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Genetic modification technology for nutrition and improving diets: an ethical perspective

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Genetically modified (GM) techniques to improve the nutrition and health content of foods is a highly debated area riddled with ethical dilemmas. Assessing GM technology with a public health ethical framework, this paper identifies public health goals, the potential burdens of the technology, and areas to consider for minimizing burdens and ensuring beneficence, autonomy, and little infringements on justice. Both policymakers and food producers should acknowledge local food environments and the agricultural context of each community in order to effectively prepare communication strategies and equitably distribute any proposed GM food intervention.

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Introduction

Agricultural production increasingly involves modern technology in order to meet growing quantity and quality global food demands [1]. One such form of new production is biofortification, or the process by which the nutritional quality of food crops is improved by adding nutrients or other health promoting properties through agronomic practices, conventional plant breeding, or modern biotechnology such as genetic modification [2,3]. Genetically modified (GM) foods with an increased micronutrient level, one type of biofortification, are foods whose genetic composition is altered in a way that does not occur spontaneously in nature. As a result, GM foods have sparked intractable debates in recent decades.

Many ethical issues arise with the production, use and consumption of GM technology when applied to foods [4••]. Beyond eating a diverse diet to deliver quality nutrients, should GM technology be used as a public health strategy to improve nutrition? Is the approach sustainable? What are the known and unknown health risks in both producing and consuming such crops, and do they outweigh potential nutritional benefits? What information should consumers expect to receive if they eat GM crops? What are the long-term social and economic costs and trade-offs of GM technology?

This paper draws on significant empirical evidence from the literature to try and answer these questions. In particular, the 'Ethics Framework for Public Health,' developed by Kass [5], serves as a tool to help stakeholders consider the ethical implications of programs with public health goals, such as GM foods in some circumstances. The use of Kass' framework (Figure 1) is not intended to answer all the ethical questions that may arise with GM technology, as its evidence base continues to evolve. Because public health promotes and protects health through social approaches, GM technology and its aims to improve population wellbeing warrant a careful analysis of ethical implications.

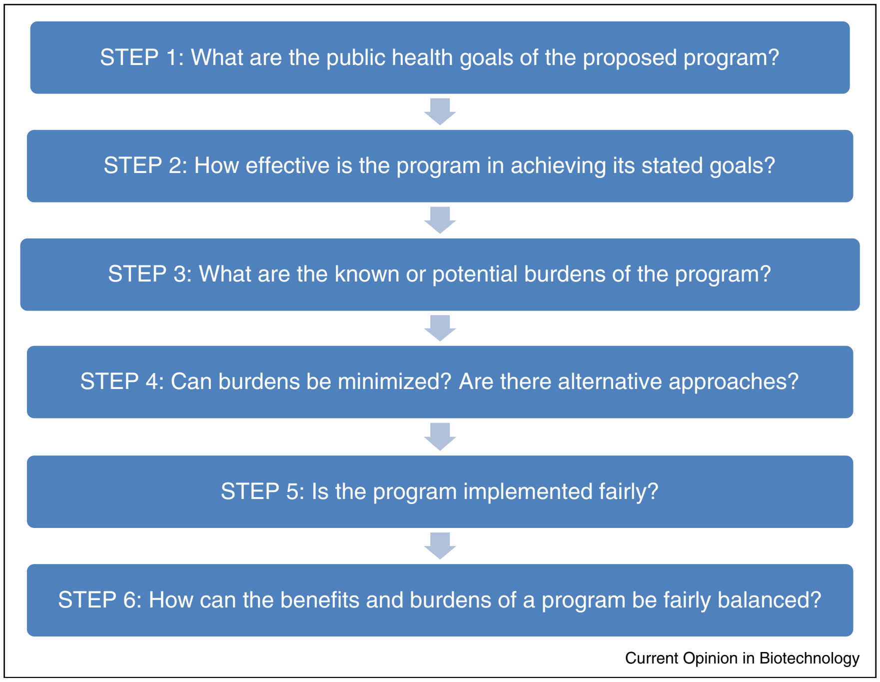
What are the public health goals of GM technology and are they being met?

Second generation GM crops are those which are bred to improve quality traits such as nutritional quality or processing traits. Alternatively, first generation GM crops are farmer-oriented, and aim to improve agronomic (quantity) traits. One goal of second generation GM crops is to address micronutrient deficiencies in rural populations. Most commonly, staple crops are bred to increase the nutritional content of Vitamin A, zinc, and iron. Golden Rice is one such example, described in Box 1.

It is important to note other second generation GM crops, which reflect public health goals that are different from biofortified crops or first generation GM crops: they aim to either increase consumption and reduce food waste or promote health/prevent disease (Table 1). Crops bred with sensory properties increase certain characteristics, such as taste, texture, or aesthetic appeal which can contribute to reducing food waste — an area of growing concern in food security and public health.

GM crops bred with quality traits to either promote health or prevent disease are also known as 'designer crops' [6•].

