
- 4 Controversy
 - 4.1 Direct action
- 5 Distribution
- 6 References
- 7 External links

Creation

Golden rice was designed to produce beta-carotene, a precursor of vitamin A, in the edible part of rice, the endosperm. The rice plant can naturally produce beta-carotene in its leaves, where it is involved in photosynthesis. However, the plant does not normally produce the pigment in the endosperm, where photosynthesis does not occur. A key breakthrough was the discovery that a single phytoene desaturase gene (bacterial *CrtI*) can be used to produce lycopene from phytoene in GM tomato, rather than having to introduce the multiple carotene desaturases that are normally used by higher plants.^[6] Lycopene is then cyclized to beta-carotene by the endogenous cyclase in Golden Rice.^[7]

Golden rice was created by transforming rice with only two beta-carotene biosynthesis genes:

1. *psy* (phytoene synthase) from daffodil (*Narcissus pseudonarcissus*)
2. *crtI* (carotene desaturase) from the soil bacterium *Erwinia uredovora*

(The insertion of a *lyc* (lycopene cyclase) gene was thought to be needed, but further research showed it is already being produced in wild-type rice endosperm.)

The *psy* and *crtI* genes were transformed into the rice nuclear genome and placed under the control of an endosperm-specific promoter, so they are only expressed in the endosperm. The exogenous *lyc* gene has a transit peptide sequence attached so it is targeted to the plastid, where geranylgeranyl diphosphate formation occurs. The bacterial *crtI* gene was an important inclusion to complete the pathway, since it can catalyze multiple steps in the synthesis of carotenoids up to lycopene, while these steps require more than one enzyme in plants.^[8] The end product of the engineered pathway is lycopene, but if the plant accumulated lycopene, the rice would be red. Recent analysis has shown the plant's endogenous enzymes process the lycopene to beta-carotene in the endosperm, giving

the rice the distinctive yellow color for which it is named.^[9] The original golden rice was called SGR1, and under greenhouse conditions it produced 1.6 µg/g of carotenoids.

Subsequent development

Golden rice has been bred with local rice cultivars in the Philippines^[10] and Taiwan and with the American rice cultivar 'Cocodrie'.^[11] The first field trials of these golden rice cultivars were conducted by Louisiana State University Agricultural Center in 2004.^[11] Field testing provides a more accurate measurement of nutritional value and enables feeding tests to be performed. Preliminary results from the field tests have shown field-grown golden rice produces 4 to 5 times more beta-carotene than golden rice grown under greenhouse conditions.^[12]

In 2005, a team of researchers at biotechnology company, Syngenta, produced a variety of golden rice called "Golden Rice 2". They combined the phytoene synthase gene from maize with *crt1* from the original golden rice. Golden rice 2 produces 23 times more carotenoids than golden rice (up to 37 µg/g), and preferentially accumulates beta-carotene (up to 31 µg/g of the 37 µg/g of carotenoids).^[4] To receive the Recommended Dietary Allowance (RDA), it is estimated that 144 g of the most high-yielding strain would have to be eaten. Bioavailability of the carotene from golden rice has been confirmed and found to be an effective source of Vitamin A for humans.^{[13][14][15]}

In June 2005, researcher Peter Beyer received funding from the Bill and Melinda Gates Foundation to further improve golden rice by increasing the levels of or the bioavailability of pro-vitamin A, vitamin E, iron, and zinc, and to improve protein quality through genetic modification.^{[16][17]}

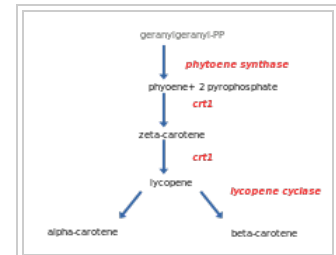
Potential use to combat vitamin A deficiency

