Benefits of Improving Livestock Feed Efficiency

Key Points and Take Home Messages:

- At currently achieved adoption rates (30% adoption), a 30% improvement in animal feed conversion ratio (FCR; 30% less feed per unit food product) would provide protein for an additional 0.5 billion people.
- If adopted completely (100% adoption), a 30% reduction in feed required to produce product would only provide enough protein for 1.5 billion additional people
- Additional gains in FCR through investments in animal nutrition research are necessary to provide protein for an additional 2 billion people by 2050.
- Researching barriers to technology adoption, improving training and prevalence of educators and improving global feed and supplement availability will also be essential in this effort.

Global Food Production System and Challenges:

The National Animal Nutrition Program (NANP) is a National Research Support Project that serves as a forum to identify high-priority animal nutrition issues and provides an integrated and systematic approach to sharing, collecting, assembling, synthesizing, and disseminating science-based information, educational tools, and enabling technologies on animal nutrition that facilitate high-priority research across livestock species. Providing sufficient high-quality protein for the future is an imperative global challenge to which animal nutrition research is vital. Global population is projected to exceed 9 billion people by 2050 [1] with substantial increases in demand for food energy and protein. Food production resources are already limited [2, 3], and livestock FCR must improve to help meet future food demand. Substantial variation in FCR is observed worldwide [4] illustrating the need for improved technology adoption. Historical improvements in FCR [5] demonstrate that additional gains can be achieved through continued investment in animal research.

Current Production Efficiencies:

Substantial global variation in animal FCR has been reported worldwide. In 2014, regions with the greatest FCR used 0.62 kg feed to produce 1 kg milk [4]. In the countries with low FCR, 2.38 kg feed was required to produce 1 kg milk [4]. Poor animal health, reproductive failure, and inadequate nutrition contribute to low efficiencies in anima production. Nutritionally balanced diets can lead to improved animal health [6], reproductive efficiency [7], and profitability [8]. As such, increasing adoption of nutritionally balanced livestock diets is a logical step toward addressing common production challenges in systems with below-optimal efficiency. When comparing between systems, opportunity for a 75% reduction in the amount of feed required to produce 1 kg milk is apparent in some systems. In more efficient systems, the opportunity to further reduce the amount of feed required to produce meat, milk or eggs in unknown. In either case, new biological research and effective technology dissemination will be important components of a strategy to improve FCR.

Applying Today's Knowledge, Using Today's Techniques:

The benefits of improved technology adoption rates and improved FCR were quantified on a global scale in terms of additional human annual protein requirements (16.4 kg protein/person/year) met from a constant feed base. The quantification of these benefits is detailed in the caption of Figure 1. Although global FCR comparisons are limited; a comparison of the dairy sector estimated average global FCR at 69% of the best FCR currently achieved [4]. Global assessments of technology adoption rates are also limited but literature in developed countries suggest rates of 22 to 65% of farmers will adopt a technology after learning about it [9]. Literature in developing countries revealed adoption rates of less than 25% [10]. The shaded region of Figure 1 shows the current opportunity to meet additional human annual protein requirements assuming 30% less feed is required to produce the same weight of food product and that 30% of farmers achieve this improved FCR. Given these rates, the improvement in FCR would result in protein to meet the requirements of an additional 460 million people.

Improve Agricultural Extension:

If adoption rates could be improved to 100%, additional feed to meet the annual protein requirements of 1.5×10^9 people could be provided given the currently achievable 30% improvement in FCR. The cultural role of livestock, history of subsistence management, lack of effective education, expense of technology, and limited availability

of feed are barriers to improving adoption of management practices that may improve FCR. Understanding social barriers to adoption is a growing research focus and will be essential to improving efficiency of extension and technology transfer efforts. Limited technology availability is another common barrier to adoption. Since 2005, global internet and mobile phone use has increased 240% and 270%, respectively [11]. In addition to connecting people more efficiently, this technology expansion demonstrates a trend towards decreasing practical adoption barriers. Information on beneficial feeding practices and computer software needed to assess nutritional needs of the animal and balance rations are available or can easily be made available to assist with the educational efforts. However, educational efforts will require a large investment in human capital. Availability of information and tools on the internet will not be adequate to substantially improve adoption rates. Trained educators knowledgeable of best management practices and proficient in the use of educational and technical tools are required. An unresolved practical barrier is the global availability of quality feedstuffs. Improving FCR will require the use of high-quality feedstuffs and supplemental feeds (forages, grains, oilseed meals, etc.) and may require the use small inclusion, specialty ingredients such as crystalline amino acids, mineral and vitamin supplements, or ruminally protected protein or fat sources. Although-well formulated products are consistently available in most developed countries, their adoption is variable, and availability of feed supplements in developing countries varies. Improving availability of feeds and supplements worldwide will help decrease practical and economic barriers associated with improving FCR.

