

Center

FEED FOR FOOD-PRODUCING ANIMALS

A Resource on Ingredients,
the Industry, and Regulation

for a
Livable
Future

Center for a Livable Future
Johns Hopkins Bloomberg School of Public Health

**Feed for Food-Producing Animals:
A Resource on Ingredients, the Industry, and Regulation**

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About the Johns Hopkins Center for a Livable Future

Founded in 1996, the Johns Hopkins Center for a Livable Future promotes research and communicates information about the complex interrelationships among diet, food production, the natural environment and human health. As an interdisciplinary center it serves as a resource to solve problems that threaten the health of the public and hinder our ability to sustain life for future generations.

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Introduction

What is fed to animals produced for human consumption can have important implications for the health of the public. The recent finding of cows in the United States with bovine spongiform encephalopathy (BSE), or mad cow disease, is one sign of the need for more public health attention to animal feed. There are others. Many of the current headline food safety issues—*Salmonella*, *E. coli* 0157:H7, antimicrobial resistance, dioxins, and arsenic, to name just a few—are related to changes in animal feeding practices that have accompanied the industrialization of food-animal production. Indeed, animal feeding practices and the feed industry as a whole have evolved in tandem with the industrialization of animal agriculture and cannot be understood in isolation.

While knowing what is in animal feed is important in order to protect the public's health, it can be very difficult to find this information. Currently, there is no source for detailed data on the variety and amounts of specific feed ingredients used. Such data are often not available for public scrutiny because the information is considered proprietary property of the \$25 billion U.S. feed industry. For example, the types and amounts of specific ingredients, such as antibiotics, animal waste, and rendered animals, are not available to the public. Moreover, there is currently no nationwide animal feed surveillance system to monitor biological or chemical contaminants in feeds, such as *Salmonella*, *E. coli* 0157:H7, dioxin and dioxin-like compounds, arsenic, and mycotoxins. These

obstacles reduce our ability to trace human illness to animal feed—despite recommendations from the Centers for Disease Control and Prevention (Crump et al., 2002; GAO, 2000, p. 24) and the Institute of Medicine of the National Academy of Sciences (IOM, 2004, p. 207).

This report provides an overview of animal feed practices in the U.S.,¹ including:

1. **Feed ingredients**—the wide range of materials used for feed² currently given to major food-producing animals (including cows, pigs, poultry, and major animal species produced in aquaculture)—with more detailed information on each ingredient given in the Appendix;
2. The feed industry, including its size, structure, and the forces shaping it;
3. Current regulatory mechanisms and examples of voluntary efforts to control the safety of feed; and
4. Some feed ingredients of particular interest from a public health perspective.

The intent is to provide a resource document and “road map” for public health professionals and others interested in the complex public health issues associated with animal feeds. Heretofore, there has not been one place where researchers could access this information; this report is intended to fill that gap.

¹ This report is limited to the U.S., although feed issues are global in nature.

² “Feed” is used throughout this report to refer to any substance, whether processed, semi-processed, or raw, which is intended for consumption by animals from which food (intended for human consumption) is derived (FAO, 1997). For the purposes of this report, natural, unrestricted grazing of food animals has not been included, nor has food for pets or companion animals not intended for food production.

I. Overview of Sources and Types of Feed Ingredients

A wide range of raw materials is allowed in the manufacture of animal feed and comes from the sources listed below. More detailed information on these feed ingredients is provided in the Appendix, and Section IV provides additional information for certain ingredients of particular interest from a public health perspective (noted in **bold** below). Information on feed ingredients is also available in the *Official Publication* of the Association of American Feed Control Officials, Inc. (AAFCO) (see www.aafco.org) (AAFCO, 2005).

Plant origin:

- Grains (e.g., corn, barley, oats, wheat, sorghum)
- Oilseed meals and cakes (e.g., soy, cottonseed, canola, sunflower seed)
- Grain by-products (e.g., distillers grains, brewer's yeast, corn gluten meal)
- Fruit and fruit by-products (e.g., dried citrus pulp, apple pulp)
- Molasses and sugar
- Alfalfa products
- Miscellaneous plant products (e.g., banana peels, coffee hulls, bean pods, acorns)

Animal origin:

- **By-products of slaughtered animals** (e.g., meat by-products, animal liver, hydrolyzed poultry feathers, unborn calf carcasses, ensiled paunch)
- **By-products of animals that have died by slaughter or otherwise**, including dead and diseased animals, road kill, euthanized animals (e.g., animal by-product meal, meat meal tankage, blood meal, hydrolyzed hair)
- Marine by-products (e.g., fishmeal, **fish oil**, fish liver, and glandular meal)
- Dairy products (e.g., dried milk, various whey products, cheese rind)
- **Animal waste** (e.g., dried ruminant³ or swine waste, dried poultry litter)

Mixed origin

- **Fats and oils** (e.g., **animal fat**, tallow, poultry grease, vegetable fat or oil)
- Restaurant/food waste (e.g., edible food waste collected from restaurants, bakeries, cafeterias, etc., including plate waste, dried bakery waste)
- Contaminated/adulterated (human) food (e.g., food originally intended for humans that has become adulterated with rodent, roach, or bird excreta and that has been heat-treated to destroy pathogenic organisms; may also include human food contaminated with pesticides, drugs, etc.)

Other (mineral, microbial, or synthetic origin)

- Drugs (e.g., **antimicrobials, organic arsenic compounds**)
- Non-protein nitrogen (e.g., urea, anhydrous ammonia)
- Polyethylene plastic in pellet form (used as a roughage substitute in cattle)
- **Minerals** (e.g., calcium, phosphorus, salt, trace minerals) and **mineral mixes/premixes**
- Vitamins (e.g., vitamins A, B12, C, D, E) and vitamin-containing oils (cod liver oil, shark oil)
- Direct-fed microorganisms (probiotics)
- Flavors (e.g., aloe vera gel concentrate, fennel, ginger)
- Preservatives (e.g., BHA, BHT, sodium bisulfite, methylparaben)
- Enzymes (e.g., lipase, pepsin)
- Other additives and “generally recognized as safe” (GRAS) ingredients (e.g., saccharin, polysorbate)
- “Nutraceuticals” and unapproved substances (herbal and botanical products and dietary supplements such as comfrey, kava)
- By-products of the manufacture of antibiotics, enzymes, amino acids
- Non-food wastes, proposed but actual use is not verified (e.g., pulp and papermaking residues, newspaper, sawdust, municipal solid waste)

³ Ruminants include cattle, sheep, goats, and other animals that chew a cud consisting of regurgitated, partially digested food.

II. The Feed Industry

A. Introduction to and Overview of the U.S. Animal Feed Industry

1. *The U.S. Feed Industry: Largest in the World*

The U.S. is the largest feed producer in the world. In 2004, the U.S. produced 120.638 million tons (109.441 metric tons) of primary feed.⁴ Global feed tonnage was estimated at 612 million metric tons⁵ in 2003 (Gill, 2004). In 1997, the U.S. feed industry was valued at over \$19 billion, and in 2002 at over \$17 billion, according to the U.S. Census Bureau; today it is valued at over \$25 billion a year according to the industry (Muirhead, 2003).

The U.S. is also the world's leading supplier of feed ingredients (including grains and animal by-products), although most animal feed produced in the United States is also consumed in the U.S. In 2001, the U.S. exported \$4.1 billion of animal feed products⁶ and imported \$744 million of animal feed products⁷ (including pet foods), according to the International Trade Centre (UNCS-TAD/WTO).

Table 1: Manufactured Feed Use in the United States, 1930–2002

	1930	1978	2002
U.S. Annual Primary Feed Production	13.1	78.2	120.8
Poultry Primary Feed Production	6.2	31.3	65.6
Dairy Primary Feed Production	3.8	14.2	13.8
Swine Primary Feed Production	0.8	12.4	15.5
Beef, Sheep Primary Feed Production	0.6	15.3	17.5

[In million tons. From Muirhead, 2003]

⁴ These industry estimates are the most recent estimates available but only include primary production of feed. Primary manufacturers process and mix ingredients such as feed grains, mill by-products, and animal proteins and may add formulations of microingredients (premixes) at a very small rate per ton of finished feed. Secondary feed manufacturers process feed by combining supplements and other ingredients. The supplements are used at the rate of 100 pounds or more per ton of finished feed. Most custom mixing is by secondary manufacturers (e-mail from Mark Ash, USDA ERS).

Estimates of primary and secondary feed production are available from the USDA Economic Research Service, which estimated that in 1984, the continental U.S. (48 states) produced a total of 109,590,000 tons of animal feed (primary and secondary feed production). Of this total, primary production of animal feed amounted to 95,415,794 tons. Of the 95,415,794 tons of primary feed production reported by USDA ERS in 1984, almost 40 percent was for poultry (36,860,512 tons), almost 40 percent was for ruminants (cows, sheep, goats) (37,435,141 tons), about 15 percent was for swine (14,259,046 tons), and 7.2 percent (6,861,095 tons) was all other primary feed production.

⁵ 612 tons (metric) equals 674.615 tons (short).

⁶ See www.intracen.org/tradstat/sitc3-3d/ep081.htm.

⁷ www.intracen.org/tradstat/sitc3-3d/ip081.htm.

⁸ The most recent nationwide data on the amount of specific feed ingredients is from 1984 (prepared by the USDA Economic Research Service; see <http://usda.mannlib.cornell.edu/data-sets/crops/89005/>).

⁹ See footnote 4.

Despite the U.S. feed industry's large size and public health importance, current data on the amounts of specific ingredients used in feed are lacking or are not widely available.⁸ Section III and the Appendix of this report provide more information on specific feed ingredients.

2. *Operation of the Feed Industry*

The number of feed ingredient suppliers is not precisely known but is estimated at "several thousand," according to the American Feed Industry Association (AFIA), a trade association representing the U.S. feed industry, which includes renderers, food processors, bakeries, distillers, non-food industries, farmers, grain elevators, and other sources (USITC, 2000; *Feedstuffs*, 2005). The large number of ingredient suppliers adds to the complexity for public health officials and others in tracking, evaluating, and assuring the quality and safety of what animals are fed.

The AFIA estimates that there are about 3,000 primary feed manufacturing plants and another approximately 5,500 secondary or custom mix plants in the U.S.,⁹ as well as a network of about 17,500 dealers of various animal feed products (USITC, 2000; *Feedstuffs*, 2005).

Animal feed is produced in one of three types of facilities (Gilbert, 2002):

- Commercial plants producing feed for sale
- Integrated operations that produce feed stuffs for their own animals (in particular large pig and poultry producers)
- Co-operative facilities where farmers jointly own the feed mill or production plant that produces the feed they use

Commercial facilities procure most ingredients from brokers, who buy ingredients from farmers, elevators, or processors, or directly from farmers in the case of specialized ingredients (e.g., high-lysine corn) (USITC, 2000). Co-operative facilities procure most ingredients directly from farmers. A wide variety of feeds is then sold to farmers, brokers, wholesalers, or feed stores, mostly in a relatively localized area.

Feed manufacturers choose ingredients that are the least costly but still meet the desired nutritive properties for a given species (USITC, 2000, p. 21). For example, corn or soy may be replaced with other feed ingredients, such as canola seed, field peas, and corn gluten feed (a by-product from the manufacture of corn syrup) depending on the relative price and availability of alternative feed ingredients. Seasonality, local conditions, and updated nutritional information all play a role. Computer programs are used to determine the optimal combination of feed ingredients. Feed manufacturers, depending on their size, may carry a couple of hundred basic feeds, and also may offer many specialty or custom-mixed feeds (Muirhead, 2003). According to the International Feed Industry Federation (IFIF), most feed industries around the world use the same feed formulation software, the same manufacturing technology, and generally the same raw materials (Gilbert, 2002).

Industry journals including *Feedstuffs* (www.feedstuffs.com/ME2/Default.asp), *Feed Management* (www.wattnet.com/FIN/Home.cfm?PG=3), and *Render Magazine* (www.rendermagazine.com/) provide useful insights to those interested in feed ingredients and other news important to the feed industry.

B. Trends in the Feed Industry

1. *Feeding Practices and Industrialized Animal Production*

Feeding practices and the animal feed industry as a whole have evolved in tandem with the industrialization of animal agriculture and cannot be understood in isolation.

The primary force driving changes in feeding practices has been economic: how to bring food animals up to weight as quickly and cheaply as possible. For example, by 1968, farmers could produce twice as much beef and more than twice as much chicken with the same amount of feed as they could in 1930.¹⁰ This remarkable success in production was achieved primarily through changes in feed and feeding practices, stimulated through research by agricultural colleges, government, and the feed and related industries, in addition to breeding for improved growth (*Feedstuffs*, 1969; NRC, 1999).

Feed availability, new feed ingredients, and new feeding practices have played important roles in the concentration of food animal production operations, in particular, the now highly concentrated production of pigs and chickens.¹¹ The intensification of livestock production has in turn had a significant impact on patterns of feed use, including increased demand for concentrates (UNCSTAD, 1984, p. 4).

