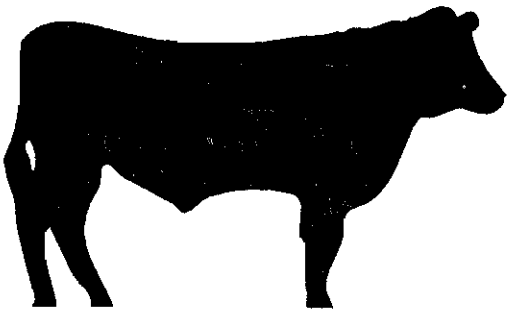
# Chemical Use in Animal Production:

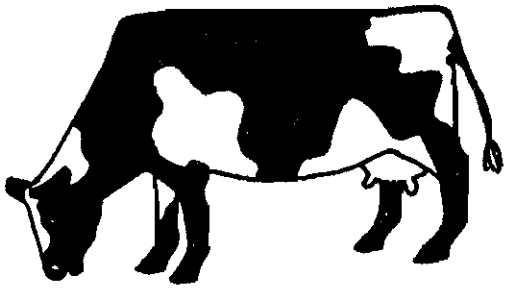
## *Issues and Alternatives*

**Case Studies in**

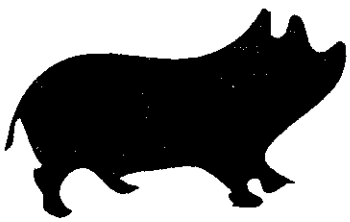
**Beef**



**Dairy**



**Swine**



**Poultry**

Report of a 1987-88 Study Group on
Chemicals in the Human Food Chain: Sources, Options, and Public Policy

Sponsored by the
University of California
Agricultural Issues Center
1989

# CHEMICAL USE IN ANIMAL PRODUCTION:

# ISSUES AND ALTERNATIVES

Report of a 1987-88 Study Group on
Chemicals in the Human Food Chain:
Sources, Options, and Public Policy

Sponsored by the

University of California
Agricultural Issues Center
1989

# TABLE OF CONTENTS


| | |
|---|---|
| PREFACE | iii |
| ACKNOWLEDGEMENTS | iv |
| INTRODUCTION | 1 |
| ANTIBIOTICS IN DAIRY PRODUCTION | 5 |
| ANTIBIOTICS IN BEEF PRODUCTION | 11 |
| SALMONELLAE AND OTHER PROBLEMS IN POULTRY PRODUCTION | 15 |
| PORCINE GROWTH HORMONE | 21 |
| SUMMARY | 23 |



**The authors are:**

*Rick Bennett*, UC Cooperative Extension, Solano County
*Bees Butler*, Agricultural Economics, UC Davis
*Noreen Roche Carter*, writer for the study group
*Anita Edmundson*, Veterinary Medicine, UC Davis
*John Glenn*, Veterinary Medicine, UC Davis
*Duncan McMartin*, Veterinary Medicine Extension, UC Davis
*Ben Norman*, Veterinary Medicine, UC Davis
*Bennie I. Osburn*, Veterinary Medicine, UC Davis
*Fred Troutt*, Veterinary Medicine Teaching & Research Center, Tulare, CA; now at the University of Illinois



A copy of this publication may be obtained for $8.00 from
Agricultural Issues Center
University of California
Davis, California 95616



Copyright © by the University of California Agricultural Issues Center

All rights reserved. No part of this book may be reproduced in any form or by any means without written permission by the publisher.

# PREFACE

*Harold O. Carter and Carole Frank Nuckton*

This is the fourth in a series of reports stemming from the UC Agricultural Issues Center's major study in 1987-88:

## Chemicals in the Human Food Chain: Sources, Options, and Public Policy

An interdisciplinary approach was used with the project as over 60 faculty and extension specialists applied their expertise from diverse fields—veterinary medicine, medicine and health sciences, nutrition, environmental toxicology, agricultural economics, food science and technology, agronomy, pomology, entomology, law, and others. Participants came from three UC campuses—Berkeley, Davis, and Riverside—and Stanford University. Many persons from outside the university also participated in the study as consultants, study-paper reviewers, and panelists at the Center's June symposium.

