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Animal Diets and Feed Management



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Animal Diets and Feed Management

Introduction

Feed management is managing the quantity of nutrients fed to livestock and poultry for their intended purpose. This involves development of diets that supply the quantity of available nutrients required by livestock and poultry for maintenance, production, performance, and reproduction. Supplying nutrients in excess of an animal's requirement results in additional nutrients being excreted. In many circumstances, confined livestock and poultry operations find themselves under a whole-farm nutrient imbalance. In this scenario, there are more nutrients being imported on the farm than is being exported from the farm or utilized by current cropping rotations. As a result, soil saturation with various nutrients, especially phosphorus (P), or excess losses of nitrogen (N), can have a deleterious impact on the environment through runoff, soil erosion, and leaching. Phosphorus losses from soil emptying into surrounding freshwater bodies can lead to eutrophication (Carpenter et al., 1998; Correll, 1999; Sharpley et al., 1994). Nitrate leaching from soil into drinking waters can lead to fatalities in humans (Cameron et al., 1996) and livestock (Rasby et al., 1988). Anaerobic degradation of manure or other organic matter sources (animal mortality, spoiled feed) from the operation can cause air quality pollution from the emission of ammonia and other nitrogenous compounds, sulfurous compounds, volatile organic compounds that often are odorous, and can cause greenhouse gas and acid rain effects.

NRCS Conservation Practice Standard (CPS) Feed Management (Code 592) was developed with the purpose of supply and quantity of available nutrients required by livestock and poultry for maintenance, production, performance, and reproduction, while reducing the quantity of nutrients, especially N and P, excreted in manure by minimizing the overfeeding of these and other nutrients. As a result of fulfilling this purpose, the livestock and poultry operations can improve the whole-farm nutrient balance and minimize the threat of nutrients from manure impacting water and air quality. In addition, using proper feed management practices may improve net farm income by feeding nutrients more efficiently. The aim of this technical note is to outline various aspects of animal nutrition, feed formulation, and feed management practices to enhance nutrient efficiency, reduce nutrient excretion, and potentially improve net income from livestock and poultry farms. This document presents general background information about animal nutrition and feed management practices.

Definitions of Nutrition and Feed Management Terms

Nutrition Terms

Apparent digestibility.—The percentage of a feed nutrient that is digested and absorbed from the gastrointestinal tract, as indicated by nutrient intake minus fecal nutrient output.

Diet.—A mixture of feedstuffs used to supply nutrients to an animal.

Enzyme.—An organic catalyst that speeds or slows a chemical reaction without being used up in the reaction.

Essential nutrients.—Nutrients required in the diet because they cannot be synthesized within the body in sufficient amounts to satisfy metabolic needs.

Feedstuff.—Any material made into or used as feed. A feed ingredient.

Macrominerals.—Essential minerals that are required in relatively large amounts (i.e., calcium, phosphorus, magnesium, sodium, potassium).

Microminerals/trace elements.—Essential minerals that are required in smaller quantities (i.e., zinc, iodine, selenium, copper, iron, manganese).

Monogastric.—A nonruminant. An animal that has a simple stomach, typically poultry, swine, or even human.

Nutrient.—Any chemical element or compound in the diet that supports reproduction, growth, lactation, or maintenance-of-life processes.

Ration.—A daily supply of feed.

Rumen.—The largest of the four stomach compartments in the adult ruminant. The site of active microbial digestion.

Ruminant.—An animal with a functional rumen compartment in the stomach plus three other compartments. A cud-chewing animal. In U.S. agriculture, typically a cow, sheep, or goat.

Roughage.—A feed low in digestible energy and high in fiber, like hay or grass.

Six classes of nutrients.—Water, proteins and amino acids, carbohydrates, lipids, vitamins, and minerals. These nutrients support cellular needs for water, fuel, structural constituents (skin, muscle, bone, nerves, fat), and metabolic regulation.

Feed Management Terms

Ash.—Residual minerals remaining after all combustible material has been burned off in a furnace.

Crude fiber (CF).—Structural carbohydrates of plants (i.e., hemicellulose, cellulose, and lignin).