2. *Vertical Integration and Other Structural Trends*

From the 1930s through the late 1970s, the structure of the U.S. feed industry changed from an industry of large, centrally located mills toward smaller, decentralized operations.¹² In the 1930s, there were about 500 commercial feed manufacturing operations. By the late 1970s, the number had grown to about 10,000, and Muirhead estimates that there were about 5,000¹³ feed manufactur-

¹⁰For every 100 pounds of animal feed, farmers could produce eight pounds of beef in 1930 and 16 pounds in 1967; 20 pounds of chicken meat in 1930 and 50 pounds in 1968; 15 pounds of turkey meat in 1930 and 28 pounds in 1967; and 23 pounds of pork in 1930 and 32 pounds in 1967. (*Feedstuffs*, 1969).

¹¹For example, the number of hog farms in the U.S. plunged 80 percent between 1980 and 1999—from nearly 500,000 to less than 85,000—although pork production increased during that period from 16.4 billion pounds to 19.3 billion pounds (McVey and Baumel, 2003).

¹²This move was driven by economic factors, as labor and rail transportation became more expensive, truck transportation increased, and smaller operations were closer and considered more flexible, timely, and convenient for their customers (Muirhead, 2003).

¹³According to the American Feed Industry Association, approximately 3,000 primary feed manufacturing plants exist in the U.S. today, as well as approximately 5,500 secondary or custom-mix plants (*Feedstuffs*, 2003). According to USDA Economic Research Service (ERS) estimates, which are not up-to-date, there were 6,723 feed manufacturers in 1984, of which 3,936 were corporately owned (vs. owned by cooperatives, partnership, or single owner). The U.S. Census Bureau compiles information on manufacturing, including animal feed manufacturing; the most recent data are from 2002. According to the Census Bureau's data, in 2002 there were 1,567 animal feed establishments (U.S. Census, 2004). These data, however, cover only primary feed compounders that market feed for sale to others, and exclude integrated operations.

ing operations in 2003 (Muirhead, 2003) as the trend shifted again toward bigger, more integrated, and more specialized feed plants (Gill, 2004). Many mergers and consolidations have occurred and are occurring in the animal feed industry, mirroring the trend toward consolidation in livestock production. In mid-2003, the top three U.S. feed manufacturers—Land O’Lakes, Cargill, and Archer Daniels Midland (ADM)—accounted for 20 percent of the market (Muirhead, 2003). The same companies were still the top three in 2005. After the top two U.S. companies, the manufacturing capacity of the others drops off sharply (see Table 2).

Integration¹⁴ of the food animal producer sector has concentrated feed production both economically and geographically. In particular, vertically integrated firms that produce their own feed dominate the poultry feed industry. “In-house” feed mills produced 40.7 million tons of feed for the broiler industry in 2002, out of the 65.5 million tons of primary feed production for the poultry industry (Muirhead, 2003). Many integrated operations have constructed low-cost, high-volume “mega mills” to provide feed for their large-scale confinement feeding operations concentrated within a trade territory (McVey and Baumel, 2003).

**Table 2: Top 10 U.S. Feed Companies
(based on manufacturing capacity, 2005)**

Company	Annual Manufacturing Capacity (Million Tons)
1. Land O’Lakes Farmland Feed	12.5
2. Cargill Animal Nutrition	9.5
3. Archer Daniels Midland (ADM) Alliance Nutrition	3.2
4. J.D. Heiskell & Co.	2.4
5. Westway Feed Products	2.0
6. Kent Feeds	2.0
7. Southern States Co-op	1.7
8. PM Ag Products	1.7
9. Ridley Inc.	1.6 <i>(includes Canadian feed tonnage)</i>
10. Goldsboro Milling	1.0

Note: The identity of the top 10 feed companies may change due to consolidations and mergers

[From *Feedstuffs*, 2005]

The increasing vertical integration and ownership consolidation seen in the U.S. since the 1970s is now occurring worldwide. The top five countries produce nearly half of the world’s industrially manufactured animal feed (Gill, 2004). Four of the top 10 feed manufacturers worldwide in 2004 were headquartered in the U.S.: Cargill, Land O’Lakes, Tyson, and Smithfield (Gill, 2004).

Another trend in the animal feed industry is toward on-farm mixing of feed ingredients, where pre-prepared supplements are mixed with plant material such as grains and silage. However, a potential problem with on-farm mixing is that it may be associated with increased bacterial contamination of feeds (Harris, 1997).

3. *Increased Use of Antibiotics and Other Growth-Promoting Substances in Feed*

According to the animal feed industry, the use of antibiotics and other growth-promoting substances in animal feed has been critical to the remarkable gains in feed efficiency observed over the last 50 years.¹⁵ Non-therapeutic levels of antibiotics are added to feed or water to promote growth and improve feed efficiency. They are also alleged to help compensate for crowded conditions present in intensive production systems. Arsenical compounds are also added to feed to promote growth and to prevent coccidiosis when fed in combination with ionophores. Antibiotics are also administered at therapeutic levels to treat diseased animals. Additional information on antibiotics and arsenicals administered in animal feed is provided in Section III and in the Appendix.

Increasingly, concerns about the use of antimicrobials in feed have led some companies to produce antimicrobial-free feed. *Feedstuffs*, the feed trade magazine, asked major North American feed manufacturers for the first time in 2003 what percentage of their total feed produced is antibiotic-free or organic. Of those responding, 27.6 percent said they produced some antibiotic-free feed, and 6.4 percent reported producing organic feed (*Feedstuffs*, 2003). However, these data do not indicate what percent of total production such feeds represent, and antibiotics can still be added through on-farm mixing after feeds have been shipped from manufacturers. Some major food producers claim to be using antibiotic-free feed (see Section IIIC for additional information).

¹⁴ Integration is the process whereby companies control more than one phase of food animal production, feed manufacturing, processing, and distribution.

¹⁵ A 1969 issue of the trade journal *Feedstuffs* devoted to celebrating progress in the efficiency of animal feeding states: “The growth promoting and disease control benefits of the additives and drugs used in scientific feeds are by far one of the most important factors in improving conversion of grain and other feedstuffs into animal food products” (*Feedstuffs*, 1969, p. 6).

4. *Cutting Costs: Use of Waste as Feed*

Feed remains one of the top costs for farmers, accounting for about 50 percent to 75 percent of total livestock production expenditures (Muirhead, 2003). Therefore, the use of less costly ingredients that still meet the nutritional requirements of the animal is another major trend in the animal feed and animal production industries. Including material considered as waste in animal feed has been a frequent strategy of the feed industry. Indeed, the commercial animal feed industry “was born out of the needs of grain, oilseed and meat processors to find an economical and safe way to dispose of their waste byproducts” (Muirhead, 2003). The industry refers to the practice as “recycling.” For this reason, the rendering industry, which deals with the large quantities of animal products/parts not suitable for use as human food, is closely associated with the animal feed industry.

Indeed, the commercial animal feed industry “was born out of the needs of grain, oilseed and meat processors to find an economical and safe way to dispose of their waste byproducts”

(Muirhead, 2003).

The use of animal waste (manure or a mixture of manure, urine, and litter) as a feed ingredient is one type of “recycling” practice that has accompanied the shift to concentrated animal feeding operations. Whereas manure from animals was traditionally used to fertilize locally grown crops, the manure output from these concentrated

operations overwhelms the capacity of local croplands to absorb it. The bulk and weight of animal waste generally makes transporting it not economical, and its use in feed is considered by practitioners to be a viable alternative to disposal in a landfill. While FDA does not endorse the use of recycled animal waste for feed, it recognizes that it has been deliberately incorporated into animal feed for many years. Additional information on waste used as an ingredient in feed is provided in Section III and in the Appendix.

5. *The Growing Demand for Meat and Aquaculture Products Fuels Demand for Feed*

The rapid growth in world production and consumption of meat and meat products, called “the Livestock Revolution,” has fueled feed demand. Feed and feed ingredients, unlike meat, can easily be stored and shipped over long distances. For example, it is estimated that the cost of shipping frozen meat, per ton, is from 10 to 20 times the cost of shipping grain. Therefore, there is a tendency to use imported grain and other feed ingredients and to raise food-producing animals domestically, rather than to import meat (Upton, 2002). The U.S. is the largest source of feed grains: 56.5 percent of world coarse grain exports and 71 percent of world corn exports were from the U.S. in 1999 (FAOSTAT, 2001, cited in Upton, 2002).

Feed for aquaculture production is one of the most rapidly growing sectors, since aquaculture production has risen about 9.2 percent per year globally since 1970, fueling the demand for feed, compared to growth rates of 1.4 percent for capture fisheries and 2.8 percent for terrestrial farmed meat production systems (FAO, 2002).

III. How Are Animal Feeds Regulated?

Animal feed is regulated at both the federal and the state level. Monitoring and enforcement responsibilities are fragmented over a number of different agencies. This section reviews federal and state activities, and also gives a brief overview of some notable industry initiatives and international developments.

A. Federal Activities

Four federal agencies are responsible for regulating animal feed: the U.S. Food and Drug Administration (FDA), the U.S. Department of Agriculture (USDA), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Transportation (DOT). The FDA serves as the main federal agency responsible for feed regulation. Aside from FDA regulations, government involvement in the animal feed industry is fairly limited and is mostly concerned with providing funds for promoting and facilitating exports (USITC, 2000).

1. U.S. Food and Drug Administration (FDA)

FDA regulates animal feeds or feed ingredients either as foods (defined to include feeds), food additives, or drugs, under the authority of the Federal Food, Drug and Cosmetics (FD&C) Act. It also establishes guidelines for the types and dosages of drugs and food additives that can be used in animal feed.

- Animal feeds/feed ingredients regulated as *food* include grains, hays, etc., and are considered safe and do not require pre-market approval. While food includes feed,

historically FDA has made a distinction between food for animals and food for humans.¹⁶ FDA has used the phrase “otherwise unfit for food” to distinguish between human food and animal feed, arguing that a substance that is unfit for human food because of aesthetic reasons might NOT be unfit for animal feed (Taylor and Geyer, 1979). This argument has been used to allow food considered adulterated for human use to be diverted into animal feed (see Section C of Appendix on contaminated/adulterated food).

- Animal feeds/feed ingredients regulated as *drugs* are regulated more stringently than foods and require pre-market approval based on safety and efficacy testing. Whether a feed or feed ingredient is regulated as a drug depends on its intended use. The intended use is established from claims made about the product.¹⁷ A feed ingredient that contains a drug residue is not regulated as a drug.
- Ingredients in feed or used to make feed that are not regulated as drugs or foods must be either “generally recognized as safe” (GRAS) or used in accordance with a food additive regulation (21 CFR 573) based on an evaluation that the use of the additive is safe; otherwise, their presence legally makes the feed adulterated. Most vitamins and minerals used in feed are considered GRAS. Regulations that apply specifically to food additives in feeds are published in Title 21, Part 570 of the Code of Federal Regulations,¹⁸ and a list of approved food additives for use in animal feed¹⁹ is found in Part 573.

¹⁶Section 402 of the FD&C Act states that a food is adulterated if it consists wholly or in part of filthy, putrid, or decomposed substances or is “otherwise unfit for food.”

¹⁷Expressed or implied claims that establish the intended use to cure, treat, prevent, or mitigate disease, or affect the structure/function of the body in a manner other than food (nutrition, aroma, taste), identify the product as a drug.

¹⁸Title 21 of the Code of Federal Regulations can be searched from the FDA website, at www.accessdata.fda.gov/scripts/cdrh/cfdocs/cf-cfr/cfrsearch.cfm.

¹⁹These include Acrylamide-acrylic acid resin, Aminoglycoside 3'-phospho-transferase II, Ammoniated cottonseed meal, Ammoniated rice hulls, Anhydrous ammonia, Condensed animal protein hydrolysate, Feed-grade biuret, 1,3-Butylene glycol, Calcium periodate, Calcium silicate, Feed-grade calcium stearate and sodium stearate, Choline xanthate, Crambe meal, heat toasted, Diammonium phosphate, Diatomaceous earth, Disodium EDTA, Ethoxyquin in animal feeds, Ethoxyquin in certain dehydrated forage crops, Ethyl cellulose, Ethylene dichloride, Fermented ammoniated condensed whey, Formaldehyde, Formic acid, Condensed, extracted glutamic acid fermentation product, Hemicellulose extract, Hydrogenated corn syrup, Hydrolyzed leather meal, Iron ammonium citrate, Iron-choline citrate complex, Lignin sulfonates, Menadione dimethylpyrimidinol bisulfite, Menadione nicotinamide bisulfite, Methyl esters of higher fatty acids, Methyl glucoside-coconut oil ester, Mineral oil, Natamycin, Sodium nitrite, Petrolatum, Odorless light petroleum hydrocarbons, *Pichia pastoris* dried yeast, Poloxalene, Polyethylene, Polyethylene glycol (400) mono- and dioleate, Polyoxyethylene glycol (400) mono- and dioleates, Polysorbate 60, Polysorbate 80, Poly(2-vinylpyridine-co-styrene), Normal propyl alcohol, Pyrophyllite, Salts of volatile fatty acids, Selenium, Silicon dioxide, Sorbitan monostearate, Taurine, Verxite, Xanthan gum, Yellow prussiate of soda.