Each of the three main topics—Sources, Options, and Public Policy—was divided into a number of subgroups. Co-leaders of the Sources group were James N. Seiber, professor of environmental toxicology and associate dean for research, College of Agricultural and Environmental Sciences, UC Davis, and Michael W. Stimmann, statewide pesticide coordinator, UC Division of Agriculture and Natural Resources, and extension entomologist, UC Davis. This group examined five major sources of chemicals in the human food chain—animal products, crop plant products, food additives, natural toxicants, and industrial/environmental contaminants.

The overall chair of the Options group was James M. Lyons, professor, Vegetable Crops, UC Davis and acting director, Office of Program Information and Analysis, Division of Agriculture and Natural Resources, University of California. The Options group had three study teams: animal products chaired by Bennie Osburn, professor of pathology and associate dean of the research and graduate programs at the School of Veterinary Medicine, UC Davis; plant products, chaired by William C. Liebhardt, extension specialist, Agronomy and Range Science, UC Davis and director of the UC Sustainable Agriculture Program; and postharvest handling and processing, chaired by Adel A. Kader, professor and chair of the Pomology Department, UC Davis. This report represents the efforts of the animal products group which selected four case studies: antibiotics in dairy, antibiotics in beef, salmonella in poultry, and growth hormone in swine.

The Public Policy group, chaired by Archibald, assistant professor, Stanford University, was concerned with society's mechanisms for dealing with chemicals, including criteria for food safety, risk assessment and the regulatory environment. Its approach was to involve panels of experts to solicit differing perspectives on regulatory effectiveness. Participating were consumer groups, food producers-processors-retailers, chemical manufacturers, risk assessors, and regulators.

Key findings of the study groups were presented at a symposium on June 2-3, 1988. (The proceedings may be ordered from the Center.) The complete study group reports are published or are in preparation for publication. Supplementing this report on case studies in animal products are: *Agricultural Chemicals in California Plant Production: Are There Alternatives?* and *Chemical Use in Food Processing and Handling: Issues and Alternatives.* A reference book on sources of chemicals in the human food chain is being compiled, and a report documenting the varying viewpoints of the participants in the policy process is now available: *Regulating Chemicals: A Public Policy Quandary.* Video tapes from the symposium have been produced for classroom and extension workshop use. Additional outreach is planned, and new areas of research inquiry have been opened that may well continue for a number of years.

The efforts, comments, responses and cooperation of the many experts from within and outside of the university who contributed to this study are greatly appreciated. Their names are acknowledged on the next page.

# ACKNOWLEDGMENTS

*Noreen Roche Carter* did much of the preliminary writing and editing work.

Besides the authors of the chapters, there were two other members of the study group:
*Lee Baldwin*, Animal Science, UC Davis
*Dave Hinton*, Veterinary Medicine, UC Davis

Those who contributed substantially to the chapters include:
*Francine Bradley*, Avian Science, UC Davis
*Steven Berry*, Animal Science, UC Davis
*John Gay*, Veterinary Medicine, UC Davis
*Ronald Hedrick*, Veterinary Medicine, UC Davis
*Richard McCapes*, Veterinary Medicine, UC Davis
*Thomas Richardson*, Food Science & Technology, UC Davis