Crude protein (CP).—The content of nitrogen in a sample multiplied by the factor 6.25 to provide an estimate of the protein content of the sample.

Dry matter (DM).—The portion of a sample remaining after water has been removed.

Ether extract (EE).—Composed of fats and fatty acid esters. This method of analysis is applicable for the determination of crude fat in dried forages and mixed feeds.

Units of Measure and Calculations

Example 1. Dry matter (DM) and ash

Initial sample weight = 100 g

Sample weight after drying (100 °C) = 50 g

Sample weight after furnace ashing (600 °C) = 10 g

DM = 50%

Ash = 10%

$$\frac{\text{sample weight after drying}}{\text{initial sample weight}} \times 100 = \text{percent DM}$$

$$\frac{\text{sample weight after furnace ashing}}{\text{initial sample weight}} \times 100 = \text{percent ash}$$

Example 2. Crude protein (CP)

Protein consists of 16 percent nitrogen (N); therefore, 6.25 times the amount of N in the sample equals the total amount or percentage of protein in the sample.

Weight of sample = 100 g

Amount of N in sample = 3,000 mg/kg (or 3 mg/g)

Crude protein = 18.75%

$$\frac{(\text{amount of N in sample} \times 6.25)}{\text{weight of sample}} \times 100 = \text{percent crude protein}$$

Example 3. Apparent digestibility

Nutrient intake (NI) = 20 g

Fecal nutrient output (NO) = 5 g

Apparent digestibility = 75%

$$\frac{(NI - NO)}{NI} \times 100 = \text{percent apparent digestibility}$$

General Nutrition Principles

There are six classes of nutrients: proteins, carbohydrates, fats, minerals, vitamins, and water. The roles of certain feed ingredients in a diet can be divided into groups according to how they function in the body. For instance, corn generally provides the greatest source of carbohydrates (for energy) and soybean meal is used primarily as a protein source. The regulatory nutrients include vitamins, water, minerals, and proteins. The structural nutrients also include water, minerals, and proteins, as well as fats. The nutrients that primarily supply energy are fats and carbohydrates, but proteins can be used for energy, also.

Protein (Nitrogen)

Protein is made up of amino acids which are called the “building blocks” of muscle. Chemically, protein contains nitrogen, carbon, hydrogen, oxygen, and may contain sulfur. Typically, nitrogen in protein is approximately 16 percent of the protein molecule; therefore, to convert nitrogen in feeds to a crude protein equivalent the formula is: $N \times 6.25$. Specific levels and ratios of amino acids are required by the animal to grow, reproduce, and produce milk and eggs; therefore, nutritionists try to formulate diets to contain the correct ratios and levels of the amino acids. This is especially important for pigs and poultry. For sheep, beef cattle, and dairy cattle, nonprotein nitrogen, such as urea, can be consumed, and the amino acids will be created in the digestive system by microorganisms to meet the needs of the animal.

Carbohydrates (Energy)

Carbohydrates comprise the largest proportion of livestock rations by providing energy and bulk in the diet. The carbohydrate fraction of plant feedstuffs comprises between 70 to 80 percent of the dry matter of forages and cereal grains, respectively (Kellems and Church, 2002). Chemically, carbohydrates contain carbon, hydrogen, and oxygen. Glucose, lactose, galactose, maltose, sucrose, and starch are the main components of carbohydrates that provide energy; however, the ruminant animal can create volatile fatty acids in the digestive system from specific carbohydrates that can be used for energy.

These carbohydrates that are used in plants and cereals for structural purposes are cellulose, hemicellulose, and lignin.

Fats (Energy)

Fats and oils provide additional energy in the diet and aid in the absorption of vitamins. Chemically, fats contain carbon, oxygen, and hydrogen, but they can be arranged in a triglyceride form with different length fatty acid units. The energy value of fats is 2.25 times more potent compared to carbohydrates.

