Interpretive Summaries

Endpoint Criteria: Optimal vs. Maximal
Roselina Angel, University of Maryland

Need to change focus – in order to meet target excretion/emission reductions
(2012 targets – 50% reduction in phosphorus (P) and nitrogen (N) excretion…)

- Dairy and Swine – Have been moving for some time towards feeding to genetic potential
(meeting individual or small group requirements) for production of sellable products
- Poultry – lagging behind
  o Broilers still grown as mix of males and females (as hatched)
- Optimal vs. Maximal
  • Requirements usually determined at maximal productivity
  • Must change mind set from efficacy as (feed/gain, feed/dozen eggs…) Think more
  in terms of g nutrient (N and P)/ g of sellable product, or g of nutrient per cost of
  producing sellable product or income per g of sellable product.
- Requirement information for poultry, example phosphorus requirements, is based on maximal
bone ash. But do we sell bone ash? The question should be what is the relationship between P
consumption and bone ash and production of sellable product. Establishing correlations allows
industry to choose comfort level of P in the diet to obtain results they target.
- Regulations if not carefully establish can result in unwanted consequences. In Maryland the
mandate to use phytase in poultry diets has resulted in decreases in total P in litter but in large
increase in soluble P in litter. Industry still feeding above requirements more so in areas where
phytase is not used.
- How do we make reductions actually happen
  o There must be economic incentives (cost/rewards?)
  o Clear measurable baselines must exist.
  o Decreases should be measured/kg of sellable product.
Impact of enzymes, additives, microbials, beta-agonists
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Animal nutrition is presently a relatively imprecise science due to the variable nature of nutrient availability. Two factors play a large role in this variation, that of nutrient content/availability of raw materials from sample to sample, and variation between animals in their ability to digest nutrients from the same diet. As a consequence, most nutritional programmes oversupply nutrients most of the time, the reason being to minimize the number of times that diets are offered which create a deficiency in any given nutrient. A direct result of such a practice is that those nutrients excess to requirements are excreted into the environment.

Knowledge of the likely deficiencies allows for direct remediation with amino acids and concentrated energy sources, for example, but further improvement will necessitate more precise understanding in variation in nutrient availability. Variation in ingredient nutrient availability is to some extent governed by the presence of anti-nutritive factors, some of which can be addressed through use of enzymes. Individual bird variation is a result of many factors, including resident microfloral populations and energy partitioning between maintenance and productive activities. Variation in such variables can be reduced through judicious use of microbials and beta-agonists. It is clear, however, that in order for any such approach to be successful, it is essential that the feed formulator has an immediate and continuously updated information flow with regards to the quality of raw materials at his disposal. If this information could be coupled with “titratable” solutions then there would be significant reductions in waste production.

Changes in the nutritional landscape are likely, however, accelerated by the desire to produce ethanol from starch as a green “alternative” to fossil fuels. The irony is that in the drive for more environmentally friendly fuel solutions, animal nutrition will be forced to use a greater proportion of higher fibre ingredients (such as DDGS) with concomitant increments in waste production. Solutions to such future problems are being actively researched at present, but given the regulatory environments for additives is now much more involved and can take 3-5 years, these solutions will not be in hand for many years to come.

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Lactating dairy cows are efficient converters of feed into human food but in the process excrete large amounts of methane, P and N, all potential pollutants in the environment. The greenhouse gas methane is produced as a normal consequence of ruminal fermentation. Concentrations of P and N in manure are very dilute, which compounds problems related to their disposal. The question is: “How can we minimize output of methane, P and N with minimal effect on production?”

Methane formation per unit gross energy consumed is inversely related to ruminal fiber digestion and, thus, increasing concentrate and reducing forage in the diet will reduce methane output. Dairy cows require dietary fiber to maintain rumen health and increasing amounts of feedgrains are being diverted to ethanol production. Dietary ionophores, such as monensin, have been shown to reduce methane output, although the effect may dissipate over time. A large proportion of ruminal methanogenic bacteria are associated with protozoa and suppression of protozoa decreases methane production. Reducing protozoal predation of bacteria also increases microbial protein yields in the rumen. Feeding medium-chain fatty acids (e.g., lauric acid and myristic acid) have been shown to suppress both protozoal numbers and methane output.