In addition to regulating feed ingredients as foods, food additives, or drugs, FDA monitors labeling (see 21 CFR, Part 501), as do states. Labeling includes the written material on the wrapper or container, or accompanying the product, and any marketing materials, including promotion on the Internet.

FDA regulates drugs used in food-producing animals. It establishes limits for residues of drugs in meat and milk, and inspects feed mills that manufacture medicated feeds.²⁰ The United States also participates in the Codex Alimentarius Commission, an international body that establishes food standards, including limits for animal drugs in foods.

FDA also conducts surveys, investigations, and risk assessments related to contaminants of animal feeds, such as dioxins and mycotoxins. While the Institute of Medicine has recommended that government agencies establish legally binding limits on dioxins and dioxin-like compounds in forage and feed after more complete data are generated and ways to avoid contamination are better understood (IOM, 2003, p. 9), to date there are no tolerances or other legal limits for dioxins in feed.

FDA has issued numerous Compliance Policy Guides that pertain to feed; many of these are listed in the references, and can also be found on the FDA Office of Regulatory Affairs website (www.fda.gov/ora/compliance_ref/cpg/cpgvet/default.htm#sc660, Sub Chapter 66 Animal Feed). These are voluntary, however, and are not strictly enforced.

FDA (and USDA) restrictions on feeds in response to “mad cow” (bovine spongiform encephalopathy, or BSE) developments are discussed in greater depth in Section III and the Appendix; updates can be obtained from www.fda.gov/oc/opacom/hottopics/bse.html.

2. U.S. Department of Agriculture (USDA)

The USDA monitors the safety of imported and domestically produced meat, poultry, and some egg products through the USDA Food Safety Inspection Service (FSIS). The USDA Animal and Plant Health Inspection Service (APHIS) monitors the health of domestic animals and screens imported animals and other products, such

as genetically engineered plants and microorganisms, to protect animal health.

While the USDA does not have responsibility for regulating feed *per se*, many of its actions do impact feed. For example, in January 2004, soon after a cow with BSE was discovered in the U.S., the USDA issued new regulations to address BSE. USDA gave notice that it will no longer pass and apply the mark of inspection to carcasses and parts from cattle selected for testing for BSE until the sample is determined to be negative. This helps to keep adulterated meat and meat products from being used to manufacture feed, and therefore helps protect the food supply. More information on the activities of different departments within USDA regarding mad cow are summarized at www.ers.usda.gov/Features/BSE/.

The USDA does not have the authority to shut down meat-processing plants in the event that animal products become contaminated from animals consuming contaminated feed, or via other sources, as illustrated by recent case law (U.S. Court of Appeals, 2001).

Many departments/agencies of the USDA conduct activities relevant to animal feed. For example, the Agricultural Research Service (ARS) has conducted research on pathogens and toxic chemicals in feed, including mycotoxins, drug residues, and environmental contaminants. It also conducts research relevant to antimicrobial resistance related to antimicrobials in feed. As another example, the National Animal Health Monitoring Service (NAHMS) has conducted research relating to salmonella contamination of feed and feed handling and management practices.

3. U.S. Environmental Protection Agency (EPA)

The EPA establishes tolerances for residues of pesticides applied to agricultural crops that may be used for feed. It also approves some genetically modified crops that are engineered to produce pesticides, and these may in turn be used for animal feed. For example, Starlink, which is the trade name for corn genetically modified to produce a protein called Cry9C that acts as a pesticide against pests such as the European corn borer, was registered for use in animal feed only. It was subsequently found in tacos for human consumption.

²⁰Medicated feeds are governed by the Second Generation of Medicated Feed Program of 1986 and the Animal Drug Availability Act of 1996. FDA-approved drugs are either Category I or Category II, based on whether or not a withdrawal period is required. Medicated feed products are Type A, B, or C (see glossary for definitions). The Animal Drug Availability Act of 1996 simplified the registration procedures related to Type A, Category II drugs by no longer requiring a medicated feed application (MFA) and approval for each product, and instead requiring mills manufacturing these products to be licensed. The 1996 act also created a new category of drug that can only be used in a medicated feed if accompanied by a veterinary feed directive (VFD) signed by a veterinarian.

4. U.S. Department of Transportation (DOT)

The U.S. DOT is responsible for implementing the Sanitary Food Transportation Act of 1990, which is designed to prevent unsafe backhauling of food or feed products in conveyances that also are used to haul hazardous substances, such as fertilizer, unless such conveyances are cleaned properly. DOT, however, *has never finalized regulations to implement this law*. DOT also collects statistics on the transportation of animal feed.

B. State Activities

The regulation of animal feed is a joint federal-state venture. Animal feed is subject to review by state feed officials, either by product registration and/or licensing, that may include a review of the product label. Feeds

California has developed a Safe Animal Feed & Education (SAFE) Program funded by industry through license fees and taxes paid on each ton of feed sold to livestock producers (see cdfa.ca.gov/is/safe). The SAFE program is an educational and quality assurance (QA) program that includes conduct of an audit using a "Quality Assurance Program Checklist" form (see www.cdfa.ca.gov/is/safe/default.htm). Just prior to the finding of a cow in the U.S. with BSE, California announced that they would increase ruminant feed testing by 200 percent and use a new, more sensitive lab analysis technique that allows for a 10-fold increase in testing capacity.

(Render Magazine, December 2003)

must meet the labeling requirements in accordance with the state commercial feed law (see www.fda.gov/cvm/prodregulation.htm#labeling_claims).

States, along with the FDA, inspect feed mills and renderers. For example, in 2005 FDA reported information on inspections of feed mills and renderers for mammalian protein in feeds for ruminant animals (see www.fda.gov/cvm/CVM_Updates/BSE1105.htm).

The Association of American Feed Control Officials (AAFCO) is an organization of state and federal feed regulators whose basic goal "is to provide a mechanism for developing and implementing uniform and equitable laws, regulations, standards, and enforcement policies for regulating the manufacture, distribution, and sale of animal feeds; resulting in safe, effective, and useful feeds (AAFCO, 2005). The AAFCO *Official Publication* each year lists the names and contact information of state and federal feed control officials and is overall an excellent source of information for public health researchers interested in animal feed (see www.aafco.org/OrderAAFCO-Publications/tabid/75/Default.aspx).

AAFCO has developed a model feed safety program development guide for use by officials to develop, implement, and maintain a feed safety program (see www.aafco.org/program-2004.pdf).

C. Industry Activities

A full discussion of the range of industry activities is beyond the scope of this paper but some examples of noteworthy activities follow:

- The Animal Protein Producers Industry (APPI) was founded in 1984 to develop a coordinated program for Salmonella testing in order to help control *Salmonella* in rendered products, and their quality assurance program also includes surveillance and education. Over 95 percent of animal proteins produced in North America are manufactured at facilities that participate in APPI's *Salmonella* Education/Reduction Program, according to APPI. APPI also has developed a voluntary program, available for members, for testing *Clostridium perfringens*.
- APPI developed a "third party" certification program to ensure that animal protein producers meet FDA requirements on animal proteins prohibited in animal feed. A number of feed manufacturers have developed or are developing Hazard Analysis and Critical Control Point (HACCP) programs.²¹ A partnership involving the American Feed Industry Association, the National Grain and Feed Association, Kansas State University and University of Nebraska-Lincoln, and USDA and FDA has worked to provide HACCP training to feed manufacturers and ingredient suppliers (see www.oznet.ksu.edu/grsiext/haccp/welcome.htm).

²¹ HACCP is a systematic approach involving an analysis of potential hazards during the manufacturing or other process to which HACCP is being applied, determining points where hazards can be controlled (critical control points), establishing and monitoring control measures or limits (e.g., minimum temperature), and establishing and implementing what corrective actions are to be taken when control limits are not met. Record keeping and verification that the HACCP plan is effective are also required elements of HACCP.

- The American Feed Industry Association (AFIA) has developed a “Safe Feed/Safe Food” certification for feed manufacturers, pet food manufacturers, ingredient suppliers, integrated producers, meat processors, feed purchasers, livestock producers, and other relevant companies. For example, it contains guidelines for record keeping and product tracing and tracking, and suggests that “generally, any level 2 parts per trillion of dioxin (including PCBs) [sic] or higher in finished feed should result in consideration of sampling for the source of the dioxin.” See www.afia.org/Safe_Feed_Safe_Food.html for more information.
- The California Grain & Feed Association, in cooperation with California, provides feed quality assurance training programs for commercial feed manufacturers that focus on feed quality assurance and feed safety.

While there is no formal definition of “good management practices” (GMP) for animal feed formulation, much has been written describing GMP for the feed industry (e.g., Boyd, 1994; McIlmoyle, 2002), and current GMP for medicated feeds is provided in 21 CFR 225 (www.access.gpo.gov/nara/cfr/waisidx_05/21cfr225_05.html). The Institute of Medicine recommends the definition of good animal feeding and production practices for industry to follow that would reduce dioxin contamination levels in forage and feed (IOM, 2003, p. 9).

- Some food producers (e.g., Tyson Foods, Perdue Farms, Foster Farms) claim they have eliminated the use of antimicrobials as feed additives; independent review and verification of such claims are needed.²² A number of other food companies have also announced policies limiting use of antimicrobials. For example, Compass Group, a food service company, recently announced a policy in conjunction with the non-governmental organization Environmental Defense and Smithfield Foods, the world’s largest pork processor and hog producer, prohibiting the purchase of pork in which antibiotics that belong to classes of compounds approved for use in human medicine have been used for growth promo-

tion purposes. Compass Group also requires suppliers to report and reduce antibiotic usage over time.²³

D. International Activities

While many international activities affect the safety of animal feed, they are largely beyond the scope of this paper. A few particularly noteworthy activities include:

1. Codex Alimentarius Commission

The Codex Alimentarius Commission (CAC) is an international body that establishes standards, guidelines, and related texts such as Codes of Practice that are recognized under international trade agreements.²⁴ A subsidiary body of the CAC, the Ad Hoc Intergovernmental Codex Task Force on Animal Feeding has developed a Code of Practice on Animal Feeding designed to establish a feed safety system for food-producing animals that covers the entire food chain; the CAC adopted this code at its session in July 2004. The code specifically addresses the use of antibiotics in animal feed:

“Antibiotics should not be used in feed for growth promoting purposes in the absence of public health safety assessment.”²⁵

Another subsidiary body of the CAC, the Codex Committee on Residues of Veterinary Drugs in Food (CCRVDF), developed a Code of Practice to Minimize/Contain Antimicrobial Resistance which was adopted by the CAC in July 2005. It contains some important public health recommendations that relate to the use of antimicrobials, including those used in animal feed. CCRVDF also establishes maximum recommended limits (MRLs) for animal drugs in meat and milk.

The Codex Committee on Food Additives and Contaminants (CCFAC) deals with contaminants such as dioxins.

Meanwhile, Codex recently established an ad hoc Intergovernmental Task Force on Antimicrobial Resistance, which will hold its first session in October 2007.

²²www.keepantibioticsworking.com/library/uploadedfiles/Recent_Cuts_in_Antibiotic_Use_by_Major_Food_Co.htm

²³ www.compass-group.com/CompassGroup/Media/pressrelease020805.pdf
www.keepantibioticsworking.org/new/resources_library.cfm?refID=73598

²⁴Codex Alimentarius is Latin for “food code.” Codex was created by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) of the United Nations in 1963 and is run under the joint FAO/WHO Food Standards Program. Codex’s main mandate is protection of consumer health and facilitation of fair practices in food trade.

²⁵The statement was adapted from a recommendation made by the World Health Organization: “Use of antimicrobial growth promoters that belong to classes of antimicrobial agents used (or submitted for approval) in humans and animals should be terminated or rapidly phased out in the absence of risk-based evaluations. The termination or phasing-out should be accomplished preferably by voluntary programmes of food animal producers, but by legislation if necessary” (WHO, 2000).

2. *International Activities on BSE*

The World Health Organization (WHO), Food and Agriculture Organization (FAO), and the World Organization for Animal Health (OIE) have undertaken numerous expert meetings related to bovine spongiform encephalopathy, or BSE, and other transmissible spongiform encephalopathies (TSEs). The OIE tracks the number

of reported cases of BSE worldwide by country and year. Twenty-five countries are listed as having reported cases of BSE during the period 1989–2006.²⁶ Once a country is listed by OIE as having cases of BSE, this has important trade implications for that country. For example, after the finding of a BSE-positive cow in the U.S., Japan instated a ban on all U.S. beef imports for nearly two years.

²⁶ www.oie.int/eng/info/en_esbmonde.htm.