Minerals

Minerals, including calcium (Ca), chlorine (Cl), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), phosphorus (P), potassium (K), and selenium (Se), are important for structural integrity and are critical components for maintaining the ionic balance and metabolic activity of the animal. Inorganic sources of minerals are often added to diets to provide the correct level of biologically available sources of minerals and to balance levels of minerals that are in other feed ingredients in the diet.

Vitamins (A, D, E, K, B-complex)

Vitamins are provided in small quantities in animal diets to assist in metabolic activities in the animal. Certain vitamins can be synthesized in animals; however, commercial vitamin mixes are added to the diet for those not synthesized and because normal plant feed sources do not contain enough available vitamins.

Water

Approximately 50 to 70 percent of body mass of adults and up to 90 percent of body mass of newborn animals is water (Pond et al., 1995). There are typically two major functions of water: as a component in metabolism and factor in controlling body temperature. Some of the biological functions of water include aiding digest transport through the gastrointestinal tract and as a solvent in blood, tissue fluids, secretions, and excretions.

Access to water may occur through several different avenues. One major source of water intake is through free access to drinking water (table 1). Poor water quality negatively impacts the animal's intake and therefore reduces animal performance. Water quality can be compromised by high levels of salts, nitrates, sulfates, fluoride, pathogenic microorganisms, algae, pesticides, dissolved solids, and industrial compounds that may be polluting the water supply (EPA, 2006; Kellems and Church, 2002; Hairston and Stribling, 1995). Secondly, water can be consumed through the water content of ingested feedstuffs. For example, an animal consuming 20 pounds of corn silage per day has the potential to consume 13 to 15 pounds of water per day (Kellems and Church, 2002).

Classification of Feeds

Feeds are also classified based on their chemical characteristics (National Research Council (NRC)). For instance, forages or roughages commonly fed to cattle and sheep, have more than 18 percent fiber. Energy feed sources, such as cereal grains, have less than 20 percent protein, and less than 18 percent fiber. Protein supplements, such as soybean meal and various byproduct sources, have greater than 20 percent protein and less than 18 percent fiber. Minerals, vitamins, and additives are specific for the nutrient needed in the diet for specific functions in the animal. Adapted from National Academy of Science Publications, example feed ingredients for each class of feeds are shown in table 2.

Table 1: Expected Water Consumption of Various Classes and Species of Adult Animals in a Temperate Climate

Animal	Liters/Day	Pounds/Day	Gallons/Day
Beef cattle	22–66	48–145	6–17
Dairy cattle	38–110	84–242	10–29
Sheep and goats	4–15	9–33	1–4
Horses	30–45	66–99	8–12
Swine	11–19	24–42	3–5
Chickens	0.2–0.4	0.4–0.9	0.05–0.11
Turkeys	0.4–0.6	0.9–1.3	0.11–0.16

Table 2: Classes of Feeds According to the NRC System

Class	Traits	Examples
Dry forages or roughage	> 18% fiber	Hay, straw, seed hulls, fodder, stover
Succulent forages or roughage	> 18% fiber	Pasture, green chop, cannery residues
Silages	> 18% fiber	Whole-plant grain crops, wilted or low-moisture grasses or legumes
Energy feeds	< 20% protein and < 18% fiber	Cereal grains, milling byproducts, roots and tubers, brewery byproducts
Protein supplements	> 20% protein and < 18% fiber	Animal byproducts (meat scraps) Marine byproducts (fish meal) Avian byproducts (hydrolyzed feathers) Plant byproducts (soybean meal, cottonseed meal, linseed meal, corn gluten meal)
Mineral supplements	Guaranteed analysis	Steamed-bone meal Dicalcium phosphate Iodized salt Trace mineralized salt
Vitamin supplements	Guaranteed potency	Vitamin A acetate Vitamins A, D, E B-complex vitamins
Additives	Specific	Antibiotics (chlortetracycline, oxytetracycline, tylosin) Coloring materials Flavors Hormones Medicants

Digestive Process

The initial digestive process involves the intake of feed ingredients provided to meet the maintenance, production, and reproduction requirements of the animals involved. The requirements for production are affected by stage of growth and the type of production (e.g., meat, milk, eggs) involved. How well the animal can retain nutrients for productive purposes depends on the availability of the nutrients in the diet, absorption, metabolism, and retention, and ultimately, the excretion of nutrients. The quantity of nutrients excreted by animals is affected by three main factors. They are the—

- Amount of dietary nutrients consumed.
- Efficiency with which they are utilized and retained by the animal for growth and other functions.
- Amount of normal metabolic losses (endogenous).