High levels of dietary P were recommended for many years because this was thought necessary to maintain reproduction in dairy cows. However, recent work by Wu and Satter showed that feeding 0.35% P in the DM was adequate to maintain bone mineral and services per conception. Excretion of soluble P, which has greater pollution potential, increases at dietary levels greater than 0.35%. Many byproduct feeds, notably distillers grains, are high in P and, unless some of this P is removed during processing, their feeding will contribute to excessive P excretion.

Consultants often recommend, and farmers often feed dairy cows diets with excessive amounts of CP. However, except for early lactation, properly balanced diets with about 16.5% CP are adequate to support lactation. Excessive feeding of CP results in exponential increases in urinary N, which gives rise to ammonia volatilization. A number of strategies are available to improve N efficiency in the dairy cow, including: 1) optimizing microbial protein formation in the rumen through optimizing carbohydrate fermentation and supply of rumen-degraded protein (RDP); 2) feeding rumen-undegraded protein (RUP) or protected amino acids (especially methionine) that are complementary to the amino acid profile of microbial protein; and 3) using complementary feed sources of protein and energy, such as legumes and grasses. Because the response of microbial protein formation to additional RDP appears to be relatively small, reducing RDP supply will improve net ruminal capture of recycled urea and, thus, decrease urinary N excretion. Feeding complementary RUP and/or protected methionine could help compensate for some loss in ruminal protein formation. Distillers grains, although high in RUP, have very low lysine content. It is speculated that reducing CP by 2 percentage units in a properly formulated diet would result in only small loss of milk and protein yield but would reduce N excretion by more than 10%; nearly all of this reduction would come from urinary N. Work is progressing on altering plant characteristics to enhance N utilization.
Specific regulations that affect us tend to be the focus of our concern. My intent is to stand back from the specific regulatory issues and give a framework for thinking about regulation and the regulatory policy decisions that are made. Those in the industry are far more competent to look at the specific regulatory concerns the industry faces.

Public enthusiasm to regulate ebbs and flows, but market failure is what brings about regulation. The firm with an unsafe workplace may not have to pay for the consequences, so we regulate a safe workplace. The scope of this regulation is critical to the costs of such regulation and to the incidence of who bears the cost. Can the regulated firm pass the regulatory cost on to its customers? – not if one is competing with a firm in another country with no regulation and there is free trade - not if one produces a commodity where there are many sellers and buyers and little product differentiation.

One obvious question is; what are economists good for when regulation is proposed? Economists can try to estimate the costs of the regulation and also the potential costs to society of the damage that is suffered rather than prevented through regulation expenditure. Economists must not be counted on to be the sole determinate of the level of regulation. Don’t expect economic analysis to make a good regulatory decision for you.

Recently there has been a trend to “market based” regulation. We need to recognize it is only market based within a given regulatory framework. The “market based” aspect may increase efficiency at the point of regulation, but may or may not meet the larger goals of why regulation was instituted in the first place. The most effective approach to regulation is to be sure that the right questions are asked when the initial regulatory debate occurs.

- Have we defined the actual problem or just a symptom? (Will it do the job?)
- What is the appropriate objective for the regulation?
- What is the appropriate scope for the regulation
- What is the full cost of the regulation? (not just monetary cost to my firm)

We need to be most concerned about those regulations that come up short when these basic questions are asked. In objecting to ill conceived regulations one can develop strong public support. However, when a regulation reflects a strongly held public concern, we are better off in the long run supporting better regulation than no regulation at all.
The ethanol industry is rapidly expanding, which leads to a large increase in the supply of distillers grains and other feed byproducts. The ethanol production process results in feed byproducts that have an elevated percentage of both phosphorus and protein (N) that leads to dramatic increases in the levels of N and P fed to beef cattle. Use of ethanol byproducts does not markedly change the dietary nutrient content of dairy, swine, and poultry based on inclusion levels or requirements. However, economics have dictated the use of these feed byproducts. Therefore, beef feedlots face a dilemma of using larger amounts of byproducts while also increasing the amount of P in manure as well as the potential for N volatilization.

The focus should be multi-faceted to help solve this dilemma. For example, we have developed a model to predict the amount of nutrients excreted based on the amount of nutrients fed as well as performance. This model then allows for producers to determine the crops, number of acres, distance from their operation based on local access, as well as a predicted cost of distributing manure nutrients based on equipment and time. This allows for producers and planners to appropriately distribute manure on a large enough land base, as well as determine the cost/benefit of spreading this manure. For P challenges, this is relatively simple and straightforward.