Figure 1



Ethics framework for public health. Source: Kass (2001).

One example on the market in the United States is Plenish® a high oleic soybean that has zero *trans* fat with a high amount of monounsaturated fat. As a public health measure that ultimately gave such crops as Plenish® more market potential, the Food and Drug Administration (FDA) issued a rule in 2006 that required all food production companies to display *trans* fat content in packaged foods on the Nutrition Facts label [7]. This regulatory change has raised consumer awareness and demand for reduced *trans* fat products.

Box 1 The complications of Golden Rice

Golden Rice is one example of a GM crop which was developed to produce beta-carotene, a precursor of vitamin A, in the grain of rice (Golden Rice Project, URL: http://Goldenrice.org). Ex ante studies have shown that Golden Rice can be a cost-effective strategy to achieve a public health goal–alleviating vitamin A deficiency (VAD) [25,27]. Although Golden Rice was initially developed over a decade ago, a complex regulatory framework for GM crops has significantly bottlenecked public rollout [28–30]. Agronomic properties, such as yield potential, and the opposition to GM technology itself, are two main constraints [21••]. During the period in which Golden Rice has been in the R&D stage, other public health initiatives in the Philippines have helped to decrease the prevalence of VAD in the country, with rates falling from 40.1% in 2003 to 15.2% in 2008 [21••]. Strong public ethical opposition to the technology reflects delays in research and implementation as seen in 2013 when activist organizations destroyed Golden Rice field trials in the Philippines [31]. In 2002, the Philippines was the first country in Asia to approve GM commercial crop cultivation. As of October 2016, Golden Rice is still awaiting release.

GM technology is also a tool to help address food security [8]. In some cases, first generation crops such as Bt eggplant are projected to increase income generation by improving yields and decreasing the necessity to invest in costly insecticides [9]. This can have potential indirect benefits on nutrition if additional income garnered from this 1st generation crop is spent on nutrition-direct interventions. An additional step in the consideration of GM as an ethical production technique reflects the fact that many of these crops were developed to provide global health *beneficence* by decreasing health disparities, particularly for the more vulnerable populations [4••,10].
Many crops bred for nutritional (quality) traits are still in the research and development (R&D) phase [11•], so assessing success in achieving the desired public health goal has yet to be determined. Delineating the public health goals of GM crops inform other ethical points of the framework and enhance the argument that GM technology should be assessed on a case-by-case basis. De Steur *et al.*, in this issue, provides insight on this claim by offering *ex ante* assessments on cost-effectiveness and the potential efficacy of GM [12,13].

What are the known or potential health burdens of GM technology?

Maleficence, or inflecting harm, is a potential burden of any new food production technique. Maleficence is of heightened concern with GM technology, particularly because research has yet to determine the extent to adverse

Table 1

Public health goal of second generation GM crops

Public health goal	Species	Trait-product
Increase consumption/ reduce food waste	Apple	Artic® Apples, non-browning
	Potato	Reduced production of acrylamide after cooking
		Innate™, non-browning biotechnology, reduced production of acrylamide
	Tomato	Enhanced shelf life
Nutrient deficiencies	Banana	Banana21, enriched in pro vitamin A and iron, disease resistance, drought tolerance
	Cassava	Increased nutrient (zinc, iron, protein and vitamin A) levels
		BioCassava Plus (BC+) increased iron and provitamin A[a]
	Corn	HarvestPlus Program: Vitamin A biofortification
		Vitamins A, B9 and C enriched corn
	Potato	Enriched in protein
	Potato, tomato, strawberry	Vitamin C biofortified
	Rice	Golden Rice, biofortified in beta-carotene
		Rice enriched in zinc and iron
		High-folate rice[b]
	Sorghum	Biofortification with iron and zinc
		Protein (+ iron, zinc and provitamin A levels)[c]
	Wheat	High Iron[a]
Health promotion/ disease prevention	Canola	High content in omega 3 fatty acids
	Grape vine	Increased anthocyanin production
	Pineapple	Enriched in lycopene, 'Rosé' variety
	Potato, tomato, strawberry	Vitamin C biofortified
	Soybean	Plenish® high oleic
		Vistive® Gold low saturated high oleic
		Stearidonic acid omega-3 varieties, high threonine
	Tomato	Enriched in anthocyanins
		Enriched carotenoid and flavonoid content
	Wheat	Gluten-free (celiac disease)
		High amylose

Adapted from: Ricroch and Hénard-Damave 2016.
[a] HarvestPlus brief #17 page 33: http://www.harvestplus.org/sites/default/files/Biofortification_Progress_Briefs_August2014_WEB_0.pdf
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outcomes [14,15]. About 36 countries, including over half of the European Union, have prohibited the cultivation of GM crops due to their potential risk of causing harm [16]. While the precautionary principle has been strongly interpreted to justify imposing an outright ban on GM technology, it is nearly impossible for any scientist to promise absolute risk regardless of the proposed food technology [17••]. One could argue obscuring such technology is a harm in and of itself, especially when its public health goal is to alleviate micronutrient deficiencies. Do we have a moral obligation to provide such technology without knowing all of the evidence? How much science is enough?