IV. Some Feed Ingredients of Particular Public Health Interest

Some ingredients of particular interest from a public health perspective are discussed below. More detailed information on these and other feed ingredients is contained in the Appendix.

1. *Specified Risk Materials (SRMs)*

SRMs are materials known to harbor the highest concentrations of prions, the agents that are believed to cause bovine spongiform encephalopathy, or BSE, commonly known as mad cow disease. Different scientists, countries, and agencies define SRMs differently, and the definition may depend on the age and/or species of the animal in question and/or the BSE risk status of the country of origin of the animal. For example, the brain of a cow that is 14 months old would not be considered an SRM by USDA but would be considered an SRM under the European definition.²⁷

In 2004, soon after the first BSE case in the U.S. (identified in a dairy cow in Washington State in December 2003), both the FDA and the USDA's Food Safety and Inspection Service (FSIS) defined certain materials as SRMs and prohibited them from human food. Specifically, in January 2004, the FSIS issued an interim final rule²⁸ that designated the following materials from cattle as SRMs: the brain, skull, eyes, trigeminal ganglia, spinal cord, vertebral column (excluding the vertebrae of the tail, the transverse processes of the thoracic and lumbar vertebrae, and the wings of the sacrum), and dorsal root ganglia of cattle 30 months of age and older; and the distal ileum of the small intestines and tonsils from all cattle (9 CFR 310.22[a]). This interim rule declared that SRMs are inedible and prohibited their use for human food. Also in January 2004, FDA announced that a number of materials, including some SRMs, would be banned from

FDA-regulated human food (including dietary supplements) and cosmetics, and issued an interim final rule in July 2004.²⁹ This rule essentially extends the FSIS prohibition to cover FDA-regulated human foods and cosmetics. Materials that were designated as SRMs in the FDA rule are the same as the materials designated as SRMs by FSIS. (The FDA rule also prohibits from human food the small intestines from all cattle, material from non-ambulatory disabled cattle, material from cattle not inspected and passed for human consumption, and mechanically separated beef.)

In September 2005, three months after the second BSE case in the U.S., the FSIS issued an interim final rule³⁰ that amended the January 2004 interim final rule to permit beef small intestines, excluding the distal ileum, to be used for human food, provided that such product is derived from cattle that were slaughtered in an official establishment in the United States or in a certified establishment in a foreign country that is eligible to export beef products to the United States. (The distal ileum was found to be infective in cows, and previously FSIS requested comments on whether beef processors could effectively remove it from the rest of the small intestines.)

SRMs, along with *any* animal protein derived from mammalian tissues, have been prohibited since 1997 in *animal feed for ruminants*. SRMs, however, were permitted to be used in *animal feed for non-ruminants*, and in turn, manure and slaughter by-products from these non-ruminant animals were permitted to be fed to ruminants. This contradicts recommendations from an international panel of experts appointed by the secretary of agriculture,³¹ and from AAFCO (AAFCO, January 15, 2004), that SRMs be reduced or eliminated from all animal feeds.

²⁷ SRMs are defined in cattle starting at 12 months in Europe vs. 30 months in the U.S. See Regulations (EC) No. 999/2001 (human food) and (EC) No. 1774/2002 (animal by-product not intended for human consumption) and *Federal Register* 69 (7): 1862–1891, January 12, 2004.

²⁸ "Prohibition of the Use of Specified Risk Materials for Human Food and Requirements for the Disposition of Non-Ambulatory Disabled Cattle." Interim Final Rule. *Federal Register* 69 (7): 1862–91, January 12, 2004.

²⁹ "Use of Materials Derived From Cattle in Human Food and Cosmetics; and Recordkeeping Requirements for Human Food and Cosmetics Manufactured From, Processed With, or Otherwise Containing, Material From Cattle"; Final Rule and Proposed Rule. *Federal Register* 69(134): 42255–42274, July 14, 2004.

³⁰ "Prohibition of the Use of Specified Risk Materials for Human Food and Requirements for the Disposition of Non-Ambulatory Disabled Cattle." Interim Final Rule. *Federal Register* 70 (172): 53043–53050, September 7, 2005.

³¹ The report of an international panel of experts appointed by the secretary of agriculture (Subcommittee, 2004) states, "All SRMs must be excluded from all animal feed, including pet food." It also considered brain and spinal cord of all cattle over 12 months of age (vs. 30 months, as defined by USDA and FDA) to be SRMs.

In July 2004, a joint USDA-FDA Advanced Notice of Proposed Rulemaking³² recommended banning SRMs in all animal feed, but this proposal was never finalized. Instead, in October 2005 the FDA issued a Proposed Rule³³ that certain materials from cattle, but not the entire spectrum of SRMs, be prohibited from all animal feed (not just limited to feed for ruminants). The materials to be prohibited included the brains and spinal cords from cattle 30 months of age and older, the brains and spinal cords from cattle of any age not inspected and passed for human consumption, the entire carcass of cattle not inspected and passed for human consumption if the brains and spinal cords have not been removed, tallow derived from these materials proposed to be prohibited if it contains more than 0.15 percent impurities, and mechanically separated beef derived from these materials proposed to be prohibited.

As noted above, these actions are not fully in line with recommendations from both an international panel of experts appointed by the secretary of agriculture³⁴ and from AAFCO (AAFCO, January 15, 2004), that SRMs be reduced or eliminated from all animal feeds.

Identifying ways to safely destroy or dispose of SRMs previously used in animal feed is another important public health issue but beyond the scope of this paper.

2. Mammalian and Poultry Protein (including blood and blood products, plate waste, animal waste, deer and elk, road kill, and euthanized animals)

A number of rendered animal by-products are used in feed (see Appendix). Instead of listing specific ingredients, labels may use collective terms such as “animal protein

products” that could include products other than fats from animals, including dairy products (whey, milk), products from aquatic animals, and products from both food-producing and non-food-producing animals.

According to the Institute of Medicine, the rendering processes used by most U.S. plants would not eliminate BSE infectivity. In most cases, the process would reduce the infectivity of the raw materials (if it were present) by 1 to 2 logs (IOM, 2004, p. 173). Recent research by the National Institute of Allergy and Infectious Diseases shows that the minimal infectious dose is equivalent to 5 to 10 prion protein molecules, and that small prions (but larger than minimal size for infectivity) are much more efficiently infectious than large ones.³⁵

Due to concerns about BSE, as noted above, in 1997 FDA restricted some animal product ingredients³⁶ to non-ruminant feeds only, and required feeds containing them to bear the label statement, “Do not feed to cattle or other ruminants.”

In January 2004, the FDA announced that it was issuing an interim final rule that would place additional restrictions on animal products used in feed, including blood, poultry litter, and plate waste, but the rule was never issued. In July 2004, FDA announced that it was only considering such issues in an “Advance Notice of Proposed Rulemaking,” a preliminary stage in the rulemaking process that might never result in final FDA action. In October 2005, the FDA concluded that restrictions on blood, poultry litter, and plate waste were not needed. This went against the advice of an international panel of experts appointed by the secretary of agriculture.

³² “Federal Measures to Mitigate BSE Risks: Considerations for Further Action.” Advance notice of proposed rulemaking. Federal Register 69 (134): 42287–42300, July 14, 2004.

³³ “Substances Prohibited From Use in Animal Food or Feed.” Proposed Rule. Federal Register 70 (193): 58570–58600, October 6, 2005.

³⁴ See footnote 31.

³⁵ See www3.niaid.nih.gov/news/newsreleases/2005/Caughey.htm and www.niaid.nih.gov/factsheets/priondis.htm.

³⁶ Meat, meat by-products, animal liver, dried meat solubles, fleshings hydrolysate (obtained by acid hydrolysis of the flesh from fresh or salted hides), meat meal, meat and bone meal, animal by-product meal, meat meal tankage, meat and bone meal tankage, hydrolyzed hair, hydrolyzed leather meal, glandular meal, unborn calf carcasses, animal digest, cooked bone marrow, mechanically separated bone marrow, stock/broth, meat protein isolate. Products from blood are not restricted to non-ruminant feeds. Bone meal (considered a mineral product) is restricted, although bone charcoal, bone ash, and bone phosphate are not.

Blood was used by about 69 percent of commercial feed mills in 1999, 50 percent in 2003, and 39.6 percent in 2004 (Gill, 2005). The Institute of Medicine (IOM, 2004) has concluded that there is evidence that blood (e.g., from sheep) can carry the agent that causes transmissible spongiform encephalopathies (TSEs) (IOM, 2004, pp. 2, 13, 108–112).³⁷

One BSE-related concern with poultry litter is that it can contain poultry feed that has spilled onto the litter, and poultry feed may legally contain ingredients such as bovine meat and bone meal that are prohibited from use in ruminant feed.

FDA also announced in January 2004 that materials from “downer” cattle (cattle that cannot walk) and dead cattle would be banned from FDA-regulated human food (including dietary supplements) and cosmetics, but use in non-ruminant feed is still permitted.

Materials from deer and elk not considered at high risk for a disease related to BSE, called chronic wasting disorder (CWD), are considered by FDA to be acceptable for use in non-ruminant animal feeds. Moreover, if deer and elk from a captive herd initially thought to be CWD-free are later found to have contained a CWD-positive animal, FDA is not recommending that the feed be recalled (FDA Guidance 158).

An international panel of experts appointed by the secretary of agriculture recommended that all mammalian and poultry protein should be prohibited from all ruminant feeds, and that this prohibition should be strictly enforced (Subcommittee, 2004, p. 9). This would include blood, plate waste, animal waste, deer and elk, road kill, and euthanized animals. AAFCO

An international panel of experts appointed by the secretary of agriculture recommended that all mammalian and poultry protein should be prohibited from all ruminant feeds, and that this prohibition should be strictly enforced.

(Subcommittee, 2004)

also supports adding poultry litter and other recycled poultry waste products to the list of prohibited material in ruminant feed (AAFCO, January 15, 2004). Other public health issues (e.g., microbial pathogens, drug residues) may be raised by the use of these ingredients as well. All of these ingredients are discussed in more detail in the Appendix.

3. Antimicrobials

Antimicrobials are added to feed, primarily at subtherapeutic levels.³⁸ Such uses are alleged to help compensate for crowded conditions present in intensive production systems (National Research Council, 1999, pp. 4, 28), and to promote growth. The Union of Concerned Scientists estimates that 70 percent of all antimicrobials used in the U.S (24.6 million pounds or 12,300 tons) are fed non-therapeutically to cattle, swine, and poultry annually in the U.S.. Of those, half belong to eight classes of drugs that are identical or closely related to antimicrobials used to treat humans (Mellon, 2001). An additional estimated 200,000–400,000 pounds are used in aquaculture production, mostly in feed (Benbrook, 2002).

Many FDA-approved drugs are available over the counter at feed supply, cooperatives, or general farm supply stores (National Research Council, 1999, p. 46). Of the 32 antimicrobials approved for use in broiler feeds in the U.S. without a veterinary prescription, 11 are listed as growth promoters, and seven are also used in human medicine (Jones and Ricke, 2003).³⁹

Globally, there is widespread use and misuse of antibiotics to control diseases in aquaculture species (Garrett et al., 1997; Hernández-Serrano, 2005). In many Southeast Asian countries, antimicrobial use is unregulated and involves antimicrobials not permitted in the U.S. (e.g., nitrofurans and chloramphenicol) (Choo, 2001). Chloramphenicol, a potent antimicrobial linked to aplastic anemia in humans, has been detected in imported shrimp and crayfish from Asia.⁴⁰ Though FDA has identified more than 30 drugs used in foreign aquaculture, it tests for only six of them, some only in certain products. For example, salmon is tested for only one drug, oxolinic acid (Young, 2002). Aquaculture production is rapidly

³⁷ Transmissible spongiform encephalopathies (TSEs) include a number of different transmissible diseases that cause destruction of brain tissue in a variety of species, such as BSE (affecting cows), scrapie (affecting sheep), chronic wasting disease (affecting deer), and Creutzfeldt-Jacob Disease (CJD) (affecting humans).

³⁸ Use at less than 200 g per ton of feed is defined as subtherapeutic use.

³⁹ Bacitracin, chlortetracycline, erythromycin, lincomycin, novobiocin, oxytetracycline, penicillin.

⁴⁰ See for example www.cfsan.fda.gov/~lrd/fpshrimp.html.

increasing in the U.S. and worldwide, yet only four antimicrobials⁴¹ are presently approved and available for use in aquaculture in the U.S. (see www.fda.gov/cvm/aqualitoc.htm) The lack of approved antimicrobials puts pressure on some producers to use unapproved products.

FDA has issued (non-binding) guidance for those seeking approval to use an antimicrobial drug with food-producing animals (FDA Guidance 152); the guidance is for evaluating the safety of new rather than currently used drugs and looks at each drug individually rather than by use or class of drug. As in its recent withdrawal of approval for fluoroquinolones in poultry, FDA's practice of gathering evidence before taking action does not prevent resistance. By the time approval is withdrawn, the "genie is out of the bottle" (Turnidge, 2004).