The larger challenge will be N and managing N losses from open-lots. When protein is overfed, N excretion is dramatically increased in the urine (across all species). Depending on the housing system and manure management practices, 10 to 80% of excreted N may be lost, primarily via volatilization as ammonia.

In the future, a systems-based approach should be implemented whereby nutrient flow is adequately monitored from feeding until nutrient utilization by crops. One method of decreasing these challenges is to feed less. In the near future, this approach will be economically infeasible, therefore, other approaches are warranted. Other approaches may include different cropping systems, extraction of P from the process and use as a higher value fertilizer, changing the housing systems to minimize N losses, changing the application systems and incorporation of manure, etc. However, a critical first step is to recognize the dramatic change that feeding practices will have in the future on nutrient balance. Lastly, a vast educational effort is needed to enhance the use of manure as a fertilizer and to value this manure as a fertilizer source in replacing inorganic or commercial fertilizer use. This focus is already occurring in some land-grant universities, but more is needed to ensure that nutrient losses are minimized. Unfortunately, environmental policies (laws) in place currently discourage the use of manure as a fertilizer source relative to commercial sources.
Panel Discussion: Meeting Potential Environmental Goals
Thomas W. Graham, Owner, Veterinary Consulting Service

I do not lay blame for land, air and water degradation on agriculture, but on the expanding human population requiring its products. Virtually all of these problems can be corrected if we spend enough money on remediation or reapply those nutrients back on the land from which they came, but at what cost? I will try to set the stage for my rationale for those statements by a series of questions.

The demand for food for the human population is expanding geometrically along with the population expansion and the consequence of failure to meet basic needs of the population increases international tensions for these competing limiting resources. Energy, water and food are the limiting sources for economic and social stability. Historically this means war is inevitable when any one of these resources reaches a critical limiting level.

What must be done to ensure adequate food production and distribution while ensuring a stable ecosystem, even if it is not the pristine wild lands of two or three hundred years ago?

I believe the basic requirements in the current NRC describe the needs of feeding dairy and beef cattle well. When feed quality and management is appropriate, current recommendations allows for efficient meat and milk production. That does not mean we will not improve those systems, but these recommendations have greatly increased the efficiency of meat, milk and hide production in our nations beef and dairy industries.

What do we need to do to sustainably produce food in this country?

This nation has always produced its own food and we must now ask whether we are trading self-sufficiency in food for a reduction in domestic pollution or for production of alternative fuels? This is the not in my backyard mentality, but does not alleviate the issues of the effects of the human population on their immediate and global environment, irrespective of animal agriculture.

Are we making the assumption that we can trade dependency on foreign oil for foreign food? No empire in history has sustainably existed while they depended on foreign powers for basic food security. Given this past months pet food contamination and subsequent poisoning of the dog and cat population in this country, it would be prudent to realize the intentional contamination of the human food chain would be far easier than we would have hoped. This accidental poisoning should be a clarion call to us all about complacency in our national security needs.

What are the consequences of “biofuels” on our nations basic national security needs? This comes to the heart of the matter for altering feeds for cattle production. There will be an excess of P and fats in many of these by-products as we will remove all the starch for the production of ethanol. If we can efficiently extract the oil, we will be left with a huge abundance of P rich protein (N) sources which will make balancing rations more challenging, but not impossible. That the livestock industry is to pay the price for the environmental remediation of the waste products of the energy sector and human food products waste disposal seems odd at best. Why shouldn’t the agricultural commodity sectors be paid to deal with these waste products? Certainly our garbage collectors in our towns are paid well to deal with all of our waste generation. Why shouldn’t the ethanol, cottonseed, canola, almond, soybean, etc., producers pay to deal with the excess P and N contained in their waste products from processing their human food and energy products? Environmental remediation costs for these products should be passed up the food and energy (gas and heating) chain where they belong: This will allow for appropriate accounting of nutrient contamination from the source industry. Without the use of these by-products in ruminant feeds the cost of waste disposal, methane, CO₂, NH₄, etc., generation will actually increase because these products will not be incorporated into the end-products of nutrient metabolism and used as a more highly valued, nutrient dense product (meat, milk, hides and fiber). As stated in the EPA presentation these costs are to be passed on to the consumer, as they should be to reflect the true costs of production of human food, fiber and fuel products.
All the required environmental remediation is predicated on the assumption that we will have ample land available to apply this waste, which will necessitate more habitat disruption to gain more ground. Given the consequence of the inflationary trends in land values (1031 exchanges have inflated land values tremendously 50 – 400%) many dairies will be choose to go out of business (or be forced out) because they will need to down size to accommodate the waste generation from their facilities. This loss of cow numbers for an individual dairy may reduce their income to a low enough point they will be unwilling to remain in a business that has about an 8% return on investment (excluding inflating land values, which are cyclically dependent on the strength of the economy and are what will greatly drive up the costs of production for food).