In other words, the amount of excreted nutrients can be expressed as:

$$\text{Nutrients excreted} = \text{nutrient intake} - \text{nutrient utilized} + \text{nutrients from endogenous sources}$$

The primary means of reducing the amount of nutrients excreted by animals is to reduce the amount that is consumed and increase the efficiency of use (digestibility, absorption, and retention) of the dietary nutrients for formation of the product.

The goal of efficient and productive feeding of animals within economic and environmental constraints is to provide essential available nutrients for maintenance and production with minimal excess amounts.

Nutrients in feeds can vary considerably, and not all nutrients in feeds are available to the animal. Therefore, any means of increasing the digestibility or availability of nutrients will increase the potential for animal use and retention and reduce the amount of the nutrients excreted. There is increasing interest today in using enzymes, genetically modified feed ingredients, and feed processing technologies to enhance the availability of nutrients to meet the specific animal needs and reduce excretion of nutrients. In addition, a routine feed analysis program is imperative so diets can be formulated and periodically adjusted to meet but not exceed nutrient requirements of the animal.

Feed Management Systems

Feeding farm animals involves a series of diets with all nutrients required for maintenance, growth, reproduction, and production of products (meat, eggs, and milk). While different feeding systems are utilized, the most common approach is to use diet formulation to combine exact quantities of feed ingredients into a total mixed ration (TMR) for delivery to the animals. The TMR is constantly available to meat type (broiler) chickens, layer (egg-producing) chickens, turkeys, ducks, and growing pigs; whereas, the TMR is provided to dairy cows and fattening cattle generally two to three times per day. Breeding animals are generally fed once or twice daily to control weight.

Feed Formulation

Formulation of diets involves combining various available, economical sources of feed ingredients into a ration that animals will consume, digest, and utilize the nutrients to meet the nutrient needs of the animal for maintenance or productive purposes. The individual responsible for ration formulation should be aware and understand the concepts of nutrition, the animal's production status, and the physical and chemical composition of various available feedstuffs. The NRC has developed nutrient requirements for all species of animals that can be used as a reliable tool for ration formulation for a stage of production. Animal nutrient requirements can also be obtained from extension or university publications. These may

provide modifications to nutrient requirements depending on regional differences in environment, animal, or feed conditions.

Choosing feed ingredients for ration formulations may focus on developing least-cost rations or the most predicted profitable ration based on productivity. It also considers availability of ingredients. In some cases, the impact of ration formulation on nutrient excretion is not considered. However, with adoption of NRCS CPS Feed Management (Code 592), and with the development of a feed management plan, nutrient excretion is identified as another important consideration when formulating rations.

Maintaining the nutritional quality of feed ingredients can be difficult. Feedstuff quality can be altered by physical or genetic differences. Physical differences include the amount and type of soil nutrients available during plant growth, temperature, water supply, length of photoperiod and light intensity, cultivation practices, plant maturity at harvest, and storage. Genetic variety also plays a significant role in determining the nutrient composition and quality of a feed ingredient.

Improvements in genetic selection have allowed for novel nutrient-dense plant variety development. An example of this is a nutrient-enriched corn variety that contains approximately 30 percent more lysine, 50 percent more total sulfur-containing amino acids, 18 percent more threonine, and 6 percent more metabolizable energy than a normal corn variety. Another example is a low-phytic acid corn variety with the benefit of containing approximately 75 percent available P compared to yellow dent corn at about 12 percent available P. Low phytic acid corn in broiler diets resulted in a 50 percent reduction in phytate-bound dietary P, translating into a 20 percent reduction in fecal P excretion compared to birds fed a yellow dent corn diet. Similar genetic changes in chemical composition are also available for soybean varieties. Because of such feed ingredient variations, a subsample of each ingredient should be analyzed for nutrient composition prior to diet formulation. This feed management practice allows optimization of the ration to the animal's nutrient requirements. Many States have university or commercial laboratories specializing in feed analysis. Computer software programs are available for more accurate diet formulation.