Improve Biological Efficiency:

Assuming adoption rates remain around 30%, research aimed at improving FCR provides a remarkable opportunity to improve global protein security. Biological maximum FCR are unknown; thus, establishing practical bounds for improving FCR is difficult. To feed 2×10^9 additional people by 2050, animal products would need to be produced from 65% less feed if technology adoption rates remain at 30%. Although a 65% shift seems large, in the U.S. between 1944 and 2007 the dairy industry decreased feed use per kg milk by 86% [5], demonstrating that remarkable improvements in FCR are possible when enabling technologies are identified and adopted. In Figure 1, the barrier between the slope and the plateau represents the combination of biological and technology transfer efficiency improvements that would help to feed an additional 2×10^9 billion people. Comparing this barrier with the dark-shaded square (the currently achievable opportunity) demonstrates that simply adopting today's technologies using today's outreach practices will be insufficient to feed the growing global population. Both biological and social research aimed at improving FCR and improving technology adoption will be required. The assumptions made in this analysis are listed in Table 1.

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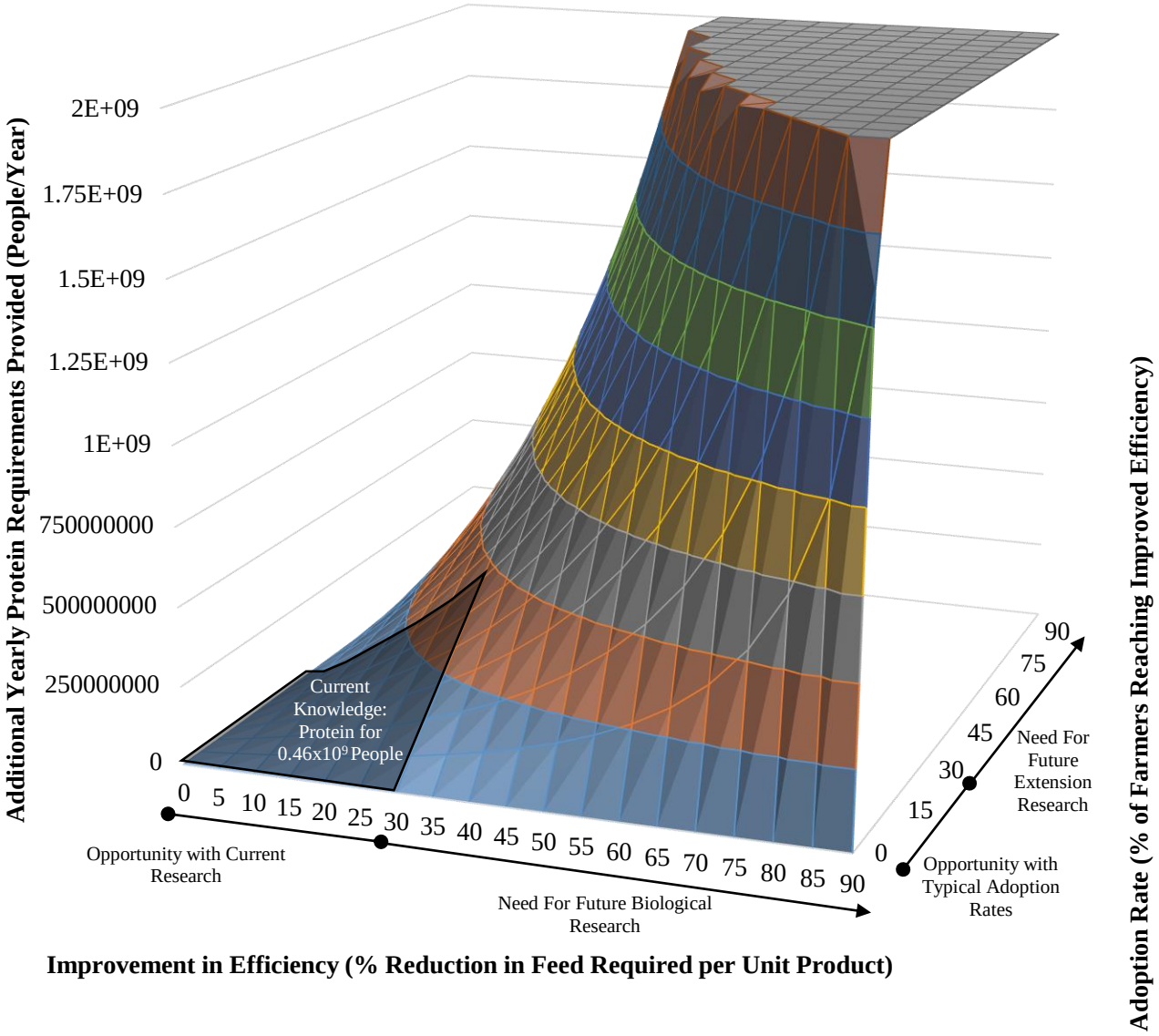