These laws will greatly expedite the shift of cows to areas that have a low human and cow population density, so that more cows will likely be moved to the arid West. This will affect water resources more dramatically in these drier ecosytems. Alternatively, producers will choose to allocate their assets to other enterprises for a greater return rate (why my wife’s family decided to quit milking cows). The United States was self sufficient in all dairy production 25 years ago and now imports about 14% of our total dairy product needs. Beef cattle imports continue to increase to supply the American markets, though the United States is still a net exporting country. Much of this decline in export was associated with BSE in the American cattle causing closure of several countries borders to our products. It is likely that the US will continue to import beef and some is coming from areas such as Brazil, where slash and burn deforestation is still practiced. What have we gained by indirectly promoting these unsustainable agricultural and ecosystem management practices which we have no authority to control?

Given the trends over the past 5 years there is a continuously downward return on assets to the dairy industry, though the beef industry has enjoyed some of their more profitable years in the last 20 years. With the increased costs of corn, this trend will continue to marginalize their asset value making many producers question whether this is the best time to exit the industry. Consumers are looking at moving to organic and “natural” milk and meat products because they do not like “factory farms”. However, the effects of these regulations may well be to cause this shift to large intensively reared milk production facilities.

What do we do with waste products of human food production and what would be the consequence of not feeding this to our domestic meat producing animals? I would suggest that animal agricultural, and ruminants in particular, do a great service by allowing better use of feeds like cotton seed, almond hulls, dried distillers grains, rice bran, etc., than their use in land fill. It also reduces the costs associated with food production because of the more efficient use of this waste.

Given the negative consequences of excess P and N in some environments what needs to be done to ameliorate these effects of feeding livestock for domestic meat, milk and fiber production?

Selection pressure on our nation’s gene pools has in part been predicated on the assumption that continually increasing milk and meat production per animal is more efficient and a better use of available land. This assumption has been based on the higher efficiency of rapidly growing animals and higher amounts of milk per cow, allowing for more efficient feed conversion to the desired end products.

Are maximum milk output per cow or growth rates are necessarily more efficient? Production curves are asymptotic suggesting that some optimum return on nutrient management can be obtained, albeit at the expense of maximum output per animal. What is the optimum nutrient throughput? I am not sure that has been well quantified.

Human pathogen issues of manure and other animal waste: What needs to be done to make the products the safest they can be? What needs to be done to minimize human pathogen transference while ensuring the most uniform distribution of waste products to soils. How do we minimize weed contamination or other biological (plant, nematode, arthropod or other infectious or parasitic) hazards to other plant and animals species?

Depending on foreign food does nothing to assure us protection from bioterrorism, it increases our risk tremendously. However, ignoring the potential of terrorism, historically outbreaks of FMD, Rinderpest, Hog
Cholera, etc have been brought in by the usual means of transporting foods. Mistakes will happen and at what cost to the domestic food production system? Self sufficiency is expensive, but allows for the best control of ones own markets and economies. The recent contamination of pet food should be a clarion call to be very wary of imported food products when we have no direct control of the source nations supply chain. That does not impugn China; it is applicable to all nations.

Welfare issues: Costs of food production, commodity price index, effects on the market basket price on the lowest socioeconomic groups.

Third world and developing world production without similar constraints on labor, emissions, P and N pollution, deforestation, etc just means we’ve moved the problem, but worse have no oversight on even pretense of control.

Are we looking at this whole issue in a truly ecosystem approach and looking at best practices to utilize human and animal waste stream products to maintain our soils and production capacity? In the process of doing this we could very well reduce the needs of importation of N and P for use as fertilizer and find better ways to ensure the highest utilization of this fertilizer for other crops.