Feed Storage, Handling, and Processing

Feed Ingredient Quality

Feed ingredient quality (grains, forages, fats, minerals, and vitamins) is a critical part of animal nutrition. Good storage facilities and conditions are vital. However, the quality of the grains and forages starts with a good initial-quality product at harvest. To ensure properly stored grain in bins, high-moisture grains need to be dried to at least 14 percent moisture for long-term storage and no more than 16 percent moisture for winter storage. Grain temperatures should not exceed 82 °C or there will be some browning, which is evidence of decreased lysine availability; therefore, an adequate fan system for cooling is desirable in some climates. Fats should not be stored at temperatures above 60 °C, with 49 °C being most ideal. Antioxidants extend the time period before rancidity of the oil starts. Vitamin stability varies greatly among vitamins, depending on conditions they are exposed to and storage time. Storage of the vitamin premixes should be in a cool, dark, dry place. Moisture, visible and ultraviolet light, heat, and contact with certain trace minerals are the most common factors that reduce vitamin stability.

Pelleting

Pelleting of diets is an effective way to improve feed efficiency (generally 4 to 6 percent) for all phases of swine and poultry production (Wondra et al., 1995; Szabo, 1988). The improved feed efficiency is due to a slight reduction in feed wastage and a slight improvement in digestibility of the diet because the steam heat of the pelleting process gelatinizes some of the starch, thereby increasing the susceptible area

of the feed to digestive enzyme hydrolysis. A side benefit to pelleting the diet is a 10 to 15 percent reduction in dry matter and N excretion resulting from reduced wastage and improved feed efficiency and digestibility. On the negative side, pelleting increases the cost of feed.

Grinding

Fine grinding of feed is effective in improving feed utilization and decreasing dry matter, N, and P excretion. By reducing the particle size, the surface area of the grain particles is increased allowing for greater interaction with digestive enzymes. Cereal grains with hard seed coats (grain sorghum, barley, and triticale) have the greatest improvements in digestibility by processing, but even the processing of corn is of economic benefit. When particle size is reduced from 1,000 to 400 micrometers, dry matter and N digestibility increase by approximately 5 to 6 percent (Wondra et al., 1995; Hale and Thompson, 1986). As particle size is reduced from 1,200 to 600 micrometers, dry matter and N excretion are reduced by 20 and 24 percent, respectively. The recommended particle size is between 650 and 750 micrometers for swine and poultry. Reducing particle size further increases the energy costs of grinding and reduces the throughput of the mill below the economic returns for finer grinding as well as increasing the incidence of stomach ulcers in pigs (Healy et al., 1994). Ruminants require larger particle sizes because there is a rumen stimulation factor required to provide good health of the rumen. The particle size can vary depending on the source or type of diet fed and the performance required of the animal.

Fermentation

Silage is the product of forages or a whole-plant cereal (corn silage) with a higher moisture level that have been chopped and placed in a storage structure that excludes oxygen so the forages undergo acid fermentation. Anaerobic microorganisms metabolize sugars and produce volatile fatty acids that reduce the pH of the forages, eventually stopping the fermentation process and preserving the forage until it is fed to ruminants. Storage structures used to preserve the forages include bunker silos, upright silos (either glass-lined steel or concrete), or sealed plastic bags. Important components for high quality silage require the proper maturity and moisture level of the forage at harvest, compaction of the material during filling of the storage structure to exclude oxygen, and sealing of the storage structure when the structure is full.

Other Processes

Extrusion, micronization, and steam flaking are examples of other processes designed to reduce the particle size, break the seed coat, or change the chemical structure of the feed ingredient to improve nutrient or energy digestion and improve the ability of enzyme activity on the feed resource. In most cases, these processes improve nutrient utilization and efficiency results with less nutrient excretion.