Figure 1. Response surface of expected improvements in global protein availability when livestock FCR and adoption of agricultural technologies are improved. Feed conversion ratios within the current opportunity range represents improving the global average FCR to efficiencies achieved within well-managed systems (current efficiencies in the best region). Improving FCR beyond that range will require additional biological research to identify efficiency-improving technologies. Improving adoption of agricultural technologies within the current opportunity with typical adoption rates reflects the proportion of producers adopting the improved FCR technology. Expanding adoption rates past 30% will likely require investment in social research and technology transfer efforts. The values in the chart were calculated by identifying the meat, milk and eggs attributable to individual farmers given population and production statistics from FAOStat, and employment data from the World Bank. The increase in meat, milk and eggs at each efficiency level for farmers adopting the technology was added to the baseline meat, milk and egg production for farmers not adopting (0% improvement and 0% adoption). Meat, milk and egg production was converted to protein requirement units using protein content of products provided by USDA/ARS, human daily nutrient requirements from USDA weighted by population age and gender distribution. Meat was assumed to dress out at 63%, of which 50% was available to humans; milk and eggs were assumed 90% available. Meat protein content (125 g/kg to 183 g/kg) and milk or egg protein content (33 g/kg to 126 g/kg) ranged with species. Each break between colors represents the production of protein to meet requirements of 0.25×10^9 people. Assumptions about this system and baseline FCR are listed in Table 1.

Table 1. Assumptions about the food production system required to produce Figure 1.

Assumption	Justification
An additional $2x10^9$ people will require animal protein	The increasing population and demand for meat and milk may yield a net increase in animal protein demand. Identifying the improvements required to achieve an extreme scenario, like $2x10^9$ additional people, is a prudent method of setting research targets.
The animal populations worldwide will remain constant	Expanding animal agriculture may be one way to meet growing demand for animal protein; however, given land and water limitations, it is more prudent to assume animal populations must remain constant.
Global average FCR will vary by animal	Baseline global FCR for chicken meat (2.5 kg/kg meat), eggs (1.5 kg/kg eggs), cattle meat (8 kg/kg meat), cattle milk (1 kg/kg milk), goat/sheep meat (9 kg/kg), goat/sheet milk (1.5 kg/kg milk), and pig meat (3.5 kg/kg meat) were assumed to 68% of currently achieved ideals.
This analysis does not consider: (1) the quality of feed required to improve efficiency; (2) the region-specific nutrient limitations; or (3) the resources required to produce feed	(1) Improving FCR in developing nations will require new feeds. Although native range may remain a basal diet, supplementation with concentrates, oilseed meals, minerals, vitamins, or specialized fat and protein sources may be essential in improving efficiency. These feeds could be imported or produced or cultivated domestically. The social and resource-use consequences of both approaches require further evaluation. (2) In some regions, energy may currently limit efficiency and gains from improved energy balance are likely. Elsewhere, protein may be overfed and balancing amino acid requirements may be an effective method to reduce feed use. More thorough evaluation of the specific nutrient limitations must be conducted on a system-by-system basis. (3) Land and water resources for feed and food production are scarce, and social pressures may limit opportunities to devote additional land to feed production. Improved use of byproducts, recycling of animal manure, and improved understanding of animal nutrient requirements is essential to optimizing resource use.

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