The research that led to golden rice was conducted with the goal of helping children who suffer from vitamin A deficiency (VAD). In 2005, 190 million children and 19 million pregnant women, in 122 countries, were estimated to be affected by VAD.^[18] VAD is responsible for 1-2 million deaths, 500,000 cases of irreversible blindness and millions of cases of xerophthalmia annually.^[19] Children and pregnant women are at highest risk. Vitamin A is supplemented orally and by injection in areas where the diet is deficient in vitamin A. As of 1999, there were 43 countries that had vitamin A supplementation programs for children under 5; in 10 of these countries, two high dose supplements are available per year, which, according to UNICEF, could effectively eliminate VAD.^[20] However, UNICEF and a number of NGOs involved in supplementation note more frequent low-dose supplementation should be a goal where feasible.^[21]

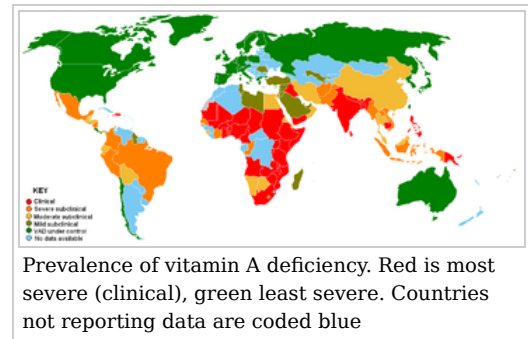
Because many children in countries where there is a dietary deficiency in vitamin A rely on rice as a staple food, the genetic modification to make rice produce the vitamin A precursor beta-carotene is seen as a simple and less expensive alternative to vitamin supplements or an increase in the consumption of green vegetables or animal products.

Initial analyses of the potential nutritional benefits of golden rice suggested consumption of golden rice would not eliminate the problems of vitamin A deficiency, but should be seen as a complement to other methods of vitamin A supplementation.^{[22][23]} Since then, improved strains of golden rice have been developed containing sufficient provitamin A to provide the entire dietary requirement of this nutrient to people who eat about 75g of golden rice per day.^[4]

In particular, since carotenes are hydrophobic, there needs to be a sufficient amount of fat present in the diet for golden rice (or most other vitamin A supplements) to be able to alleviate vitamin A deficiency. In that respect, it is significant that vitamin A deficiency is rarely an isolated phenomenon, but usually coupled to a general lack of a balanced diet (see also Vandana Shiva's arguments below). The RDA levels accepted in developed countries are far in excess of the amounts needed to prevent blindness.^[4] Moreover, this claim referred to an early cultivar of golden



A simplified overview of the carotenoid biosynthesis pathway in golden rice. The enzymes expressed in the endosperm of golden rice, shown in red, catalyze the biosynthesis of beta-carotene from geranylgeranyl diphosphate. Beta-carotene is assumed to be converted to retinal and subsequently retinol (vitamin A) in the animal gut



rice; one bowl of the latest version provides 60% of RDA for healthy children.^[24]

Research

The University of California and Rutgers University have conducted studies showing "...higher crop yields, reduced pesticide use and fewer pesticide-related health problems..." amongst Chinese farmers who used GM rice strains. This was published in the peer reviewed journal *Science* in 2005.^[25]

Dr. Jose' L. Domingo of the Laboratory of Toxicology and Environmental Health, School of Medicine, at Rovira I Virgili University in Spain said, "According to the information reported by the WHO, genetically modified products that are currently on the international market have all passed risk assessments conducted by national authorities." These assessments found no risk to human health. Dr. Domingo advocates continued research in the areas of GM rice and its effects on humans.^[26]

Clinical trials / food safety and nutrition research

In 2009, research results of a clinical trial of Golden Rice with adult volunteers from the USA, was published in the American Journal of Clinical Nutrition. It concluded that "beta carotene derived from Golden Rice is effectively converted to vitamin A in humans".^[27] In a summary about the research the American Society for Nutrition suggests the implications of the research are that "Golden Rice could probably supply 50% of the Recommended Dietary Allowance (RDA) of vitamin A from a very modest amount — perhaps a cup — of rice, if consumed daily. This amount is well within the consumption habits of most young children and their mothers".^[28]