Equip Programs are county specific so counties that are dairy counties will have available to them all the dairy programs, but if you are a dairy in a county that is primarily orchards then the programs available are focused on their commodity needs. What needs to be done to make this as equitable as is possible for all involved?

Methane production and ways to produce sufficient production to offset energy needs for irrigation, electricity needs for running the dairy and employee housing energy needs. Reduces emission of methane from dairies in particular, but the digester can be adapted to any of the production systems, at least in theory.

It is suggested that “Costs of compliance are passed through to consumers”…how so? My clients have seen a continuous reduction in inflation adjusted price for the last 30 years. They are producing milk for the same dollar amount as they did in the 1970’s. Necessarily then they are reducing the total amount of capital in rural America. If it is suggested that tax dollars are allowing this to be passed on to consumers, is there going to be an equipment revolving fund of tax dollars to offset the costs of depreciation and maintenance for the EQIP, CSP or other grants to establish and maintained lagoons, digesters, freestalls etc.? If not then the cost of animal products must necessarily increase to offset this additional cost. Following the same logic then we must consider the effects of increased cost of production, caused by the increased commodity prices, on profitability of each enterprise. In the west this has been increased by about $2/cwt to maintain the same level of production and health in the animal population.

Costs of air emission credits are skyrocketing and will cost producers a significant portion of their assets to remain in business in some regions.

Ammonia, NOx, N2O, etc. release can be major problem as a noxious air pollutant, but it is also critical for N cycling in the ecosystem providing substrate for much of the nitrogen fixation in N deficient soils. If we could remove all volatile N we would lose a major source of “fertilizer” in areas like the Sierras, Rockies, Appalachia, central plains, etc. Given the eutrophic state of good portions of California’s Central Valley some 200 years ago and before (as a large “rice field” so to speak) and the anaerobic fermentation in the now severely reduced hectares of swamp lands throughout the world, has global production of volatile N compounds been greatly increased by animal agriculture or because of the burning of all the fossil fuels and other industrial pollution? With the huge reduction in the global ruminant population over the past several hundred years has the manure production and rumination of by our restricted ruminant domestic ungulate population been responsible for all this problem? I think not. If anything the net efficiency of meat and milk production has been increased by the increased yields of from our current production practices. The bison, pronghorn, elk, moose, deer, and caribou populations have been greatly reduced and displaced by an approximately equal biomass of domestic cattle to supply food to the hugely expanded human population. Might it not be all the human manure and urban waste that is disproportionately contributing to the net gain in NH4, CH4, CO2, etc. Domestic livestock numbers have been on the decline, though
arguably turnover rates may be higher and the biomass of these animals may be equal to the larger population 100 years ago

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Nitrogen (N) efficiency (N in product/N intake) of production species ranges from a low of 25% for dairy cattle to a high of 45% for growing broilers (Bequette et al., 2003) under current management conditions. Nitrogen not captured in product represents a significant source of N export to surface water and ammonia emissions to the atmosphere. The former leads to denigration of surface and ground water, and the latter acts as a catalyst for small particulate formation resulting in degradation of air quality (Anderson et al., 2003; James et al., 1999).

Waste N arises primarily from the catabolism of dietary amino acids. The majority of productive N losses occur at 2 locations within the animal: 1) catabolism of amino acids (AA) in the rumen via microbial action (ruminants only), and 2) catabolism of AA by the splanchnic tissues (gut and liver). If significant improvements in N efficiencies are to be achieved, losses at these sites must be reduced. Additional gains in efficiency can be realized if losses at other sites in the animal are reduced, but the magnitude is less.

Nitrogen in the form of ammonia is required in the rumen to maintain optimal microbial activity. However, as N is recycled to the rumen from blood via urea, the ruminal microbial requirements for ammonia can be partially met from recycled blood urea if a diet low in ruminally degradable protein is fed. In such a case waste nitrogen from blood is recaptured in a productive form that can be utilized by the animal. Fully leveraging this approach could result in a 20% reduction in waste nitrogen output by dairy cattle and a lesser reduction in beef cattle. However, diet cost often increases when using such a strategy.