Others contributed information and/or reviewed the chapters:
*Jane Anderson*, California Beef Council, Foster City
*Alex Ardans*, School of Veterinary Medicine, UC Davis
*Lee E. Blakely*, Dairyman's Cooperative Creamery Association, Tulare
*Raymond G. Bryant*, California Department of Health Services, Berkeley
*Bob Bushnell*, Veterinary Extension, UC Davis
*Fred Conte*, UC Cooperative Extension, Animal Science, UC Davis
*Bruce R. Charlton*, California Veterinary Diagnostic Laboratory Service, Sacramento
*Art Craigmill*, Veterinary Extension, UC Davis
*Jim Farley*, UC Cooperative Extension, Merced County
*Constatin Genigeorgis*, Veterinary Medicine, UC Davis
*Ria de Grassi*, California Farm Bureau Federation, Sacramento
*Juan Guerro*, UC Cooperative Extension, Imperial County
*Royce Harr*, U.S. Department of Agriculture, Food Safety Inspection Service, Washington, D.C.
*David Johnson*, ConAgra Turkey Company, Turlock
*Hailu Kinde*, California Veterinary Diagnostic Laboratory Service, San Bernardino
*Joe Lyons*, U.S. Department of Agriculture, Food Safety Inspection Service, Washington, D.C.
*Sheila Massey*, California Cattlemen's Association, Sacramento
*Greg Moller*, California Veterinary Diagnostic Laboratory Service, Toxicology, UC Davis
*Jack Morse*, Lander Veterinary Clinic, Turlock
*Rosemary Mucklow*, Western States Meat Association, Oakland
*John Nehay*, California Food and Agriculture, Sacramento
*Hans Riemann*, Veterinary Medicine, UC Davis
*Grover W. Roberts*, California Farm Bureau Federation, Sacramento
*Tom Schultz*, UC Cooperative Extension, Tulare County
*Roy Sharp*, Livestock Systems Management, Tulare
*Patton Smith*, California Department of Food and Agriculture, Sacramento
*F. Robert Studdert*, California Aquaculture Association, San Rafael
*Richard L. Tate*, California Department of Food and Agriculture, Sacramento
*John Vavis*, Kearney Agriculture Research Center, Parlier
*Jim Ver Steeg*, Upjohn, Porterville

Helene Obradovich, publications assistant for the UC Agricultural Issues Center, designed and prepared the camera-ready copy of this report.

# INTRODUCTION

*Bennie Osburn*

Animal proteins are an important part of the human diet. When properly prepared, foods derived from animal products are generally safe and wholesome. In fact, animals' biological systems tend to screen environmental contaminants, plant and fungal toxins, and other chemicals that enter the animals, preventing them from entering the animal and eventually the human food supply.

*Animals screen chemicals/microbials from humans by their:*
- *feeding preferences*
- *natural detoxification systems*
- *illness*
- *inspection at abattoirs*
- *immune response*

Additionally, the government inspects and tests animal products to help to ensure that only wholesome, safe foods reach the consumer. In 1986, 55 million poultry and 375,000 red meat carcasses were condemned for various reasons as unsuitable for human consumption in the United States (Menning, 1988). Some 7,500 federal inspectors oversee operations in 7,200 packing and processing plants every working day. This inspection costs about $1.50 a year for each of us (FSIS, 1985).

As a result, meat, milk, and eggs are among the safest and most wholesome food products that consumers can purchase. However, despite the combined efforts of people and nature to protect the food chain, chemical and microbial agents do, on occasion, find their way into animal products.

In the United States, food-borne disease outbreaks are a major public health concern. It is estimated that there are over 83 million cases of food-borne illnesses annually and 9,000 of these result in death (Young, 1987). In more than 50 percent of the food-borne disease cases reported to the Centers for Disease Control (CDC), the causes are not known (CDC, 1986). In 1982, in outbreaks for which the cause was determined, 69 percent were due to bacterial agents; 9 percent, to viral agents; 21 percent, to chemicals (largely from fish or shellfish and mushroom toxins); and a very small proportion, to parasitic organisms.

*Magnitude of human food-borne disease problems in the United States:*
- *33 million cases of food-borne illnesses in the United States annually*
- *11 million of these were of animal origin*
- *9,000 human deaths occurred*

The overall costs for the five major food-borne diseases is estimated to be from $1.5 to $2.7 billion annually in the United States, with salmonellosis accounting for 36 percent; campylobacterosis, for 52 percent; congenital toxoplasmosis, for about 12 percent; trichinosis, for 0.1 percent; and parasitism including beef tapeworm for a very small percentage (Anon, 1987).