In response to the research, a group of 20 scientists suggested in an open letter that there might be deficiencies in clinical trials: "There is now a large body of evidence that shows that GM crop/food production is highly prone to inadvertent and unpredictable pleiotropic effects, which can result in health damaging effects when GM food products are fed to animals."^{[29][30][31]} More specifically, our greatest concern is that this rice, which is engineered to overproduce beta carotene, has never been tested in animals, and there is an extensive medical literature showing that retinoids that can be derived from beta carotene are both toxic and cause birth defects."^[32] However, it is well known that beta carotene is found and consumed in many nutritious foods eaten around the world, including fruits and vegetables. Beta carotene in food is a safe source of vitamin A.^[33]

The Food Allergy Resource and Research Program of the University of Nebraska undertook research in 2006 that showed the proteins from the new genes in Golden Rice did not show any allergenic properties.^[34]

In August 2012, Tufts University and others published new research on Golden Rice in the American Journal of Clinical Nutrition showing that the beta carotene produced by Golden Rice is as good as beta carotene in oil at providing vitamin A to children.^[35] The study states that "recruitment processes and protocol were approved",^[35] but questions have been raised about the use of Chinese children to test the effects of Golden Rice.^[36]

Controversy

Critics of genetically engineered crops have raised various concerns. One of these is that golden rice originally did not have sufficient vitamin A. This problem was solved by the development of new strains of rice.^[4] However, there are still doubts about the speed at which vitamin A degrades once the plant is harvested, and how much remains after cooking.^[37] A 2009 study concluded that golden rice is effectively converted into vitamin A in humans^[13] and a 2012 study that fed 68 children ages 6 to 8 concluded that golden rice was as good as vitamin A supplements and better than the natural beta-carotene in spinach.^[15]

Greenpeace opposes the release of any genetically modified organisms into the environment and is concerned that golden rice is a Pandora's Box that will open the door to more widespread use of GMOs.^[38]

Vandana Shiva, an Indian anti-GMO activist, argued the problem was not that the crop had any particular deficiencies, but that there were potential problems with poverty and loss of biodiversity in food crops. These problems are aggravated by the corporate control of agriculture via control of genetically modified organisms. By focusing on a narrow problem (vitamin A deficiency), Shiva argued, the golden rice proponents were obscuring the larger issue of a lack of broad availability of diverse and nutritionally adequate sources of food.^[39] Other groups argued that a varied diet containing foods rich in beta carotene such as sweet potato, leafy green vegetables and fruit would provide children with sufficient vitamin A.^[40] However Keith West of Johns Hopkins Bloomberg School of Public Health has argued that foodstuffs containing Vitamin A are either unavailable, or only available at certain seasons, or that they are too expensive for poor families in underdeveloped countries.^[15]

Citing a lack of real-world studies and uncertainty about how many people will use golden rice, WHO malnutrition expert Francesco Branca concludes "giving out supplements, fortifying existing foods with vitamin A, and teaching people to grow carrots or certain leafy vegetables are, for now, more promising ways to fight the problem".^[41]

More recently, author Michael Pollan, who had attacked the product in 2001, while still dubious about the benefits, expressed support for the continuation of the research.^[42]

Direct action

An experimental plot of golden rice being grown in the Philippines was uprooted during direct action on August 8, 2013.^{[24][43]} While the action was initially attributed to 400 local farmers, it was later found to have been carried out by a group of 50 anti-GMO activists.^[44]

Distribution

Potrykus has spearheaded an effort to have golden rice distributed for free to subsistence farmers.^[45] Free licenses for developing countries were granted quickly due to the positive publicity that golden rice received, particularly in *Time* magazine in July 2000. Golden rice was said to be the first recombinant DNA tech crop that was unarguably beneficial. Monsanto Company was one of the first companies to grant free licences.^[46]

The cutoff between humanitarian and commercial use was set at US\$10,000. Therefore, as long as a farmer or subsequent user of golden rice genetics does not make more than \$10,000 per year, no royalties need to be paid. In addition, farmers are permitted to keep and replant seed.^[47]