Amino acid catabolism by the splanchnic tissues is largely supply dependant. If the diet has an excess of some amino acids relative to others, those in excess will be preferentially catabolized at an elevated rate. If the supply of all amino acids is great, then catabolism of all amino acids will be elevated. Greater than 80% of the amino acid supply to these tissues is from arterial blood, and thus a good share of catabolism results from failure of productive tissues (muscle, mammary, reproductive tissues, etc.) to utilize amino acids. Stimulation of amino acid use by the productive tissues would result in a decline in catabolic use resulting in improved efficiencies. Alternatively if productive use can be maintained while dietary amino acid supply is reduced, N efficiency will also improve. This latter strategy underlies the use of amino acid supplementation in monogastric diets which has resulted in significant improvements in N efficiency relative to ruminants. Some near-term improvements in efficiency may be achieved in monogastrics using this approach with mixed economic costs. However, significant additional research is required to fully leverage the strategy in both ruminants and non-ruminants. Potential reductions in N release associated with this strategy may be as much as 20% in monogastrics and even greater in ruminants where amino acid supplementation is not widely practiced today.

Additional progress in improving efficiency may be achieved through genetic selection of animals that will tolerate lower dietary N inputs. Selection indexes may include rates of N recycling to the rumen, affinities for AA by the splanchnic tissues, or enhanced affinities for AA by productive tissues.
Reducing methane emissions from U.S. CAFO’s
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Methane emissions from animal agriculture result from enteric fermentation and manure handling practices. Production of CH₄ is not only a waste of carbon that could be used for energy, but an addition to the global methane burden. To date there are no strategies available to livestock producers to significantly alter enteric CH₄ emissions on a consistent and economically sustainable basis. Manure CH₄ emissions can be reduced by adoption of different handling practices, but many of these practices are still in the research phase and not ready for implementation. Methane emissions should be expressed per unit of product and not per head, per CAFO or per unit of manure. In this way, animal agriculture can continue to feed the world’s population and enhance production efficiency.

Research into methods by which enteric methane emissions can be reduced include addition of feed additives (e.g. enzymes) to enhance digestibility of dietary ingredients and by-products, altering the ruminal microbial population through vaccines or genetic manipulation of specific organisms, precision nutrition including improvement of models to better predict requirements, and targeted use of supplemental nutrients. Improvements in animal performance through genetic selection for adaptability and productivity will also reduce CH₄ emissions per unit of product. Changes in grazing management and genetic selection of pasture plants are required to reduce CH₄ emission from beef cattle, stockers, and grazing dairy cattle. Advances in reproduction such as sexed semen that will allow producers to rear only the beef and dairy replacements they need or selection for bull calves to increase steers and reduce heifer numbers in feedlots will change the population demographics in the beef and dairy industries.

To reduce CH₄ emissions from manure, waste-handling systems must more effectively separate the solids from the liquid fraction. Altering or eliminating the anaerobic processes that occur in deep pits or lagoons by waste treatment technologies or aerobic systems will decrease CH₄ substantially. Any changes in management must consider the need for substrate for fermentation in anaerobic digesters as well.

Enteric and manure CH₄ are a part of the entire animal production system and changes made to reduce emissions must be made in the context of the whole enterprise. Animal agriculture is challenged to reduce several pollutant species and care must be taken when designing mitigation strategies to not reduce one species while inadvertently increasing another.

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Changes in emissions by beef cattle from 2007 to 2009 are driven by two forces. The evolving ethanol industry is an overwhelming factor. In 2007, the surge in ethanol by-product supply created a huge supply of relatively inexpensive feedstocks. Unfortunately, these feedstocks caused diets to contain excessive levels of phosphorous, crude protein, and sulfur compounds. Fortunately, that created an elevated benchmark for N, P, and S, which could be impacted greatly just by reducing dietary levels of ethanol by-products. The timing coincides with a change in ethanol by-products (primarily reduced oil content) which would have forced lower dietary inclusion rates irregardless of emissions legislation. A significant proportion of total emissions comes from overfeeding cattle, both in terms of days on feed and in diet N, P, and S content. Shortening the finishing period by a more timely marketing of finished cattle substantially lowers emissions. In addition, a simple adjustment to lower dietary crude protein from 13.5% to 11.5 to 12% for cattle weighing over 900 lb also causes a substantial reduction in N emissions.