Another potential burden of GM technology is how technology competes with alternative strategies, including localized dietary diversity, fortification, and breastfeeding campaigns. A future hypothesized risk is that GM foods dominate the food basket, and the market focuses less on other sources of nutrient-rich foods beyond staple grains. GM crops may also create an additional risk of displacing traditional crop varieties that have higher nutrient value and are locally adapted to the environment [18]. Regardless, GM foods should not be immediately discounted as one tool to ensure a diverse food environment [19]. However, knowing which interventions are planned or already implemented is critical, as is involving the community in any initial intervention or market change [20]. Easing potential burdens requires understanding the intricate and established relationship between the crop and local culture [21••]. A combination of interventions that complement each other is most likely to reach those opposed to GM technology while offering a viable and sustainable approach to meet nutrition needs.

From a nutrition standpoint, no evidence currently indicates GM foods are riskier to health than conventionally bred crops [22,23]. A developing concern, however, reflects production health risks arising with growing farmer-oriented (first generation) GM crops. While GM technology itself does not pose a health risk as far as the evidence suggests, the pesticides and herbicides used to grow first generation GM crops could potentially place farm workers and consumers at an increased and undue risk. The evidence on cancer risk and specific chemicals, such as glyphosate, is mixed [24]. From a public health nutrition standpoint, the benefits of second generation GM technology could outweigh the risks, particularly for populations suffering from micronutrient malnutrition with little access to quality and diverse foods. However, in places where GM technology requires more use of pesticides, unknown risks to population health should be deeply examined on a case-by-case basis to assess ethical trade-offs.

What should be considered to minimize health burdens and implement GM technology fairly?

It is essential to consider both the *context* in which GM crops are being debated, and the *target* population for whom these crops may benefit in order to minimize burdens [21••]. Crops bred for micronutrient deficiencies may be assessed differently than those bred for sensory or health-promoting attributes since the context of GM use is distinct. For instance, Filipino farmers could theoretically reproduce the Golden Rice seeds themselves if GM technology were widely adopted throughout the country. Such reproduction would allow the traditional pathways of the informal and formal seed markets to stay intact [25,26] (see Box 1), reducing threats to justice and the autonomy of farmers. On the other hand, targeting the general population with second generation GM crops bred for sensory traits or health-promoting attributes would likely not face significant opposition if communication of the public health goal is transparent. This exemplifies how GM technology ought to be judged by context.

Ensuring both farmers and consumers can choose whether to use, adopt, or eat GM foods reflects issues of *autonomy*. When referring to farmers' choice, Weale [17••] states: 'The moral imperative is to ensure that they are in the position both to have access to the technology and to make a choice about its use in the light of their own circumstances.' Regarding consumer autonomy, labeling of GM foods has been used as a regulatory strategy in 64 countries worldwide. As of 2016, the United States is the most recent to adopt GM labeling laws. Some view labeling as respect for consumer choice and self-liberties [4••,24,32], while others oppose it for fear of misleading consumers by inducing false harm or limiting choice by pushing GM ingredients out of the marketplace [22,33,34].

Effective *communication* strategies are critical for any public health intervention. Many consumers do not understand what GM foods are, relying on the internet and other social media sources for information to shape their beliefs [35••]. Such news may not always be fair, and is often biased in favor of one ethical viewpoint [36•]. Negative information often dominates the views of consumers even when paired with positive information [37]. Risk perceptions of GM foods also vary based on region. For example, consumers in Europe have more negative perceptions, attitudes, and intensions to purchase GM food compared to North Americans [38]. Future education strategies must target intuitive thinking modes to help improve perceptions of GM foods [39].

The intersection of information and communication is where the scientific community and seed industries can play a better role by answering the concerns, questions, and constraints faced by GM food acceptance [35••,40•,41]. Colson and Huffman [42] show consumers' willingness to pay for GM foods is positively correlated with nutritional attributes when manufacturers provide clear communication. In countries where micronutrient deficiencies are the goal of an intervening technology, drawing attention to malnutrition and the benefits of the technology along with other strategies may help decision-making [43]. Local consumer behavior, perceptions, and attitudes must be better understood in order to resolve GM conflicts [44,45]. Partnerships across disciplines are necessary to help educate and disseminate reputable information on a vast array of media platforms [26,46].

Conclusion

Collaboration between multiple pathways [47] and approaches is required to feed the world well. If GM is to be one such approach, policymakers, seed companies, and plant breeders should take into consideration the context in which the crop will be introduced and evaluate the best communication strategies to aid in fair and transparent implementation. While countries have the right to determine if GM foods are relevant in addressing public health goals, governments should not infringe on their own food sovereignty. Moreover, policymakers, researchers, and industry ought to relay both the benefits and potential risks about GM foods through transparent communication measures to the public.

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