Some countries have made efforts to reduce the use of antimicrobials in feed. For example, use of antimicrobials in Denmark has been reduced by approximately 50 percent as a result of the phase-out of antimicrobials used for growth promotion in 1999. In 2004, 112.5 tons of active compound were used, compared to 205 tons in 1994 (DANMAP, 2004, 2001).

4. Animal Fats

Up to 8 percent of animal and fish feed can be fat (according to James McKean, extension veterinarian and professor at the College of Veterinary Medicine at Iowa State University, cited in Schmidt, 2004). The annual production of animal fats (white and yellow tallow, greases, and poultry fat) is estimated to be 3.6 billion pounds of inedible tallow, 3 billion pounds of grease, and 1.4 billion pounds of recycled fat, according to an industry report (cited in Institute of Medicine, 2003).⁴² These are largely by-products and waste from rendering and meat-processing plants.

The Institute of Medicine (2003, p. 93) identified animal fats as the greatest potential source of contamination by dioxin-like compounds, and considered it a "high-priority risk management intervention" to interrupt the cycle of dioxin-like compounds (DLCs) through forage, animal feed, and food-producing animals (including fish). They recommended that "the government, in collaboration with the animal production industry, identify means to

achieve the reduction or elimination of DLC-containing animal fat as a component of animal feed."

5. Arsenic

Arsenic is added to poultry and swine feed to promote growth, improve feed efficiency, improve pigmentation, and other uses (21CFR558.530). Arsenic can contaminate poultry and poultry litter/waste, ultimately increasing levels of arsenic in the environment and possibly increasing exposures to arsenic among consumers of chicken. Cattle given feeds containing poultry litter had elevated levels of arsenic in edible muscle tissue (Westig et al., 1981). According to a recent estimate, based on an analysis of arsenic in chicken liver, people consuming large amounts of chicken can ingest a sizable proportion of the tolerable daily intake of arsenic established by the WHO (Lasky et al., 2004).

An analysis of chicken muscle and liver by *Consumer Reports* found no detectable arsenic in organic chicken livers and in 15 liver samples from a conventional chicken brand, and an average of 466 ppb of total arsenic in the remaining samples. The Consumer Reports testing found no arsenic in muscle.

A study conducted by the Institute for Agriculture and Trade Policy tested several brands of retail and fast food chicken products. While the average total arsenic found in uncooked chicken products varied substantially among brands, arsenic was detected in nearly three-quarters of the raw chicken breasts, thighs and livers from conventional producers (Wallinga, 2006).

An estimated 75 percent of the arsenic in litter is readily soluble in water (Rutherford, 2003). When the poultry litter is applied to agricultural fields, the arsenic is released into the environment and may result in increased levels of arsenic in surface and groundwater, as well as increased uptake by plants (Rutherford, 2003).

6. Minerals and Mineral Mixes

Minerals and mineral mixes and premixes used in animal feed can contain contaminants such as dioxin and various heavy metals. Some mineral mixes and premixes are by-products or co-products of industrial metal production and can become contaminated. For example, mineral

⁴¹ Oxytetracycline, sulfamerazine, sulfadimethoxine-ormetoprim, and in October 2005, florfenicol.

⁴² Dozier (2002) states that approximately 3.8 billion pounds of fat are used in animal feeds each year and that the poultry industry uses about 60 percent of this fat.

mixes containing zinc oxide obtained from brass production have been found to have high levels of dioxin contamination. FDA has issued an alert to the feed industry warning against the use of mineral mixes and premixes that are by-products or co-products of industrial metal production (FDA CVM Update, 2003).

EPA is aware that hazardous wastes are sometimes recycled as nutritional supplements in animal feed preparations but does not necessarily consider this use to constitute disposal of hazardous waste. For example, zinc oxide reclaimed from emission control dust from electric arc furnaces is a listed hazardous waste, but EPA permitted it to be used as a nutritional feed supplement for animals (EPA, 1994).

Minerals may also contain heavy metal contaminants such as lead, arsenic, cadmium, and mercury. AAFCO lists 133 different mineral products used as feed ingredients, and the “typical” levels of these contaminants in mineral feed ingredients. Lead is considered only “moderately toxic” by the American Association of Food Control Officials (AAFCO), and the maximum tolerance in complete feed is 30 ppm.

V. Summary

What we feed to animals intended for human consumption raises important public health concerns. These concerns arise not only from what is fed to animals but also from gaps in regulations and systems intended to ensure the safety of feed and the food supply.

A variety of substances, including many waste materials from the agriculture, food, and rendering industries, are “recycled” into feed for food-producing animals. Some of these ingredients used in feed, particularly those from animal and mixed sources, may result in unwanted feed contaminants or have other unintended consequences. Animal feed plays an important role in the cycling of

dioxin, arsenic, pathogens, antibiotic-resistant bacteria, prions, and other substances of public health concern.

In this report we have highlighted areas where further public health investigation is warranted, and have also identified some of the barriers to tracing the connections between animal feed and public health, in particular, the lack of effective surveillance systems. It is vital for public health professionals to better understand the feed industry, feed ingredients, and the current regulatory framework, in order to begin to address the public health risks associated with current animal feed practices.

Appendix: Feed Ingredients

A. Feed Ingredients of Plant Origin

1. **Feed grains** include corn/maize, barley, sorghum (milo), oats, wheat, and others. In the United States, more than half of all grain produced is fed to animals (e.g., about 72 percent of corn production). Non-feed uses include human food, seed, and industrial uses such as ethanol, from which by-products are often diverted to feed. Among grains used for feed, corn accounts for about 80 percent of feed grains for animals in the U.S. (USITC, 2000). While grains form a large percentage of feeds, particularly in poultry feed, the amount has declined over time. In 1984, 46,489,576 tons of grains were used in primary feed production in the continental U.S., according to data from the USDA Economic Research Service (ERS) (USDA ERS, 1988). Corn is used primarily for swine, poultry, and dairy and beef cattle. Sorghum is used primarily for beef cattle, swine, and poultry.
 - a. **Genetically modified grains:** In 2005, 52 percent of all corn planted in the U.S. was genetically modified, up from 47 percent in 2004, 40 percent in 2003, 34 percent in 2002, and 26 percent in 2001 (Taylor and Tick, 2003; NASS, 2005).
 - b. **Certified organic grains:** Acreage of certified organic corn more than doubled from 1997 to 2001, and by 2004 is expected to triple compared to 1997 levels. Despite this impressive increase, combined organic corn and soybean acreage represented only about 0.2 percent of total U.S. corn and soybean acreage in 2001/2002 (USDA NOP, 2003).
2. **Oil meals and cakes** are the by-products of oil production obtained in oil mills during the processing or solvent extraction of oilseeds such as soybean, cottonseed, canola, sunflower seed, linseed, safflower, palm kernel, copra, groundnut, and others. Oilcakes (also called expellers) are obtained by pressing, and oilmeals are obtained by solvent extraction. Soy meal constitutes more than two-thirds of protein feed given to livestock (USITC, 2000). About 60 percent of soybean production is fed to animals, primarily swine, poultry, and cattle. Other oilseed meals are lower in protein and higher in fiber, and generally are less expensive; these are more often used for feeding cows and other ruminants. Cottonseed meal is the second-most-important protein feed used in the U.S., mainly fed to beef cattle in feedlots but also in feeding fish such as catfish, salmon, and trout. In 1984, 18,975,579 tons of oilseed were used in primary feed production in the continental U.S. (USDA ERS, 1988).
 - a. **Genetically modified soy:** In 2005, 87 percent of all soy planted in the U.S. was genetically modified, up from 85 percent in 2004, 81 percent in 2003, 75 percent in 2002, and 68 percent in 2001 (Taylor and Tick, 2003; NASS, 2005).
 - b. **Certified organic soy:** Acreage of certified organic soybean more than doubled from 1997 to 2001, and by 2004 is expected to increase over sevenfold compared to 1997 levels, while representing only a small fraction of 1 percent of total soybean acreage (USDA NOP, 2003).
3. **Grain by-products** include corn gluten meal and feed, brewers and distiller's grains, malt sprouts, brewers yeast, wheat mill feed, and hominy. In 1984, 12,096,764 tons of grain by-products were used in primary feed production in the continental U.S. (USDA ERS, 1988). Grain by-products are primarily used for dairy cattle.
4. **Sugar and molasses** used in animal feed amounted to 1,854,824 tons in 1984 in the continental U.S. (USDA ERS, 1988).
5. **Fruit and fruit by-products** include dried pulp from citrus, apple pulp/pomace, pear cannery residue, cranberry pulp meal, and other fruit (no estimates of quantities available). Citrus pulp is mainly fed to dairy cattle.
6. **Alfalfa products** include sun-cured or dehydrated alfalfa meal, pellets, alfalfa nutrient concentrate, and concentrated alfalfa solubles. USDA ERS estimates that 1,100,855 tons of sun-cured alfalfa and 838,636 tons of dehydrated alfalfa were used to produce primary feeds in the continental U.S. in 1984 (USDA ERS, 1988). Alfalfa is used for ruminants.
7. **Miscellaneous plant and food products** include various oat and rice products; various nuts, seeds, and their by-products (e.g., acorns, almond hulls, alfalfa seed screenings, coffee hulls, ground date seeds, flax seeds/hulls, peanut meal/hulls); legumes and their by-products (e.g., various beans and bean straw, bean straw meal, bean pods, and bean hulls); other crop by-products (e.g., artichoke silage/tubers, asparagus butts, avocado seeds/skins, bananas/banana skins, beet by-products [pulp, silage, tops], cabbage leaves, carrot pulp/tops, tomato pomace/skins/leaves/stems; different types of leaves); and other products (e.g., dried bakery waste, dried bread, chocolate by-products, coconut meal, cookie by-products, dried kelp) (Waller, 2005). Dried roots and tubers such as sweet potatoes and manioc (cassava), traded as chips and pellets, are used in animal feed around the world, but their use is not very important in the U.S.

B. Feed Ingredients of Animal Origin

In 2002, the rendering industry produced 8,535,800 metric tons of rendered products, many of which are used in feed.⁴³ Put another way:

“Visualize a 4-lane truck convoy, placed bumper to bumper from Los Angeles, California, to New York City, New York, and that’s the amount of raw material processed by the rendering industry each year. From this waste, the rendering industry produces nearly 10 billion pounds of protein ingredients, highly valued by the feed industry. Also produced is a wide range of other lipid materials used in various feed and industrial applications, which amounts to over 9 billion pounds” (National Renderers Association, 2001).

Rendered animal by-products used in feed include meat meal tankage,⁴⁴ meat and bone meal, poultry by-product meal, poultry meal, dried animal blood, blood meal, feather meal, hydrolyzed leather meal, egg shell meal, glandular meal, hydrolyzed whole poultry, hydrolyzed hair, unborn calf carcasses, animal digest,⁴⁵ bone marrow (cooked or mechanically separated), animal plasma, leather hydrolysate,⁴⁶ and ensiled paunch⁴⁷ (fats listed separately, below). In 1984, 4,421,912 tons of animal by-products⁴⁸ were used in primary feed production in the continental U.S. (USDA ERS, 1988).

Instead of listing specific ingredients, labels may use collective terms such as “animal protein products,” which could include any of the above products (other than fats), as well as products from aquatic animals or dairy products (whey, milk).

Instead of listing specific ingredients, labels may use collective terms such as “animal protein products.”

1. Ingredients from slaughtered food producing animals—Animals slaughtered for meat are one source of animal by-products used in animal feed. About one-third or more by weight of a food-producing animal is not used directly for human consumption (including fat trim, viscera, bone, blood, feathers, hide), and this material is collected and processed by the rendering industry. This material may be obtained from packing-house offal (inedible parts), meat processing waste, and restaurant waste.

Some definitions of animal products specified by the American Association of Feed Control Officials (AAFCO, see description under Section II, States) specify that the products be made only from slaughtered animals (e.g., meat by-products, animal liver, dried meat solubles). Other definitions do not include this specification and may include sources other than animals that have been slaughtered as discussed in #2 below.

⁴³ In descending order of production, these include meat and bone meal, inedible tallow, greases, edible tallow, all other inedible products (including poultry fat and by-product meal, blood meal, and raw products for pet food), dry rendered meat meal tankage, feather meal, and lard, according to the National Renderers Association (www.renderers.org/Statistics/index.htm).

⁴⁴ According to the Association of American Feed Control Officials (AAFCO), meat meal tankage is “the rendered product from mammal tissues, exclusive of any added hair, hoof, horn, hide trimmings, manure, stomach and rumen contents, except in such amounts as may occur unavoidably in processing factory practices. It may contain added blood or blood meal; however, it shall not contain any other added extraneous materials not provided for by this definition.” The AAFCO definition contains requirements relating to calcium and phosphorus levels and pepsin indigestible residues.

