The Challenge to Meet Global Need for Protein Sources for Animal Production**

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Summary

Increasing prosperity in populous countries has accelerated animal production at a much higher rate than the growth in human population. The current annual global feed need is 1 billion tons and there is an emerging crisis for increases in high-quality protein feed sources to support animal production. Today, animal production is reliant on soybeans, which form the bulk of world commerce of feed protein. Current trends and needs show that soybean and alternative protein crops will be needed to keep pace with demands for global livestock feed. Biotechnology using new synthetic biology methods can provide the means to enhance soybean production and develop new feed sources by reconfiguring other crops as protein production platforms comparable to soybeans.

Current realities

Efficient animal production requires feed with high protein content. While maize (875 million tons produced in 2011) provides much of the carbohydrate source enabling animal production, other crops provide much of the protein. Current global feed protein supplies are dominated by soybeans, canola meal, animal by-products, fishmeal, as well as many other less abundant and regional sources. Only soybeans, canola, and fishmeal are truly products of global commerce, where the feed protein sources from one part of the globe are used to support animal production in other parts of the world, and often with delivery of the animal products to yet another part of the globe. As more populous nations become prosperous, there is and will be greater pressure to increase animal production. The impact this will have on land and water resources, competition between food, feed, and fuel, and the need to escalate feed and animal production is a global concern. Global animal production is growing much faster than the rate of human population growth.

For the foreseeable future, soybeans will remain the single greatest protein source to support animal production. The meal from 85% of the 251 million tons of soybeans produced globally (2011) is used to produce animal feed. Soybeans produced in the Americas are a global commerce product and form the basis for expanding livestock production in Asia, a region where growth in animal production has been most rapid. Canola meal, a by-product of seed oil production, is another major source of vegetable protein, although it constitutes only a fraction of the soybean commerce. Although only 2%–3% percent of global protein commerce, fishmeal remains an important contributor to protein sources for animal production. In fact, 25% of all fish caught are processed to make fishmeal. The use of fishmeal leads to human health issues by concentrating mercury and PCB pollutants that has attracted the attention of government regulators, who have issuing warnings against consumption of fishmeal-fed aquaculture products. The use of fishmeal also has a negative impact on the marine environment by removing the forage fish base of the food chain. Terrestrial animal by-products remain a significant reprocessing source of feed protein (4%–6%), although in the aftermath of the Mad Cow episode in Europe their use has been greatly diminished by regulation and by consumer choice.

There has been limited use of synthetic or transgenic biology to improve the content and quality of plant protein products used for animal feed; more effort has been directed at improving the protein quality for crops directly consumed by humans. However, the development of these products has been stymied by anti-GMO politics. The Gates Foundation has funded biotechnology projects directed at improving protein content and quality in staple crops, especially in Africa. Other international programs have used conventional breeding to create rice and maize with enhanced essential amino acid balance, and there have been similar breeding efforts to enhance the major feed

protein crops (soybeans and canola) with limited impact.

Scientific opportunities and challenges

The improvement of current feed crops through biotechnology is critically needed to enhance their production and quality. As the major global supply of feed protein, the soybean's critical role in the feed industry has made its long-term enhancement a strategic objective. However, because soybeans only grow productively in certain regions of the world, additional sources of plant protein are needed, especially if the crops can be grown productively and economically in global regions where soybeans are not produced. Such crops might be targeted for the cooler northern regions currently dominated by cereal production and/or be able to tolerate the arid and more saline regions of the globe.