References

- [^] ^{**a**} ^{**b**} Ye, X; Al-Babili, S; Klöti, A; Zhang, J; Lucca, P; Beyer, P; Potrykus, I (2000). "Engineering the provitamin A (beta-carotene) biosynthetic pathway into (carotenoid-free) rice endosperm". *Science* **287** (5451): 303–5. doi:10.1126/science.287.5451.303 (http://dx.doi.org/10.1126%2Fscience.287.5451.303). PMID 10634784 (//www.ncbi.nlm.nih.gov/pubmed/10634784).
- [^] One existing crop, genetically engineered "golden rice" that produces vitamin A, already holds enormous promise for reducing blindness and dwarfism that result from a vitamin-A deficient diet. - Bill Frist, physician and politician, in a *Washington Times* commentary - November 21, 2006 [1] (http://www.washtimes.com/commentary/20061120-094716-8709r.htm)
- [^] Black RE et al., Maternal and child undernutrition: global and regional exposures and health consequences, *The Lancet*, 2008, 371(9608), p. 253.
- [^] ^{**a**} ^{**b**} ^{**c**} ^{**d**} ^{**e**} Paine, Jacqueline A; Shipton, Catherine A; Chaggar, Sunandha; Howells, Rhian M; Kennedy, Mike J; Vernon, Gareth; Wright, Susan Y; Hinchliffe, Edward; Adams, Jessica L (2005). "Improving the nutritional value of Golden Rice through increased pro-vitamin A content" (http://www.nature.com/nbt/journal/v23/n4/full/nbt1082.html). *Nature Biotechnology* **23** (4): 482–7. doi:10.1038/nbt1082 (http://dx.doi.org/10.1038%2F76523). PMID 15793573 (//www.ncbi.nlm.nih.gov/pubmed/15793573).
- [^] PhilRice Two seasons of Golden Rice trials in Phl concluded (http://www.philrice.gov.ph/?page=resources&page2=news&id=211), 09 June 2013.
- [^] Romer, S.; Fraser, P.D., Kiano, J.W., Shipton, C.A., Misawa, N, Schuch, W. and Bramley, P.M. (2000). "Elevation of provitamin A content of transgenic tomato plants." (http://www.nature.com/nbt/journal/v18/n6/full/nbt0600_666.html). *Nature Biotechnology* **18**: 666–669. doi:10.1038/76523 (http://dx.doi.org/10.1038%2F76523).
- [^] "The Science of Golden Rice" (http://www.goldenrice.org/Content2-How/how1_sci.php). Retrieved 11 July 2013.
- [^] Hirschberg, J. (2001). "Carotenoid biosynthesis in flowering plants" (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VS4-42T4DVS-9&_coverDate=06%2F01%2F2001&_alid=261007621&_rdoc=1&_fmt=&_orig=search&_qd=1&_cdi=6252&_sort=d&view=c&_acct=C000028338&_version=1&_urlVersion=0&_userid=554534&md5=153b20341f39ec8105f53f6a7927e12d). *Current Opinion in Plant Biology* **4** (3): 210–218. doi:10.1016/S1369-5266(00)00163-1 (http://dx.doi.org/10.1016%2FS1369-5266%2800%2900163-1). PMID 11312131 (//www.ncbi.nlm.nih.gov/pubmed/11312131).
- [^] Schaub, P.; Al-Babili, S; Drake, R; Beyer, P (2005). "Why Is Golden Rice Golden (Yellow) Instead of Red?". *Plant Physiology* **138** (1): 441–450. doi:10.1104/pp.104.057927 (http://dx.doi.org/10.1104%2Fpp.104.057927). PMC 1104197 (//www.ncbi.nlm.nih.gov/pmc/articles/PMC1104197). PMID 15821145 (//www.ncbi.nlm.nih.gov/pubmed/15821145).
- [^] Watson, Todd (10 August 2013). "GM rice field destroyed by activists in the Philippines" (http://investvine.com/gm-rice-field-destroyed-by-activists-in-the-philippines/). *Inside Investor*. Retrieved 11 August 2013.
- [^] ^{**a**} ^{**b**} LSU AgCenter Communications. 'Golden Rice' Could Help Reduce Malnutrition (http://www.lsuagcenter.com/news_archive/2004/October/Headline+News/Golden+Rice+Could+Help+Malnutrition.htm), 2004
- [^] "Testing the performance of Golden Rice" (http://www.goldenrice.org/Content2-How/how8_tests.php). Goldenrice.org. 2012-08-29. Retrieved 2013-08-26.
- [^] ^{**a**} ^{**b**} Tang, G, Qin, J, Dolnikowski, GG, Russell, RM, Grusak, MA (2009). "Golden Rice is an effective source of vitamin A". *Am J Clin Nutr* **89** (6): 1776–83.