Feed Management Practices

Recommended feed management practices for an operation may include considering processing options (described previously), implementation of grouping strategies, including grouping by gender and increasing the number of production groups, appropriately adjusting diets based on climatic factors, and minimizing feed wastage.

Grouping.—Placing animals of similar ages, weights, and production levels together so more specific rations can be developed with a minimal chance of overfeeding nutrients.

Phase feeding.—Using multiphase feeding versus minimal-phase feeding. Phase feeding provides a series of diets that are formulated to more closely meet the nutrient needs of the animal at a stage of

growth or production (Henry and Dourmad, 1993). Dividing the growth period into several periods with a smaller spread in body weight, milk production, or egg production status allows producers to provide diets that more closely meet the animal's nutrient requirements and significantly reduces nutrient excretion and wastage.

Gender (split-sex) feeding.—Placing animals of the same gender together. Split-sex feeding divides the animals by gender so diets can be formulated to meet the special nutrient needs of each sex.

Climate.—Adjusting the diet to meet specific climatic conditions, i.e., temperature, wind, precipitation, or adjustments to the building climate to optimize nutrient utilization.

Wastage.—Minimizing spillage of feed and water into the manure management system. Wastage is a very important concept because all the nutrients found in the feed must be dealt with in the environment rather than just production by the animal. There are a variety of feed and watering systems that can be used with variable impacts on feed and water spillage. Wet-dry feeders for swine generally reduce the volume of water spillage and the volume of liquid manure for storage by 30 to 50 percent, primarily due to much less water wastage. Specialized feeder designs and adaptations that can be used to minimize wastage are available for all livestock types.

Diet Manipulation Factors

Diet formulation and ingredient selection considerations include formulation based on feed-available nutrients, use of growth promotants, genetic factors, use of specialty feeds and additives, and water supplies.

Available nutrients.—If the biological availability of nutrients in feed ingredients is known, diets can be formulated more accurately to supply needed nutrients and reduce excess nutrient excretions.

Genetics.—Knowing the genetic capability of the animals producing meat, milk, and eggs is critical so adjustments can be made for diet formulation to provide adequate nutrients. Feed intake levels and responses to environmental conditions, i.e., climate, disease pressure, and housing system are also important for formulation adjustments.

Growth promotants.—Antibiotics, enzymes, probiotics, and other feed additives that are growth promoters or enhance the health of animals which will increase feed efficiency and animal productivity. Growth promoters can reduce nutrient excretion by increasing nutrient utilization.

Specialty feeds.—Providing specific feed ingredients (e.g., high-oil corn, nutrient-dense corn, low-phytate corn, and soybeans) helps achieve a proper balance or increased availability of nutrients.

Water supplies.—Water supply sources can make a significant contribution to mineral intakes of the animal. Routinely analyze water sources and account for any contribution of minerals from drinking water when making necessary adjustments to the diet formulation.

Supplemental phosphorus.—Reduce supplemental P and add phytase to swine and poultry diets to reduce P excretion. Remove all supplemental P in beef cattle diets and most of the supplemental P in dairy cattle diets to reduce P excretion.

Crude protein.—Reduce dietary protein content and add supplemental amino acids to swine and poultry diets; reduce protein and select N sources for cattle that can be absorbed more effectively. Each of these practices will reduce N excretion.

Dietary Adjustments

Table 3 provides a summary of potential reductions in the excretion of nutrients with dietary and/or feeding management adjustments mentioned above for livestock and poultry. It should be noted that these potential effects are not additive. For more specific information, see the Feed Management fact sheets from the Federation of Animal Science Societies (FASS) (available on the FASS Web site at <https://www.fass.org/>) and the four NRCS Feed Management Technical Notes in this series related to the specific animal species (available on the NRCS eDirectives Web site at <https://directives.sc.egov.usda.gov/>).