The use of synthetic biology to enhance crops is still in its infancy. Almost all of the current transgenic crops exhibit traits designed to limit the impact of insects, viruses, or competitive weeds, which primarily benefit producers. Only recently have consumer-valued traits begun to emerge, such as low *trans*-fat soybean oil conferring a health benefit as a source of fry oil. Engineering a plant's protein quality and quantity to date has largely been in the context of attempting to improve protein content and quality in the starchy staple crops used as human food in less-developed nations. Biotechnology may be able to create a new "soybean" from other crops. By using genomics as the basis to alter the genetic program of other crops, it is feasible to use synthetic biology to engineer other crops to possess protein qualities similar to soybeans. One example is our project at the University of Arizona where we have altered *Camelina*, an oil seed crop related to canola, to have output traits very similar to soybean plants. This plant grows in northern climates, tolerates arid and marginal conditions, and can be grown as a winter crop between soybean crops, enhancing the productivity of existing farmland. We are developing this as a potential feed source engineered by synthetic biology because, from an agronomic perspective, it can be grown in competition with maize and soybeans, including on marginal land. *Camelina*'s other favorable characteristics are that it is not used as human food, thereby avoiding issues of transgenics in food, and being European in origin, there are no native plants capable of genetic out-crossing with *Camelina*. Current *Camelina* production is directed at biofuels with a meal side-product, a situation we envision to reverse, with the meal being the primary product for feed and the oil as a by-product.

Policy issues

- **International centers for feed research and development.** The increasing need for protein sources for livestock feed is a global concern and should be supported through education and research investments by transnational projects. There are ample opportunities for NGOs as well as governments to use livestock feed for bilateral and multinational projects. There are many international organizations involved in crop improvement, but none of them are specifically directed at animal feed. The Food and Agriculture Organization (FAO), the Pew Trusts, and other organizations have published white papers on the needs and the looming crisis in animal production, but these have not specifically called for establishing one or more international centers encompassing terrestrial and aquatic animal species. Such centers would, of necessity, need to bridge crop improvement and animal health and production. Animal feed research centers will need funding streams that require government, industry, and foundation support.

- **Enhance the productivity and composition of current feed crops**. For example, as a global commodity, fractional increases in soybean production could have immense impact. Because soybean trait enhancements will likely be transgenic through synthetic biology, there are persistent regulatory impediments.

- **Develop new feed crops.** There are many potential plants that could be developed into enhanced feed using synthetic biology. The *Camelina* research under way at the University of Arizona is but one possible example. The U.S. Department of Agriculture currently funds development of new crops with intramural and extramural programs primarily aimed at human food and biofuels. This program could be expanded to include animal feed crops and serve as an example for the funding agencies in other nations.

- **Address the competition between biofuels and feed.** The use of food crops for fuel is increasingly controversial, exchanging global food supplies for fuel predominantly for industrialized nations. There is a growing world opinion that using food as fuel increases food costs and decreases supply. Moving to next-generation biofuels or nonbiological alternatives will increase global food supply. Transgenic synthetic biology will enable the development of fuel crops or algae to be superior sources of fuel, releasing the crops currently converted to ethanol and biodiesel oil. Current global funding for next-generation biofuels should evolve quickly to support the goal of transferring food/feed crops to their traditional use.

- **Increasing regional production of alternative vegetable feed.** With soybeans and maize as the current primary global feed sources, the center of their production in the Americas is far distant to the growing sites of animal production in Asia. Alternative feed sources from other continents will improve sustainability and economic viability. Alternative feed development should be a priority for international research centers funded by government and/or NGO sources, needing only a small fraction of the funding now expended on research on important human food crops.

- **Abolish the use of fishmeal for animal feed and replace it with sustainable vegetable protein**. Fishmeal provides only a small fraction of global protein for animal production, but its use has a major impact on world fisheries and ocean productivity. By using transgenic synthetic biology approaches, it should be feasible to engineer sustainable vegetable protein substitutes for the small fraction of global feed protein currently supplied by fishmeal.

*** A policy position paper prepared for presentation at the conference on 21st Century Borders/Synthetic Biology: Focus on Responsibility & Governance, convened by the Institute on Science for Global Policy (ISGP) Dec. 4–7, 2012, at the Hilton El Conquistador, Tucson, Arizona.*