- doi:10.3945/ajcn.2008.27119 (<http://dx.doi.org/10.3945/ajcn.2008.27119>). PMC 2682994 (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2682994>). PMID 19369372 (<http://www.ncbi.nlm.nih.gov/pubmed/19369372>).
14. ^ Datta, S.K.; Datta, Karabi; Parkhi, Vilas; Rai, Mayank; Baisakh, Niranjani; Sahoo, Gayatri; Rehana, Sayeda; Bandyopadhyay, Anindya; Alamgir, Md. (2007). "Golden rice: introgression, breeding, and field evaluation". *Euphytica* **154** (3): 271–278. doi:10.1007/s10681-006-9311-4 (<http://dx.doi.org/10.1007/s10681-006-9311-4>).
 15. ^ ^a ^b ^c Norton, Amy (15 August 2012) Genetically modified rice a good vitamin A source (<http://www.reuters.com/article/2012/08/15/us-genetically-modified-rice-idUSBRE87E0RO20120815>) Reuters, Retrieved 20 August 2012
 16. ^ Bill & Melinda Gates Foundation, Grand Challenges in Global Health Initiative Selects 43 Groundbreaking Research Projects for More Than \$436 Million in Funding (<http://www.gatesfoundation.org/press-releases/Pages/funding-groundbreaking-research-050627.aspx>), Press release, June 27, 2005 (Retrieved 24 November 2009)
 17. ^ Grand Challenges in Global Health, Engineering Rice for High Beta Carotene, Vitamin E and Enhanced Fe and Zn Bioavailability (<http://www.grandchallenges.org/ImproveNutrition/Challenges/NutrientRichPlants/Pages/Rice.aspx>), Accessed 14 April 2012
 18. ^ Staff (2009) Global Prevalence Of Vitamin A Deficiency in Populations At Risk 1995–2005 (http://whqlibdoc.who.int/publications/2009/9789241598019_eng.pdf) WHO Global Database on Vitamin A Deficiency. Geneva, World Health Organization, ISBN 978924159801, Retrieved 10 October 2011
 19. ^ Humphrey, J.H.; West, K.P. Jr; Sommer, A. (1992). "Vitamin A deficiency and attributable mortality in under-5-year-olds". *WHO Bulletin* ([http://whqlibdoc.who.int/bulletin/1992/Vol70-No2/bulletin_1992_70\(2\)_225-232.pdf](http://whqlibdoc.who.int/bulletin/1992/Vol70-No2/bulletin_1992_70(2)_225-232.pdf)) **70**: 225–232.
 20. ^ UNICEF. Vitamin A deficiency (http://www.childinfo.org/eddb/vita_a/index.htm)
 21. ^ Vitamin A Global Initiative. 1997. A Strategy for Acceleration of Progress in Combating Vitamin A Deficiency (http://www.unicef.org/immunization/files/Vit_A_strategy.pdf)
 22. ^ Dawe, D.; Robertson, R.; Unnevehr, L. (2002). "Golden rice: what role could it play in alleviation of vitamin A deficiency?". *Food Policy* **27** (5–6): 541–560. doi:10.1016/S0306-9192(02)00065-9 ([http://dx.doi.org/10.1016/S0306-9192\(02\)00065-9](http://dx.doi.org/10.1016/S0306-9192(02)00065-9)).
 23. ^ Zimmerman, R.; Qaim, M. (2004). "Potential health benefits of Golden Rice: a Philippine case study" (<http://croplife.intraspin.com/Biotech/potential-health-benefits-of-golden-rice-a-philippine-case-study/>). *Food Policy* **29** (2): 147–168. doi:10.1016/j.foodpol.2004.03.001 (<http://dx.doi.org/10.1016/j.foodpol.2004.03.001>).
 24. ^ ^a ^b Amy Harmon (August 24, 2013). "Golden Rice: Lifesaver?" (<http://www.nytimes.com/2013/08/25/sunday-review/golden-rice-lifesaver.html>) (News Analysis). *The New York Times*. Retrieved August 25, 2013.
 25. ^ Bailey, Pat (2005) Genetically modified rice in China benefits farmers' health, study finds (<http://www.universityofcalifornia.edu/news/article/7108>) University of California Newsroom.
 26. ^ Domingo, Jose' (2007) Toxicity Studies of Genetically Modified Plants: A Review of the Published Literature (<http://www.biosafety.ru/ftp/domingo.pdf>) Critical Reviews in Food Science and Nutrition, 47:721–733 (2007) Copyright Taylor and Francis Group, LLC
 27. ^ Golden Rice is an effective source of vitamin A (<http://ajcn.nutrition.org/content/89/6/1776.full.pdf>), by Guangwen Tang, Jian Qin, Gregory G Dolnikowski, Robert M Russell, and Michael A Grusak in the American Journal of Clinical Nutrition, 2009;89:1776–83.
 28. ^ American Society of Nutrition: Researchers Determine That Golden Rice Is an Effective Source of Vitamin A (<http://asn-cdn-remembers.s3.amazonaws.com/1247eb83af3c2c77fb8cf75d5e158f1f.pdf>)
 29. ^ Pusztai, Arpad; Bardocz, Susan (2007). "Potential Health Effects of Foods Derived from Genetically Modified Plants: What Are the Issues?" (<http://www.twinside.org.sg/title2/biosafety/pdf/bio14.pdf>). In Terje Traavik and Lim Li Ching. *Biosafety First – Holistic Approaches to Risk and Uncertainty in Genetic Engineering and Genetically Modified Organisms*. Trondheim: Academic Press. ISBN 9788251921138.
 30. ^ Schubert, 2008
 31. ^ Dona, A.; Arvanitoyannis, I. S. (2009). "Health Risks of Genetically Modified Foods". *Critical Reviews in Food Science and Nutrition* **49** (2): 164–175. doi:10.1080/10408390701855993 (<http://dx.doi.org/10.1080/10408390701855993>). PMID 18989835 (<http://www.ncbi.nlm.nih.gov/pubmed/18989835>).
 32. ^ "Scientists Protest Unethical Clinical Trials of GM Golden Rice" (<http://www.i-sis.org.uk/SPUCTGM.php>). I-sis.org.uk. Retrieved 2013-08-26.
 33. ^ β -Carotene Is an Important Vitamin A Source for Humans (<http://jn.nutrition.org/content/140/12/2268S.full>). *J. Nutr.* December 1, 2010 vol. 140 no. 12 2268S–2285S
 34. ^ Goodman RE, Wise J. Bioinformatic analysis of proteins in Golden Rice 2 to assess potential allergenic cross-reactivity. Preliminary Report. (<http://www.allergenonline.org/Golden%20Rice%202%20Bioinformatics%20FARRP%20006.pdf>) University of Nebraska. Food Allergy Research and Resource Program. May 2, 2006.
 35. ^ ^a ^b Beta carotene in Golden Rice is as good as beta carotene in oil at providing vitamin A to children (http://www.goldenrice.org/PDFs/GR_bioavailability_AJCN2012.pdf)
 36. ^ "China continues to probe alleged GM rice testing" (<http://www.globaltimes.cn/content/731557.shtml>). Globaltimes.cn. Retrieved 2013-08-26.
 37. ^ 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." Foodwatch in Germany http://www.foodwatch.de/foodwatch/content/e6380/e23456/e23458/GoldenRice_english_final_ger.pdf.
 38. ^ Greenpeace. 2005. All that Glitters is not Gold: The False Hope of Golden Rice (<http://www.greenpeace.org/international/Global/international/planet-2/report/2005/5/all-that-glitters-is-not-gold.pdf>)
 39. ^ "THE "GOLDEN RICE" HOAX -When Public Relations replaces Science" (<http://online.sfsu.edu/~rone/GEessays/goldenricehoax.html>). Online.sfsu.edu. 2000-06-29. Retrieved 2013-08-26.
 40. ^ Friends of the Earth. Golden Rice and Vitamin A Deficiency (<http://www.foe.org/safefood/rice.html>)
 41. ^ Enserink, M. (2008). "Tough Lessons From Golden Rice". *Science* **320** (5875): 468–471. doi:10.1126/science.320.5875.468 (<http://dx.doi.org/10.1126/science.320.5875.468>). PMID 18436769 (<http://www.ncbi.nlm.nih.gov/pubmed/18436769>).
 42. ^ [[Andrew Revkin|Andrew Revkin]] (2013-09-01). "From