⁴⁵ According to AAFCO, animal digest is “a material which results from chemical and/or enzymatic hydrolysis of clean and undecomposed animal tissue. The animal tissues used shall be exclusive of hair, horns, teeth, hooves, and feathers, except in such trace amounts as might occur unavoidably in good factory practice and shall be suitable for animal feed.”

⁴⁶ According to AAFCO, leather hydrolysate “is obtained from chromium tanned unfinished leather shavings, trimmings, and/or lime fleshings that may or may not be pressure-cooked with the addition of steam, sodium hydroxide, lime, or magnesium oxide. Chromium is precipitated and separated so that only trivalent chromium at less than 1000 ppm on a dry matter basis remains in the hydrolysate.”

⁴⁷ According to AAFCO, ensiled paunch is “a product composed of the contents of rumen of cattle slaughtered at USDA- inspected facilities. The moisture level is reduced to 50 percent from 78 percent. The product is then packed into an airtight environment, such as a silo, where it undergoes an acid fermentation that retards spoilage. The ensiled product will have a pH of 4.0 or less.”

⁴⁸ This estimate includes meat meal tankage, meat and bone meal, poultry by-product meal, and feather meal; it does not include fat or marine by-products.

2. Ingredients from animals that may have died otherwise than by slaughter—Animal by-products can also be obtained from animals “that have died otherwise than by slaughter” (FDA Compliance Policy Guide 7126.24). Animals that have died otherwise than by slaughter could include ill food-producing animals that don’t make it to the slaughterhouse, as well as animals that are not food-producing animals (e.g., “road kill” animals, euthanized companion animals, other euthanized animals).

The following are examples of animal by-products that can be used in feed but need not come from slaughtered animals, according to AAFCO definitions: meat meal, animal by-product meal, meat meal tankage, hydrolyzed hair, blood meal, blood protein, animal digest.

Dead, dying, diseased, or disabled (“4-D”) animals

FDA has stated that it is aware of the sale of “dead, dying, disabled, or diseased animals” (“4-D animals”) to salvagers for use as animal feed. Uncooked meat derived from such animals is considered legally adulterated under Section 402(a)(5) of the Federal Food, Drug, and Cosmetic Act, and its shipment in interstate

FDA has stated that it is aware of the sale of “dead, dying, disabled, or diseased animals” (“4-D animals”) to salvagers for use as animal feed.

commerce for animal feed is subject to regulatory action (FDA Compliance Policy Guide 7126.23).

Material from 4-D animals, including downer cows and dead cows, can be legally used to manufacture animal feed for non-ruminants. This use does occur according to Steve Traylor, former feed coordinator for the state of Kentucky and investigator and section writer of the Animal Products section in AAFCO Official Publication 2004 and 2005 (Traylor, phone conversation, 3/12/04). Non-ruminants consuming dead or down cows—believed to have a greater risk for BSE—can in turn be processed into feed for ruminants.

Road kill and euthanized companion and non-food animals

According to Steve Traylor, euthanized cats and dogs and road kill are not prohibited from animal products used in feed unless the feed products specifically restrict animal protein to that from slaughtered animals (Traylor, phone conversation, March 12, 2004). He stated, however, that road kill and euthanized pets are not used by the

majority of renderers for “consumer-driven” reasons, and because “reputable renderers” won’t accept material from unknown animals. He cited results from an FDA study (described below) and a study by the Pet Food Institute (testing for dog and cat DNA in meat and bone meal) in support of that conclusion.

Nevertheless, there is some evidence that euthanized pets may be used to produce feed. FDA conducted two surveys looking for pentobarbital, which is primarily used to euthanize dogs and cats, in dry dog food (FDA, 2002). The sampling was not statistically representative of dog food sold nationally, but instead focused on products with rendered or hydrolyzed ingredients ranked high on the ingredient statement. FDA concluded that “there appear to be associations between rendered or hydrolyzed ingredients and the presence of pentobarbital in dog food. The ingredients Meat and Bone Meal, Beef and Bone Meal, Animal Fat, and Animal Digest are rendered or hydrolyzed from animal sources that could include euthanized animals.” In one survey there was an association between Animal Fat near the first position in the ingredient list and the presence of pentobarbital. In the first survey, 44 out of 87 samples (50.5 percent) were confirmed positive for the presence of pentobarbital. In the second survey, which attempted to quantify the amount of any pentobarbital present, 16 out of 60 samples (26.7 percent) contained pentobarbital. In 10 samples, pentobarbital was detected at levels ranging from 3.9 ppb to 32 ppb, and in an additional six samples pentobarbital was detected in the 1–2 ppb range, which was not accurately measurable (FDA, 2002).

FDA concluded, however, that the pentobarbital residues were likely from euthanized, rendered cattle or horses, and not from euthanized pets. These conclusions were based on testing performed on a subset of dog food samples from the second survey (including all those testing positive for pentobarbital) for the presence of dog or cat remains, using a test FDA developed to detect dog and cat DNA in the protein of the dog food. “The results demonstrated a complete absence of material that would have been derived from euthanized dogs or cats,” according to the FDA report, which stated that the sensitivity of the method used was 0.005 percent on a weight/weight basis (i.e., 50 ppm). Some doubt the accuracy of FDA’s conclusion, however, given unanswered questions about the reliability and efficacy of the test used (no further details about the DNA test were made available), and noting both the large number of samples positive for pentobarbital and the evidence that pentobarbital is rarely used to euthanize horses or cattle.

Deer and Elk

Material from deer and elk is prohibited for use in feed for ruminant animals, but it can be used in feed for non-ruminant animals. Deer and elk are species known to harbor a type of transmissible spongiform encephalopathy (TSE) called chronic wasting disease (CWD). According to FDA, material from animals known to have CWD may not be used in any animal feed or feed ingredient, and animal feed or feed ingredients containing material from a CWD-positive animal would be considered adulterated (FDA Guidance 158). FDA recommends that deer and elk considered at high risk for CWD⁴⁹ “no longer be entered into the animal feed system,” but, this is a non-binding recommendation. Materials from deer and elk not considered at high risk for CWD are considered by FDA to be acceptable for use in non-ruminant animal feeds. If deer and elk from a captive herd initially thought to be CWD-free are later found to have contained a CWD-positive animal, FDA is not recommending that the feed be recalled (FDA Guidance 158).

Blood

FDA announced in January 2004 that it would no longer allow mammalian blood and blood products to be fed to ruminants, but then decided in October 2005 that such a measure was not necessary, as noted above. Blood was used by about 69 percent of commercial feed mills in 1999, 50 percent in 2003, and 39.6 percent in 2004. (Gill, 2005). According to the Institute of Medicine, there is evidence that blood can carry the agent that causes transmissible spongiform encephalopathies (TSEs) (IOM, 2004, pp. 2, 13, 108–112).

3. Marine by-products

Marine by-products used in feed include fishmeal (e.g., from menhaden, anchovy), condensed (or dried) fish solubles, crab meal, shrimp meal, fish oil, fish residue meal,⁵⁰ fish liver and glandular meal, fish protein concentrate, and fish by-products.

About 30 percent of the annual world catch of fish is used not for direct human consumption but to make fishmeal and fish oil (FAO, 2002). In fact, according to International Fishmeal and Fish Oil Organization (IFFO), fishmeal is produced almost exclusively from fish that are not used for human consumption, or which are only used in limited quantities for human consumption, primarily small, bony, oily species of pelagic fish (living in the surface waters or middle depths of the sea), such as anchovy, herring, mackerel, and capelin. Trimmings/offal (inedible parts) from the food fish processing sector are also used to make fishmeal. Fishmeal is made by cooking fish, pressing the cooked mass to remove most of the oil and a large proportion of the water, drying the resultant presscake, and then adding back (in more concentrated form) part of the aqueous portion removed during pressing. (Sometimes the pressing stage is omitted with white fish raw material because there is no oil to be removed.)

World fishmeal production in 2002 was estimated to be over 6 million tons (FIN, 2003). Global fish oil production is over 1 million tons (Pike and Barlow, 2002). This level of production is expected to be stable over the rest of the decade, according to the fishmeal industry (FIN, 2003).⁵¹ Consumption of fishmeal fell 65 percent between 1993 and 1997 in the U.S., according to the International Trade Commission (USITC, 2000, p. B-9), but was still used by about three quarters of commercial feed mills in 1997 and 1998 (USITC, 2000, p. B-6).

In 1984, 815,202 tons of fishmeal were used in primary feed production in the continental U.S. (USDA ERS, 1988). Most fishmeal is used in feed for fish (35 percent), followed by pigs (29 percent), poultry (24 percent), ruminants⁵² (3 percent), and others (9 percent) (FIN, 2003). The proportion of fishmeal and fish oil used for fish feed is increasing. For example, while in 2002 about 34 percent of fishmeal and 56 percent of fish oil were used for fish feed, it is estimated that about 48 percent of fishmeal and 79 percent of fish oil will be used for fish feed in 2010 (Pike and Barlow, 2002). It requires about 2–5 kg of wild fish to produce 1 kg of fishmeal-fed cultured fish (Black, 2001).

⁴⁹ Deer and elk considered at high risk for CWD include (1) animals from areas declared by state officials to be endemic for CWD and/or to be CWD eradication zones; and (2) deer and elk that at some time during the 60-month period immediately before the time of slaughter were in a captive herd that contained a CWD-positive animal.

⁵⁰ The clean, dried, undecomposed residue from the manufacture of glue from non-oily fish, according to AAFCO.

⁵¹ Declining sources of raw materials for fishmeal production due to increased demands for fish for human consumption and reduced fishing quotas are expected to be offset by the increased availability of trimmings/offal from farmed fish for meal and oil production. According to the industry, catch limits are in place for all species used to produce fishmeal (FIN, 2003).

⁵² The suitability of fishmeal for ruminants can be affected by the type and freshness of fish used, addition of preservatives, and other processing factors (Hussein and Jordan, 1991).

4. Animal waste

Animal waste is used in feed, including dried ruminant waste (e.g., cow manure), dried poultry waste, dried poultry litter, dried swine waste, undried processed animal waste products,⁵³ and processed animal waste derivatives.⁵⁴

Processed animal waste products, according to AAFCO, “shall be free of harmful pathogenic organisms, pesticide residues, parasites, or drug residues, above levels permitted by State or Federal statute or regulation which could be harmful to animals or could result in residues in human food products or by-products of animals at levels in excess of those allowed by State or Federal statute or regulation” (AAFCO, 2005). Furthermore, according to AAFCO, the registrant, manufacturer, or producer of any processed animal waste product ingredient must test for the following: drugs “suspected or known to be used in the feed or as a therapeutic treatment of source animals”; pesticides used on the source animal, facility, and waste; pathogenic organisms including at least *Salmonella* and *E. coli*; heavy metals at least to include arsenic, cadmium, copper, lead, mercury, and selenium; parasitic larva or ova; and mycotoxins such as aflatoxin. If the waste product contains drug residues, then a warning statement⁵⁵ must appear on the label. Similarly, if the product contains 25 ppm or greater of copper, a warning statement⁵⁶ and maximum guarantee of copper is required.

The extent to which a “don’t ask, don’t tell, don’t test” attitude prevails, the amount of comprehensive testing done, and whether processing adequate to destroy pathogens occurs are issues that deserve further scrutiny but are beyond the scope of this report.

One concern is that poultry litter may contain poultry feed that has spilled onto the litter, and since poultry feed may legally contain ingredients such as bovine meat and bone meal (which are prohibited from use in ruminant feed), it is possible that ruminants could still be exposed to these ingredients through the ingestion of feed containing poultry litter.

While recognizing that recycled animal wastes have been deliberately incorporated into animal feed for almost 40 years, FDA does not endorse the use of recycled animal waste, and previously had a policy that raised concerns about drug residues and pathogens in animal waste, particularly poultry litter. In 1967 FDA stated that “it is not possible to conclude that poultry litter is safe as a feed or as a component of feed for animals, nor is it possible to conclude that there will be no drug residues in the tissues and by-products of animals fed poultry litter” and concluded that poultry litter may be considered adulterated (Taylor and Geyer, 1979). FDA revoked that policy statement in 1980 in favor of state controls, however, and stated it would not take an active surveillance role in the regulation of processed animal waste as an animal feed ingredient, since animal waste is generally used locally and is not transported across state lines, and since states “have the capacity to effectively regulate its use” (FDA CPG 7126.34).⁵⁷

AAFCO has published a definition for use of animal waste as feed, even though its use has not been sanctioned by FDA (Taylor and Geyer, 1979). (AAFCO ordinarily does not publish a definition for a feed ingredient unless FDA has sanctioned its use.) FDA has stated, however, that it expects states to require animal waste products to conform to the definitions promulgated by AAFCO. FDA’s Center for Veterinary Medicine (CVM) is an active participant in AAFCO.

⁵³ A processed animal waste product composed of excreta, with or without litter, from poultry, ruminants, or any other animal except humans, which may or may not include other feed ingredients. It can contain up to 30 percent combined wood, wood shavings, litter, dirt, sand, rocks, and similar extraneous materials.