Depending on facility design and location, several facility management options were employed. Development of “Dynamic Pen Size” to increase surface moisture and timely pen grooming of earthen-floored pens reduced particulate matter and NH₃ emissions. In other regions, increased use of bedding improves capture and retention of N, P, and S. Settling basins installed prior to retention ponds reduce NH₃ and H₂S emissions. In some areas, vegetative filters, artificial wetlands, or soil infiltration systems integrated into runoff control systems reduced emissions.

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The efficiency of livestock production systems is a result of improvements in genetics, nutritional management, assisted reproduction techniques, and environmental comfort. Intensive production operations have resulted in amounts of emissions that pose threats to the soundness of the environment. Expected changes in legislation will require the livestock industry to comply with stricter regulatory demands. The role of genetic improvement of livestock in attaining these goals is briefly discussed.

Rapid reduction in emissions are possible with direct changes in nutritional management require upkeep because these gains will disappear if the changes are dropped. “Permanent” solutions in nutrition could include using better ingredients (e.g., corn with lower phytate phosphorus content) but this approach does not address direct changes in the animal for improved efficiency. Other problems with modifying diet composition may be reduced economic performance or increased health problems in animals. Rapid reduction in emissions like amounts of phosphorus and nitrogen in the excreta are not possible with genetics. Slow and permanent gains are a realistic goal that can be achieved without compromising technical performance of livestock or the economic viability of industry. At present there is no adequate knowledge that would enable industry to make any significant strides toward reducing emissions by 2012. At most, the results of one generation of selection would be reflected in commercial animals. Selection and crossbreeding strategies must be initially identified and combined in breeding plans for every livestock species.

After these initial steps are taken, a look into year 2017 should aim at further progress toward incorporating marker-assisted selection (MAS) into breeding programs. MAS could play an important role in early response to selection because excreta composition traits have not been directly selected for in the past. Steps in this approach include finding loci that are directly responsible for genetic variability in excreta composition and identifying animals with favorable genotypes to promote reduction in emissions.

It is anticipated that private industry will play the leading role for poultry and swine while the public sector will be the primary player for large animals. Investment in basic knowledge should be made available by the public sector but dissemination of gains will be rife where artificial insemination and embryo transfer are common practices. High level of coordination between industry and public agencies could optimize dissemination of genetic gains but it is uncertain if particular industry interests will not supersede broader goals for dissemination of genetic gains.

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Formulation to Include Environmental Impact
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Historically, ration formulation has not accounted for the cost and impact of nutrient excretion on the environment. Ration optimization can be accomplished by linear programming if all inequations in the set of constraints are linear. Nonlinear programming would be used otherwise. For a given nutrient, the amount excreted is equal to the amount supplied by the diet, minus the amount excreted in milk, and minus the amount retained (generally small). An additional equation to calculate the amount excreted is easily added to the constraint set. This amount is then added to the objective function (minimize feed cost) where it is multiplied by a coefficient representing the cost per unit of nutrient excreted. This coefficient is a function of storage, hauling, and land control costs. The first two of these require a prediction of manure volume (mass) for a given diet fed to a given animal. A meta-analysis of 14 fecal collection experiments done at the Ohio Agricultural Research and Environmental Center was performed (old data). The dataset included 55 diets of various compositions. The average cow had a DMI of 46 lbs/d and produced 67 lbs/d of milk. In addition, results from a recently completed experiment using 15 diets were used (new data), where cows averaged 53 lbs/d DMI and 84 lbs/d of milk (new data). Manure excretion averaged 140 lbs/cow per d in the old data and 176 lbs/cow per d in the new data. In both datasets, dry matter intake was the primary determinant of total manure excretion. Urine output was affected by crude protein, K, and NDF concentration of the diet, as well as the type of forage used. Fecal excretion was affected by NDF concentration of the diet as well as the type of forage used. Each percentage of corn silage used (expressed as percent of forage DM) reduces total manure output by 0.4 lbs/cow per d.

Nitrogen excretion and its reduction through diet formulation and management practices adds a dimension to the problem because the production response to dietary N is typically nonlinear. A simulation model was built to assess the effect of different optimization objectives on N excretion, cost of production and profitability. Dietary crude protein concentration that results in maximum profits is 3.1% percentage units greater than that required for maximum N efficiency. Maximal N efficiency of the national dairy herd would result in a reduction of 165,000 tons of N excretion per year, a 15% reduction. This, however, reduces total national dairy profitability by $1.6 billion/year, a 41% reduction. Expressed differently, it would cost $9.60/kg of reduction in N excretion in the form of taxes or incentives for maximum N efficiency to become the economic optimum.
Technologies and Strategies Available to Meet 2009 Reduction Goals.