- Lynas to Pollan, Agreement that Golden Rice Trials Should Proceed" (<http://dotearth.blogs.nytimes.com/2013/08/27/from-mark-lynas-to-michael-pollan-agreement-that-golden-rice-trials-should-proceed/?src=recg>).
43. ^ Ronalyn V. Olea (August 9, 2013). "Farmers in Bicol uproot golden rice" (<http://bulatlat.com/main/2013/08/09/farmers-in-bicol-uproot-golden-rice/>). *Bulatlat.com*. Retrieved August 25, 2013.
 44. ^ http://www.slate.com/blogs/future_tense/2013/08/26/golden_rice_attack_in_philippines_anti_gmo_activists_lie_about_it/
 45. ^ Potrykus, I. (2001). "Golden Rice and Beyond". *Plant Physiology* **125** (3): 1157-1161. doi:10.1104/pp.125.3.1157 (<http://dx.doi.org/10.1104%2Fpp.125.3.1157>). PMC 1539367 (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1539367>). PMID 11244094 (<http://www.ncbi.nlm.nih.gov/pubmed/11244094>).
 46. ^ Dobson, Roger (2000) Royalty-free licenses for genetically modified rice made available to developing countries ([http://whqlibdoc.who.int/bulletin/2000/Number%2010/78\(10\)news.pdf](http://whqlibdoc.who.int/bulletin/2000/Number%2010/78(10)news.pdf)) Bulletin of the World Health Organisation, 78 (10), P 1281, retrieved August 10, 2010
47. ^ http://www.goldenrice.org/Content3-Why/why3_FAQ.php#Licence. Goldenrice.org. 2004-10-13. Retrieved 2013-08-26.