⁵⁴ A product resulting from the chemical, physical, or microbiological alteration of an animal waste. Examples include composts, yeasts, algae, or other organisms produced from non-human animal wastes, or wastes treated with ammonia, formaldehyde, or other chemicals.

⁵⁵ It must state, “WARNING: THIS PRODUCT CONTAINS DRUG RESIDUES. DO NOT USE WITHIN 15 DAYS OF SLAUGHTER AND DO NOT USE 15 DAYS PRIOR TO OR DURING THE FOOD PRODUCTION PERIOD OF DAIRY ANIMALS AND LAYING HENS.”

⁵⁶ “WARNING: CONTAINS HIGH LEVELS OF COPPER: DO NOT FEED TO SHEEP.”

⁵⁷ However, FDA stated that if the waste was shipped across state lines and presented a health hazard brought to FDA’s attention, and the state(s) involved could not take appropriate regulatory action, it would consider action, if the waste was shown by analysis to contain levels of pathogens, drugs, chemicals, or other contaminants considered harmful to the animal or which may result in illegal residues in edible animal products.

The commissioner of FDA appointed an FDA task force in the late 1970s to determine whether the agency's "do not sanction" position could be changed in light of new evidence, and while several approaches were considered, none were found to be acceptable (Taylor and Geyer, 1979). Meanwhile, the AAFCO model regulation was adopted in 1979 and is followed by many states. Under the AAFCO model regulation, animal waste that will be used in a commercial feed must be registered/licensed within a state and be assayed periodically for Salmonella and E. coli, heavy metals, pesticides, drugs, parasitic larva or ova, and mycotoxins.

While a "tentative" AAFCO definition of Dried Poultry Waste defined the product as feces from commercial laying or broiler flocks "not receiving medicants," and not containing "any substances at harmful levels" (Taylor and Geyer, 1979), the current definition does not contain these two provisions (AAFCO, 2005).⁵⁸

In January 1994, FDA announced that it intended to ban the use of poultry litter as a feed ingredient for ruminant animals. In July 2004 the agency decided to publish an Advance Notice of Preliminary Rulemaking. However, in October 2005, it decided against such a measure (see Section IV [1] above).

5. Dairy products

Dairy products used for feed include dried skimmed milk or buttermilk or chocolate milk, various whey products, cheese rind, dairy food by-products, dried milk protein, dried cheese, and dried cheese product. USDA ERS estimates that 175,984 tons of milk powder was used to produce primary feeds in 1984 in the continental U.S. (USDA ERS, 1988).

C. Feed Ingredients From Mixed Origin

1. Fats

Fats used in feed can come from animal or plant sources. Examples of fat used as feed ingredients include animal fat, poultry grease, tallow, vegetable fat or oil, hydrolyzed fats (obtained from edible fat processing or soap making), esters (methyl, ethyl, or other non-glyceride ester of fatty acids derived from animal and/or vegetable fats), hydrolyzed sucrose polyesters such as olestra (a fat substitute), corn syrup refinery insolubles (obtained from refining corn syrup and consisting predominantly of the fatty fraction of corn starch together with protein and residual carbohydrate) and vegetable-animal fat blends. (Marine fats are listed separately; see below.)

In 1984, 1,337,237 tons of fats were used in primary feed production in the continental U.S. (USDA ERS, 1988). The annual production of animal fats (white and yellow tallow, greases, and poultry fat) is estimated to be 3.6 billion pounds of inedible tallow, 3 billion pounds of grease, and 1.4 billion pounds of recycled fat, according to an industry report (cited in Institute of Medicine, 2003).

Up to 8 percent of animal and fish feed can be fat (according to James McKean, extension veterinarian and professor at the College of Veterinary Medicine at Iowa State University, cited in Schmidt, 2004).

Animal fats were identified by the Institute of Medicine (2003, p. 93) as the greatest potential source of contamination by dioxin-like compounds. AAFCO states that fats or fat derivatives "must come from acceptable animal feed sources," and notes that wastewater sludge that contains sanitary sewer water is not an acceptable source of animal feed. Sludge material from the processing of animal or plant tissue for human food that does not contain sanitary wastewater may be used; AAFCO recommends that FDA be contacted regarding its safe use in animal feed (AAFCO, 2005).

⁵⁸ Interestingly, the FDA does have a Compliance Policy Guide (7126.28), "Use of Drug-Contaminated Products in Animal Feed," which was developed in response to a request to permit use of penicillin-contaminated nonfat dry milk in the manufacture of animal feed. The policy states that use of penicillin-contaminated nonfat dry milk as an ingredient in a non-medicated feed would be considered a violation of the Food Drug and Cosmetic (FD&C) Act. The policy goes on to say, "A product contaminated with a drug, but otherwise suitable for use as an ingredient in feed, may not be used indiscriminately in a feed. Use of such a drug-contaminated product as a feed ingredient would be allowed only in a feed that contains that specific drug at therapeutic or sub-therapeutic (growth-promotion) levels. The drug-contaminated product may then be used to contribute to the feed an amount of drug up to the level approved for the feed."

2. Restaurant/food waste

This is human food waste collected from restaurants, cafeterias, and other institutions that prepare food. According to AAFCO, processing and/or handling must remove any and all undesirable constituents including crockery, glass, metal, string, and similar materials.

FDA announced in January 2004 that it would ban the use of "plate waste" as a feed ingredient for ruminants, as part of its response to finding a cow with BSE in the U.S., but in October 2005 it decided it would not do so.

Producers who use food waste that contains material of animal origin as feed for swine must be licensed. USDA surveyed 1,175 licensed waste feeders of food waste to swine and estimates that the median amount of food waste fed to swine is 87,500 pounds per year, per farm, although some farms feed over 400,000 pounds per year. Most of the waste was bakery waste and fruit and vegetables; about 13 percent was animal products (eggs, pork, beef, dairy, poultry) (USDA, 1985).

Under current regulations, food waste must be boiled for 30 minutes before being fed to swine. USDA conducted a risk assessment that found that if an average licensed waste feeder in the continental U.S. did not cook food waste before feeding it to swine for a year, there was essentially a 100 percent chance that at least one portion of that waste would contain *Toxoplasma* organisms, and a 100 percent chance of contamination of at least one portion per year with *Salmonella*, and 100 percent/year with *Campylobacter*. For *Trichinella* larvae, the chances were about 37 percent.

3. Contaminated/adulterated food

Contaminated or adulterated (human) food can in some circumstances be used in animal feed. This includes food adulterated with rodent, roach, or bird excreta that has undergone heat treatment to destroy pathogenic organisms (FDA CPG 7126.05), and in some cases may also include (human) food contaminated with (a) a pesticide(s) in excess of the permitted tolerance or action level, or that is unapproved for use on that food or feed commodity, (b) industrial chemicals, (c) natural toxicants, (d) filth, (e) microbiological contamination, or (f) overtolerance or unpermitted drug residues (FDA CPG 7126.20). Requests to divert contaminated food to animal feed are handled by FDA on an ad hoc basis, and data are required to demonstrate that "the diverted use poses no safety hazards to the animals consuming the diverted food and to the public who may be exposed to edible tissues of such animals," according to FDA (FDA CPG 7126.20).

D. Feed Ingredients of Other Origins (Mineral, Microbial, Synthetic)

- 1. Non-protein nitrogen** includes urea and anhydrous ammonia.
- 2. By-products of antibiotic drug manufacture and other fermentation products.** These products include spent mycelium obtained in the production of antibiotic drugs by fermentation of penicillium and streptomycetes and other mold fermentation products used to make enzymes, amino acids, vitamins, etc., and are widely sold for use as ingredients in animal feed in the U.S. (FDA CPG 7126.31; AAFCO, 2004, 2005; Allewynse, 2004). FDA does not object to these being used in feed provided that the antibiotic activity does not exceed 2 grams per ton of cake and that no more than 3 pounds of cake is used per ton of feed. This would provide about 0.002 ppm antibiotic activity to the final feed, which FDA considers insignificant. FDA's policy applies only to antibiotics approved for use in food-producing animals before August 24, 1982.
- 3. Direct-fed microorganisms** (sometimes called probiotics) are also used. Such products are purported to contain live (viable) organisms (bacteria and/or yeast). According to FDA (CPG 7126.41), marketing of such products has greatly increased in recent years, and claims for these products are unproven. AAFCO lists 45 organisms reviewed by FDA that were found to present no safety concerns, including *Enterococcus faecium*, various *Lactobacillus* species, and *Aspergillus niger*. Some firms, however, have marketed direct-fed microbial products other than these, or have permitted more organisms than usual, and FDA is concerned about the safety of such products (FDA CPG 7126.41).
- 4. Other non-food industrial wastes**, such as those from the organic chemical, municipal solid waste, and forest industries, have been suggested as possible feeding stuffs (e.g., by the National Research Council [NRC], 1983), but we did not find any information to indicate that these products are currently used. For example, one review of by-products and unusual feedstuffs (Waller, 2005) did not include such products. Cows have been fed newspaper in some studies (e.g., as a carrier for molasses in cattle feeding and as a replacement of cottonseed bulk in dairy steer and lactating dairy cows) (National Research Council, 1983). The NRC has raised concerns, however, about the use of newspaper and municipal solid waste in animal feed due to polychlorinated biphenyls (PCBs) and other harmful compounds that may be present and that would be expensive to remove (National Research Council, 1983). NRC did consider the use of sawdust,

in concentrations of 5 to 15 percent, in feed for beef cattle to “appear practical.” It also considered foliage “quite useful as a feedstuff,” and some pulp and paper-making residues to “have excellent potential as ruminant feedstuffs” (National Research Council, 1983, pp. 116–117). The NRC also proposed that wastes from organic chemical production could be used to grow bacteria, yeasts, or other single-cell organisms that could in turn be used in feed for food-producing animals, with harmful substances such as heavy metals or toxic organic chemicals removed through solvent extraction.

5. **Polyethylene** in pellet form of certain dimensions is used as a replacement for roughage in feedlot rations for finishing slaughter cattle, and is used at 0.5 pound of pellets per head per day for six days (CFR 573.780).
6. **Minerals** such as calcium, phosphorus, salt, trace minerals, and other minerals. In 1984, 5,049,570 tons of minerals were used in primary feed production in the continental U.S. (USDA ERS, 1988). AAFCO lists 133 different mineral products used as feed ingredients. AAFCO lists “typical” levels of toxic contaminants such as cadmium, arsenic, lead, and mercury in mineral feed ingredients, and suggests guidelines for highly toxic, toxic, moderately toxic, and slightly toxic contaminants in complete feed and in mineral feed ingredients. For example, the maximum tolerance level in complete feed is based on the dietary level that, for a limited time period, will not impair animal performance and should not produce unsafe residues in human food derived from that animal, cited from the most sensitive animal species according to National Academy of Sciences/National Research Council data. The levels are 0.5 ppm for cadmium, and 2 ppm for mercury and selenium. Lead is considered only “moderately toxic” by AAFCO and the maximum tolerance in complete feed is 30 ppm.

7. **Mineral mixes and premixes** for animal feed can be by-products or co-products of industrial metal production and may contain high levels of dioxin, according to FDA (FDA CVM Update, 2003). For example, mineral mixes containing zinc oxide obtained from brass production have been found to have high levels of dioxin contamination. In 2003 FDA issued an alert to the feed industry warning against the use of mineral mixes and premixes that are by-products or co-products of industrial metal production. Iodine, manganese, phosphate rock, potash, and selenium are all used (USGS, 2006).

EPA is aware that hazardous wastes are sometimes recycled as nutritional supplements in animal feed preparations but does not necessarily consider this use to constitute disposal of hazardous waste. For example, zinc oxide reclaimed from emission control dust from electric arc furnaces is a listed hazardous waste, but EPA permitted it to be used as a nutritional feed supplement for animals (EPA, 1994).

8. **Drugs** including antimicrobials, organic arsenic compounds, and other drugs used for growth promotion and feed efficiency, as well as drugs for parasites and other medical conditions. In 1984, 98,072 tons of drugs were used in primary feed production in the continental U.S. (USDA ERS, 1988). The actual amount is higher since this estimate does not include drugs in premixes (e-mail from Mark Ash, USDA ERS). Seventy-two animal drugs for use in animal feed⁵⁹ are currently listed in the online version of CFR Part 558.⁶⁰

Drug ingredients not deliberately added to feed may end up in feed via other routes—such as feed derived from poultry litter, rendering animals that have been euthanized, etc.