Theo van Kempen, Provimi RTC, Brussels, & North Carolina State University, Raleigh, and Ruurd Zijlstra, University of Alberta

Scope of problem: The government has mandated 20% reductions in excretion of N and P, and a 20% reduction in the emission of ammonia, 10% of dust, and 10% of hydrogen sulfide.

Possible solutions: Improving animal health is likely the most cost-effective way for minimizing the environmental impact per unit of product produced (but not on a facility basis). An animal not marketed is the biggest waste of nutrients that exists. Animals with sub-optimal feed intakes utilize proportionally more nutrients for maintenance and thus excrete more nutrients. Farms should thus do whatever possible to optimize health and performance in their operation.

Precision nutrition can achieve many of the targeted reductions without strongly affecting the profitability. E.g., quality control methods for feed ingredients should focus on nutritionally relevant parameters rather than on tradition and ideally quality control should be carried out in-line rather than on random samples or after the fact. Feeds themselves should be manufactured with equipment that is suited for the task; too often (micro)ingredients are dosed and weighed with oversized tools. The result is diets that are excessively variable hurting efficiency.

Feed formulation should be based on animal requirements that are linked to the performance of animals in the field, e.g., through slaughter records. Feeds should also be formulated to maximize profitability of an operation, rather than simply minimize feed costs. Thus, actual lean gain, the cost of nutrient disposal, as well as the value of lean meat and facility costs should be included in feed formulation.

Enzymes are economically attractive tools for reducing nutrient waste. Fiber-degrading enzymes reduce the volume of waste produces and improve the efficiency of N utilization. Phytases can greatly reduce the indigestible P in feeds; usage levels well beyond current practices can result in virtually all feed P becoming digestible.

On farms, feeds should be distributed in as many phases as possible (ideally continuously adapted) to optimally follow animal requirements. Feed waste should also be aggressively combated. Not only is this a serious waste of money, wasted feed contributed to waste load and to odor. Pelleting is a simple step that can reduce feed waste while also improving the digestibility of feed.

Ammonia emission can effectively be reduced through precision nutrition but also through the use of fermentable fiber and agents that lower urine pH. The downside of fermentable fiber is that it increases manure volume and possibly odor. Dust can be controlled by working with fat in feed or by directly misting the barn with it.

Last but not least, the animal industry is urged to rethink the way it operates in light of our changing environment. An initiative in North Carolina to do exactly that led to a swine facility that has the potential to be cheaper to construct and operate, with better animal performance, more flexible animal waste streams (e.g., feces suitable for energy production) and with drastic reductions in emissions. A commercial-size facility based on this concept has shown that the improvements achievable with this system are realizable in practice.

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Defining Efficiency – Animal vs. Farm-Scale
Michael VandeHaar, Associate Professor, Michigan State University

Many consumers want to know what we in animal agriculture are doing to the environment, to their health, and to the animals we raise. Efficiency per se is not a general concern, but of course efficiency is one key to achieving sustainable agriculture. The objective of this presentation is to consider whether new metrics can be designed that include environmental, health, and animal welfare concerns.

In the past, we generally have defined efficiency as animal product output per unit of food input. We have made tremendous gains in efficiency using this type of definition, and much of the increase over the last 100 years is the result of improved productivity (increased milk/cow or daily gain of consumable lean muscle). However, as we consider the environmental impact of agriculture, defining efficiency simply with food in and food out is no longer adequate. We must consider efficiency of human-consumable inputs, efficiency of land use, impacts on the environment, and even impacts on animal welfare and healthfulness of products. Striving for increased efficiency on one variable may have unintended negative consequences on other variables. For example, feeding a low protein diet to increase animal product per unit ammonia emitted might decrease animal product per unit of methane or carbon dioxide emitted.

Consumers will likely become increasingly interested in understanding the environmental and welfare consequences of their food choices. Perhaps one way to put all these considerations together is to assign economic value to all hidden costs and benefits and strive for improved "true" economic efficiency.

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