Some infections, such as salmonellosis, have increased from 11 cases per 100,000 population in 1971 to over 27 cases per 100,000 population in 1985. Others, such as shigellosis, remain the same at 7.5 cases per 100,000, while trichinosis has declined from 0.05/100,000 to 0.02/100,000 during this period (Menning, 1988).

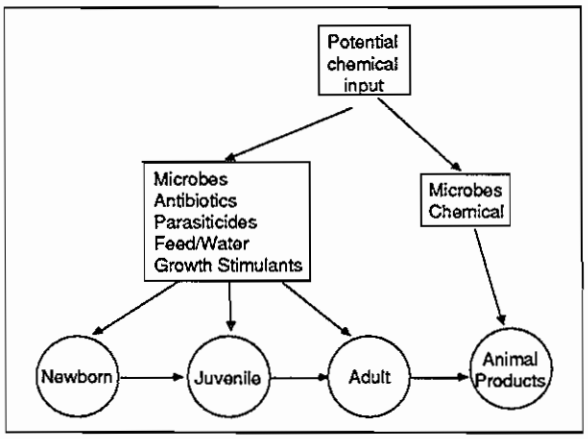
Some reasons for the recent increase in food-borne illnesses include:

1. Changes in the handling and feeding of animals
2. Intermingling of animals before slaughter
3. Cross contamination of carcasses on production lines
4. Fresh-marketing practices, which prolong the period before the product is sold
5. Quick cooking methods, such as uneven cooking in microwave ovens
6. Less use of salt, nitrites, acids and other microbial-reducing agents
7. Lowered natural resistance of humans to diseases
8. Mishandling of exotic delicacies
9. Greater preference for meats that are cooked rare
10. Reduced awareness of safe food handling
11. Reliance on others to ensure food safety

There is a sharp contrast between the progress made in protecting the public from transmittable diseases and the relatively unchanged occurrence of food-borne outbreaks. Some illnesses and other effects that may be, but are not exclusively, caused by food-borne hazards are diarrhea, cramping, vomiting, septicemia, muscle weakness, paresis and paralysis,

allergies, malabsorption syndromes, nutritional syndromes, rheumatoid-like arthritis, altered secondary sex characteristics, liver failure, kidney failure, antibiotic resistant infections, abortions, stillbirths, blindness, mental retardation, uraemic syndrome, and possibly death. Cancer and birth defects are also thought to be related to food intake.

The modern animal production unit is a highly sophisticated system where size, efficiency, and economy all act as important considerations in




management decisions. These systems are complex because, over the course of their lives, animals are affected by both management procedures and environmental conditions. Chemicals are administered to animals to treat and control disease and to promote growth and product quality. Animals are unintentionally exposed to chemicals through feed, water, and environmental contamination. Microbial contaminants may be acquired through animal feeds or by exposure to other infected animals. In some instances, humans may be the source of contamination through handling the products at slaughter or by contaminating animal feed stuffs. Contamination can also occur at the processing level where infection from one or a small number of animals can be easily disseminated to large numbers of other carcasses.

Microbial contaminants in foods of animal origin are the most important of the food-borne hazards to humans. The second most important are those associated with over-consumption or inadequate intake of essential nutrients. The third hazard, although less significant, consists of the natural toxins in food, such as aflatoxin in peanut butter, while environmental contaminants, such as mercury in fish products, come much lower on the list. And last, with a very low risk, is the hazard from chemical residues in food, including pesticides and various animal health products. The assessment of risks associated with foods is a difficult concept for the consumer to understand, since no activity, including eating or drinking, can be free from all risks. A framework for gauging the risks associated with contaminated foods compared to other events is given in Table 1.

Table 1. Risks of Death Associated with Daily Activities, Atmospheric Disasters and Medical Procedures.

| Adverse or dangerous event | Risk of death per million at risk |
|---|---|
| Automobile accident | 220 |
| Liver biopsy | 200 |
| Child bearing (UK c. 1970) | 100 |
| Having a fall | 71 |
| Surgical anesthesia (UK c. 1970) | 40 |
| Fires | 29 |
| Airplane travel (US 1978) | 8 |
| Railway accidents (US 1978) | 3 |
| Electrocution at home (US 1978) | 1 |
| Vaccination (UK c. 1970) | 1 |
| Lightning | 0.6 |
| Tornado, flood, earthquake | 0.5 |
| Venomous insects, snakes, etc. | 0.2 |
| Botulism (US 1978) | 0.02 |
| Salmonellosis (US 1978) | 0.01 |

Adapted from Mossel, 1988.