Table 3: Potential Reduction of Nitrogen and Phosphorus Excretion from Feed Management Practices

Strategy*	Nitrogen Reduction %	Phosphorus Reduction %
Formulation closer to requirement	10–15 (nonruminants) 10–25 (ruminants)	10–15 (nonruminants) 10–30 (ruminants)
Reduced protein/AA supplementation (nonruminants)	10–25 (poultry) 20–40 (swine)	
Protein manipulation (ruminants)	15–25	
Use of highly digestible feeds	5	5
Phytase/low P (nonruminants)	2–5	20–30
Selected enzymes	5	5
Growth promotants	5	5
Phase feeding	5–10	5–10
Split-sex feeding	5–8	

*Fineness of grind/pelleting the diet from 1,000 microns to 700 microns for swine can reduce manure excretion by 20 to 25 percent and N excretion by 5 percent. Use of chelated and organic minerals for swine (zinc, copper, selenium) can potentially reduce these mineral excretions by 15 to 50 percent.

Impact of Diet on Volume of Manure Generated

The volume of manure (excreta) generated depends upon the digestibility of the feed ingredients, especially dry matter, the intake of the animal, and the type and amount of fiber in the diet. The more digestible or degradable the dry matter is to microbiological and physical breakdown, the lower volume of solids that will be excreted. Conversely, if fiber is added to the animal's diet in increasing amounts, generally there will be an increased bulk or volume of solids excreted.

The composition of the diet has an impact on the amount of urine excreted. If a reduced crude protein diet with supplemental amino acids is fed to swine, less water is consumed by the pig and lower amounts of urine excreted. Conversely, if higher dry-roughage diets are fed to ruminants, more water is consumed by the animal that is excreted through urine. If higher salt concentrations are in the ration, the result will be greater water consumption by the animal. Feeding high-moisture forages to ruminants reduces water consumption.

Impact of Diet on Composition of Manure Generated

As expected, diet composition has a significant impact on the composition of manure (excreta) generated. Important dietary factors affecting manure excretion are—

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- Composition, quality, and maturity of the individual feed ingredients,
 - Nutrient availability of the feed components,
 - Levels and ratios of specific nutrients,
 - Enzymes, feed additives, antibiotics, and other growth promoters in the diet, and
 - Processing methods used for ration preparation.

In addition to these factors, the chemical form of nutrients excreted can be affected by diet composition. For example, addition of fiber to swine diets increases the amount of organic N in manure compared to ammonium N. Similarly, if phytase is fed to swine or poultry, without concomitant reductions in inorganic P and/or feeding well above the P required by the animal, the proportion of water soluble P increases in the excreta. Phytase is a synthetic enzyme added to nonruminant diets that releases bound forms of P normally found in feed ingredients such as corn and soybean meal. This bound form of P becomes available for the animal to utilize and reduces P excretion. High concentrate diets fed to cattle increases the amount of soluble carbohydrates excreted compared to cattle fed high forage diets.

Excess nutrients are excreted if they are added to the diet significantly above the nutrient requirements of the animal at a specific phase in its life cycle. Therefore, reducing this overage of nutrient formulation can have a significant impact on reducing nutrient excretion.

Impact of Diet on Gaseous Emissions from Manure

Animal production facilities are a point source for various airborne contaminants. Odorous and gaseous emissions are generated by livestock and poultry manure decomposition shortly after excretion, during storage and treatment, and during land application (Bicudo et al., 2002). The generation and potency of odor and gases are influenced by weather conditions, time, species, housing strategy, manure handling systems, feed type, and general management scheme. Various control strategies are currently being explored to reduce the generation of airborne contaminants, including dietary modification.

Ammonia

Inefficient use of N or excess N excretion can result in increases of ammonia emission from livestock and poultry operations. Several dietary strategies including improved feed management practices (described previously), selective feed ingredients such as chemical compounds and microbial additives, and modified ration formulation have been employed to reduce excess N excretion and aerial ammonia emissions. Implementation of phase feeding or split-sex feeding allows for greater matching of the diet to the growth stage of the animal. Examples of impact of diet and feed management practices are feeding in a multiphase system with the potential to reduce urinary nitrogen excretion and ammonia emission in swine by between 15 and 17 percent, respectively (van der Peet-Schwering et al., 1996).