External links

- Golden Rice Project (<http://www.goldenrice.org/>)
- The Philippines Rice Research Institute - Golden Rice Questions and Answers (http://www.philrice.gov.ph/index.php?option=com_content&task=view&id=650&Itemid=246)
- Helen Keller International - Golden Rice (<http://www.hki.org/reducing-malnutrition/biofortification/golden-rice/>)
- Grains of delusion: golden rice seen from the ground: joint report by Biothai (Thailand), Cedac (Cambodia), DRCSC (India), Grain, Masipag (Philippines), Pan-Indonesia and Ubinig (Bangladesh) (<http://www.grain.org/briefings/?id=18>)
- "Golden Rice: Fool's gold or golden opportunity?" (<http://grist.org/food/golden-rice-fools-gold-or-golden-opportunity/>)

Retrieved from "http://en.wikipedia.org/w/index.php?title=Golden_rice&oldid=576428787"

Categories: Genetically modified organisms in agriculture | Rice varieties

-
- This page was last modified on 9 October 2013 at 12:39.
 - Text is available under the Creative Commons Attribution-ShareAlike License; additional terms may apply. By using this site, you agree to the Terms of Use and Privacy Policy.
 - Wikipedia® is a registered trademark of the Wikimedia Foundation, Inc., a non-profit organization.