⁵⁹ Aklomide, Amprolium, Amprolium and ethopabate, Apramycin, Arsanilate sodium, Arsanilic acid, Bacitracin methylene disalicylate, Bacitracin zinc, Bambermycins, Carbadox, Carbarosone (not U.S.P.), Chlortetracycline, Chlortetracycline and sulfamethazine, Chlor-tetracycline, procaine penicillin, and sulfamethazine, Chlortetracycline, sulfathiazole, penicillin, Clopidol, Coumaphos, Decoquinat, Diclazuril, Dichlorvos, Eftromycin, Erythromycin thiocyanate, Famphur, Fenbendazole, Halofuginone hydrobromide, Hygromycin B, Iodinated casein, Ivermectin, Laidlomycin, Lasalocid, Levamisol, hydrochloride (equivalent), Lincomycin, Maduramicin ammonium, Melengestrol, Mibolerone, Monensin, Morantel tartrate, Narasin, Neomycin sulfate, Nequinat, Nicarbazine, Nitarosone, Nitromide and sulfanitran, Novobiocin, Nystatin, Oleandomycin, Oxytetracycline, Penicillin, Poloxalene, Poloxalene free-choice liquid Type C feed, Pyrantel tartrate, Ractopamine, Robenidine hydrochloride, Roxarosone, Salinomycin, Semduramicin, Sulfadimethoxine, ormetoprim, Sulfaethoxyypyridazine, Sulfamerazine, Sulfaquinoxoline, Tiamulin, Thiabendazole, Tilmicosin, Tylosin, Tylosin and sulfamethazine, Virginiamycin, Zoalene.

⁶⁰ www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcr/CFRSearch.cfm

9. Vitamins A, B12, C, D, and E and vitamin-containing oils such as cod liver oil, carotene, niacin, shark liver oil, wheat germ oil are also added to feed. In 1984, 89,604 tons of vitamins were used in primary feed production in the continental U.S. (USDA ERS, 1988). The actual amount is higher since this estimate does not include drugs in premixes (e-mail from Mark Ash, USDA ERS).

10. Flavors. In 1984, 5,698 tons of flavors were used in primary feed production in the continental U.S. (USDA ERS, 1988). Aloe vera gel concentrate is considered a flavoring agent. Various spices such as fennel and ginger may be used.

11. Chemical preservatives such as BHA (butylated-hydroxyanisole), BHT (butylated hydroxytoluene), ascorbic acid, ethoxyquin, sodium bisulfite, methylparaben. Thirty-six preservatives are listed by AAFCO; some preservatives have no limitations or restrictions (e.g., calcium propionate, citric acid), whereas others may only be used under certain conditions (e.g., sulfites may not be used in meats or vitamin B1 sources; benzoic acid levels may not exceed 0.1 percent).

12. Enzymes including carbohydrases (e.g., cellulose, amylase), lipases, proteases (e.g., pepsin, trypsin), oxidoreductases (e.g., glucose oxidase), phytases. AAFCO lists 25 enzymes, their source, function, and typical substrate. The AAFCO official publication states, "In the case of microbial enzymes it is understood that they are produced from nonpathogenic and nontoxic strains." Enzymes are proteins that catalyze a defined chemical reaction and are used at low levels to alter animal feed. FDA considers all feed enzymes to be either food additives or GRAS (generally recognized as safe) substances as defined by the federal Food, Drug and Cosmetic Act. FDA uses regulatory

discretion in the regulation of feed enzymes and does not usually require a formal food additive petition, unless the agency has concerns about an enzyme/source organism.

a. Genetically modified sources of enzymes may be used. According to AAFCO, if a source organism has been genetically modified to contain an antibiotic resistance gene, then the enzyme product should contain no viable source organisms and no transformable antibiotic resistance DNA.

13. Other additives and GRAS (generally recognized as safe) ingredients include anti-caking agents (e.g., silicon dioxide, diatomaceous earth), artificial sweeteners (e.g., saccharin), color additives (e.g., algae meal, tagetes [astec marigold] meal and extract to enhance the yellow color of chicken skin and eggs), emulsifiers (e.g., polysorbate), pelletizing agents (e.g., lignin sulfonate), spices, and stabilizing ingredients (e.g., sodium carboxymethylcellulose). Ball clay, previously used as an anti-caking agent, is no longer accepted for use as a feed ingredient when it was discovered to be contaminated with dioxin. Formaldehyde is used to improve the handling characteristics of animal fat in combination with certain oilseed meals, and as an antimicrobial agent used to maintain complete animal feeds or feed ingredients Salmonella negative for up to 21 days (CFR 573.460). There are hundreds of additives and GRAS ingredients that may be used in feed. Regulations for 56 food additives⁶¹ are listed as of this writing in the online version of Part CFR 573.⁶²

14. "Nutraceuticals" and ingredients not recognized or approved for use in animal feed include various herbal and botanical products and dietary supplements. The Dietary Supplement Health and Education Act (DSHEA), passed by Congress in 1994, is not considered by the FDA to apply to animals.

⁶¹ Acrylamide-acrylic acid resin, Aminoglycoside 3'-phospho-transferase II, Ammoniated cottonseed, meal, Ammoniated rice hulls, Anhydrous ammonia, Condensed animal protein hydrolysate, Feed-grade biuret, 1,3-Butylene glycol, Calcium periodate, Calcium silicate, Feed-grade calcium stearate and sodium stearate, Choline xanthate, Crambe meal, heat toasted, Diammonium phosphate, Diatomaceous earth, Disodium EDTA, Ethoxyquin in animal feeds, Ethoxyquin in certain dehydrated forage crops, Ethyl cellulose, Ethylene dichloride, Fermented ammoniated condensed whey, Formaldehyde, Formic acid, Condensed, extracted glutamic acid fermentation product, Hemicellulose extract, Hydrogenated corn syrup, Hydrolyzed leather meal, Iron ammonium citrate, Iron-choline citrate complex, Lignin sulfonates, Menadione dimethylpyrimidinol bisulfite, Menadione nicotinamide bisulfite, Methyl esters of higher fatty acids, Methyl glucoside-coconut oil ester, Mineral oil, Sodium nitrite, Petrolatum, Odorless light petroleum hydrocarbons, *ichia pastoris* dried yeast, Poloxalene, Polyethylene, Polyethylene glycol (400) mono- and dioleate, Polyoxyethylene glycol (400) mono- and dioleates, Polysorbate 60, Polysorbate 80, Poly(2-vinylpyridine-co-styrene), Normal propyl alcohol, Pyrophyllite, Salts of volatile fatty acids, Selenium, Silicon dioxide, Sorbitan monostearate, Taurine, Verxite, Xanthan gum, Yellow prussiate of soda.

⁶² www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcr/CFRSearch.cfm.

According to AAFCO, many undefined or unrecognized ingredients are being marketed for use in animal feed, or they are being marketed for unapproved purposes (AAFCO EMSI Working Group, undated). Recently AAFCO has recommended nationwide “enforcement events” to crack down on two botanical products, the herb comfrey, and kava, a plant in the pepper family (AAFCO, 2003a, b). Comfrey can

cause liver damage in humans and animals; FDA advised manufacturers not to use comfrey in human dietary supplements due to safety concerns. Kava is banned in Canada and in some European countries due to reports of serious side effects in humans, primarily liver damage, and a public health advisory for kava was issued by FDA in 2002 (www.aaeco.org/news.htm).

Glossary: Types of Feed

Feeds are defined and classified in a variety of ways. Below are some common classifications and terms used to describe types of feeds (Ash, 2004; Association of American Feed Control Officials (AAFCO), 2004 and 2005; Boyd, 1994; Feedstuffs, 2005; UNCTAD, 1984).

Complete Feeds vs. Supplement Feeds vs. Premixes

Complete feeds are nutritionally adequate and can be fed as the sole ration.

Supplement feeds are intended to be (1) fed undiluted as a supplement to other feeds; (2) offered free choice (i.e., animals are given unlimited access to it) with other parts of the ration separately available, or (3) further diluted and mixed to produce a complete feed.

Premixes are feeds that contain one or more concentrated products, such as vitamins, minerals, or drugs, that are added to complete feeds. In 1984, 651,087 tons of premixes were used in primary feed production in the continental U.S. (USDA ERS, 1988).

Compound/Formula Feeds

Compound feeds are made up of two or more ingredients proportioned, mixed, and processed according to certain specifications. They are designed to provide the nutritional requirements of a certain type of livestock. There is a wide range of compound feeds available; the most important are for cattle, poultry, and pigs. The exact ingredients in a compound feed are interchangeable, to some extent, considering nutritional value of the major items used, cost of ingredients, and limits on toxic levels in certain ingredients. Computer software is used to formulate least-cost formulations.

Formula feeds are another term for compound feeds; they may also be called **mixed feeds** or **prepared feeds**.

Concentrates vs. Roughages

Concentrates are feeds low in fiber and high in total digestible nutrients; they include various grains and high-grade by-products such as wheat bran, oilcake, skim milk, etc. Concentrates are intended to be further diluted and mixed to produce a supplement or a complete feed.

Roughages are feeds such as hay, straw, and silage, which are high in fiber but low in total digestible nutrients. The most common type of roughage used in the U.S. is hay. Silages are derived from legumes and grasses that have been anaerobically fermented. About 70 percent of hay is consumed on-farm (USITC, 2000).

Energy vs. Protein Feeds

Energy feeds include staple grain and vegetable crops of varying degrees of refinement, such as corn, wheat, barley, oats, sorghum, potatoes, wheat bran, wheat middlings, corncobs, rice bran, groats, and dried beet pulp. Corn is the most commonly used energy feed.

Protein feeds include oilseed meals and cakes (e.g., soybean meal, cottonseed meal), corn gluten meal, animal products such as meat and bone meal, and fishmeal. Soybean meal is the most commonly used protein feed in the U.S., followed by cottonseed meal (USITC, 2000).

Medicated Feeds (vs. Unmedicated Feeds)

Medicated feeds are any feeds that contain one or more substances considered to be an animal drug by the Food and Drug Administration (FDA). Antimicrobials included in a feed for growth promotion are included in the definition.

Type A medicated articles are regulated as drugs, and may or may not contain a carrier (e.g., corn gluten, rice hulls), or inactive ingredients. They are used to manufacture another Type A medicated article, or a Type B or Type C feed. They are a drug “premix” or concentrated source of the drug for mixing purposes.

Type B feeds are medicated concentrate or supplement feeds intended to be mixed with feed that is not medicated; they contain less drug than type A but substantially more than type C. Type B feeds are considered medicated feeds, and there are limits on how much drug they can contain.

Type C feeds are medicated feeds that are considered complete, ready for direct consumption by animals, and are regulated as feeds.

Organic Feed (vs. Conventional Feed)

Organic feed is strictly defined by regulation. Like any feed, organic feed must comply with the law regulating the use of feed, feed additives, and feed supplements, but in addition, organic feed cannot contain any of the following components which may be found in **conventionally produced feed** (National Organic Program, §205.237, see www.ams.usda.gov/nop/NOP/standards/ProdHandReg.html)

- a. Animal drugs or hormones to promote growth
- b. Feed supplements or additives in amounts above those needed for adequate nutrition and health maintenance for the species at its specific stage of life
- c. Plastic pellets (for roughage)
- d. Urea or manure
- e. Mammalian or poultry slaughter by-products to mammals or poultry

Physical Forms of Feed

Mash (Meal) is ground.

Pellets have been agglomerated by compacting and forcing through die openings using a mechanical process.

Biscuits are shaped and baked dough.

Blocks have been compressed into a solid mass cohesive enough to hold its form and weighing over two pounds (generally 30 to 50 pounds). May also be called **bricks**.

Cakes are a mass resulting from the pressing of seeds, meat, or fish in order to remove oils, fats, or other liquids.

Diluents are used to mix with and reduce the concentrate of nutrients and/or additives to make them more acceptable to animals, safer to use, and more capable of being mixed uniformly in a feed.

Fines have been passed through a screen.

Flakes have been rolled or cut into flat pieces with or without prior steam conditioning.

Scratch is whole, cracked, or coarsely cut grain.

Uncleaned feed contains foreign material.

Wafers are made from fibrous ingredients that have been agglomerated by compressing them into a form.

Wet feed contains liquid or has been soaked or moistened with water or other liquid.

Primary vs. Secondary Feed

Primary feed is feed mixed from individual ingredients such as feed grains, mill by-products, and ingredients of animal origin, sometimes with the addition of a premix at a rate of less than 100 pounds per ton of finished feed. Primary feed may be a complete feed, a supplement, a concentrate or other feed product for mixing with more ingredients. Generally primary feed does not include feed grains, wheat, rye, or by-product feeds (oilseed meals, animal protein, protein feeds, wheat mill feeds, alfalfa meal, etc.) that may have been purchased or ground and added as a feed supplement or feed concentrate.

Secondary feed is made by combining supplements and other ingredients. It is often custom-mixed for clients, and generally used at a rate of 300 pounds or more per ton of finished feed, depending on the protein content.

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 - 21 CFR 558 New Animal Drugs for Use in Animal Feeds (see www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm).
 - 21 CFR 558.530 Roxarsone
 - 21 CFR 589 Substances Prohibited from Use in Animal Food or Feed
 - 21 CFR 570 Food Additives;
 - 21 CFR 573 Food Additives Permitted in Feed and Drinking Water of Animals (see www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm).
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