Reducing the crude protein of the diet and adding supplemental synthetic amino acids to balance the correct amino acid levels and ratios on the diet for pigs and poultry will reduce N excretion and ammonia emissions. As a rule, for every 1 percentage unit of crude protein reduction, ammonia emissions will be reduced by 8 to 10 percentage units. Adding small amounts of fiber (5 to 10%) in the pig's diet reduced ammonia emissions also, but there can be a resultant increase in total manure excretion. Feeding zeolite, urease inhibitors, and organic acids can also reduce ammonia emissions substantially. Reducing crude protein levels, adjusting the protein to carbohydrate (available energy generally from grains) ratio in the diet, and selecting the correct protein sources have the most impact on reducing N excretion from ruminants and consequent ammonia emissions up to 50 percent. If byproduct feeds are included in rations, they may increase the potential for ammonia emissions since, in many

cases, the amount of protein is overfed, and the protein is not utilized effectively because of the methods of byproduct processing.

Hydrogen Sulfide

Hydrogen sulfide emissions primarily come from the microbial degradation of sulfur-containing amino acids and mineral sulfates provided as sources of minerals in the diet. Methods to reduce hydrogen sulfide emissions aim to reduce these sources in the diet and to provide alternative mineral sources that do not contain sulfur. In some geographical areas, drinking and cleaning water may contain high sulfur concentrations, which add significantly to the emissions of hydrogen sulfide. Filtering high sulfur water would be required to alleviate the problem. Because of the nature of processing ethanol, distiller's dry grain with solubles contains high concentrations of sulfur. Feeding this ingredient in animal diets very likely increases the emissions of hydrogen sulfide. Therefore, when byproducts are used in animal diets, there could be increased nutrient excretion and potentially gaseous emissions.

Methane

Methane emissions come from the anaerobic microbial degradation of organic matter. With swine and poultry, methane can be generated from manure storage facilities. With ruminants, the microorganisms in the rumen (first compartment of the ruminant stomach) produce methane from the forages and other carbohydrate sources in the feed, and the ruminant belches or eructates the methane into the air. Feeding a low-forage, high-grain ration reduces methane emissions compared to a high-forage, low-grain ration. Methane production can also be lowered in ruminants by feeding high quality forages, so in pasture systems, quality of pasture becomes very important from a greenhouse gas mitigation standpoint. To a certain extent, addition of certain feed additives to the diet, such as ionophores, reduces methane emissions from the ruminant.

Impact of Diet on Pathogen Content of Manure

Livestock waste contains many microorganisms, some of which can cause illness or death in animals and humans that come into contact with them. The diet of the animal can provide nutrients for the maintenance and growth of these pathogens in the animal and provide the food source for these microorganisms after the waste is excreted. Changes to the diet, feedstuffs, or the inclusion of appropriate additives can help decrease the number of pathogens that enter the environment with the manure.

Diet selection to decrease pathogens is possible. Organic acids have been shown to decrease the level of *Campylobacter* and *Salmonella* in poultry diets. Switching cattle from a grain-based diet to a high quality, hay-based diet can reduce the presence of *Escherichia coli* (*E. coli*) in the manure. The physical form of feed can also affect pathogen levels in the manure; pigs fed coarsely ground diets are less likely to test positive for *Salmonella*. Supplementation of prebiotics and probiotics can also decrease pathogen levels in manure.

Summary

Manure from livestock and poultry production can be effectively utilized as a nutrient resource for crop production. However, if not managed properly or if there is greater import of nutrients on a livestock or poultry operation than export of nutrients, there can be an environmental impact on water or air quality from manure produced on the farm. Purchased feed is a major import of nutrients on livestock and

poultry operations. Development of a feed management plan can help reduce whole-farm nutrient imbalances and excess nutrient excretion by reducing excess feeding of nutrients to animals or by improving the utilization of nutrients in the animal diet. Understanding general nutrition principles and guidelines and implementing tools (fact sheets, computer aids, etc.) can help in the development of effective feed management plans that help reduce nutrient accumulations on the farm, environmental impacts, and that meet the requirements of NRCS CPS Feed Management (Code 592).

Additional Resources

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