### Microbial Agents

Microbial agents are associated with acute and chronic diseases in humans. These microbes may come from animals, from the environment, or from humans. Organisms such as *Brucella, Salmonella, Listeria, Campylobacter, Yersinia, Clostridium perfringens,* and hemolytic *Escherichia coli* may come from animals and can cause infection, disease, or food-poisoning cases in humans. In individuals with weakened immune systems, such as the very young or very old, infections from these sources can cause death. There is also evidence that some food poisoning infections lead to chronic malabsorption and nutritional syndromes, aberrant immune responses and/or rheumatoid—like joint disease (Menning, 1988). *Escherichia coli* 0157:H7 can cause a fatal hemolytic and uraemic syndrome in humans (Menning, 1988).

*Campylobacter* is currently the leading cause of bacterial gastro-enteritis in humans in the United States. Surveys of retail meat and poultry products indicate contamination rates as high as 67

percent for *Campylobacter*, 65 percent for *Salmonella*, 50 percent for *Listeria*, and up to 30 percent for *Toxoplasma* in pork (Menning, 1988).

Other bacterial products, such as *botulinum* toxin, have been associated with contaminated meats. Parasitic diseases such as beef measles (tapeworm eggs), *trichinella* (especially in pork), and *toxoplasmosis* (pork and other meats), may contaminate animal products and result in gastrointestinal, muscular, and congenital diseases, respectively.

## Chemicals

Chemical residues resulting from antibiotics, hormones, pesticides, fungal toxins, plant toxins, and environmental contamination can enter animal systems unintentionally through feed and water or may be intentionally administered to promote growth, enhance product quality, or control pests. No human disease has been shown to be caused by residues resulting from the use of animal health products when they were administered in an approved manner.

### Toxins

Many toxins occur naturally; these are the most important chemical food-borne hazard that cause disease in people. Mushroom poisoning is an excellent example. Certain fungi found on plants produce toxins which, when eaten by animals in sufficient amounts, can cause disease. Aflatoxin is an example of a fungal toxin shown to cause disease in livestock and liver damage and cancer in laboratory rodents. It occurs commonly on peanuts, beans, and cereal grains used in feed and food. Low levels of these toxins may also appear in animal products where the animals ingested (were fed) contaminated (moldy) feed. Similar situations sometimes occur with plant toxins. Toxic honey due to bees collecting rhododendron nectar is well documented (Stowe, 1988). However, the risk to humans from consuming toxin-contaminated products is much lower than direct consumption of the toxin would be.

Certain seafoods may contain toxins, such as ciguatoxin (occasionally in Caribbean fish), tetrodotoxin (puffer fish, Japan), and scombrotoxin (particularly in tuna and mackerel). Ciguatoxin and tetrodotoxin cause neurologic symptoms including paraesthesia, while ciguatoxin and scombrotoxin are associated with gastrointestinal symptoms.

### Environmental contaminants

A large variety of compounds adulterate our environment and may enter the human food chain by contaminating plants and animal products. Halogenated cyclic hydrocarbons (HCH), such as PCB, PBB, and dioxin, are widespread environmental contaminants. They were used as industrial lubricants and fire retardants or occurred as unwanted by-products. Since these agents are chemically stable and fat soluble, they can enter the food chain long after their initial use. Heavy metals, such as mercury, also contaminate the environment and can be found in shellfish and fish products.

### Antibiotics

Antibiotics are used to control, treat, and prevent microbial diseases in animals. Additionally, they are used for enhancing animal growth rates and food conversion rates, making animal production more technically and economically efficient. The use of antibiotics destroys only susceptible bacteria—resistant bacteria remain following effective therapy. Therefore, the widespread use of antibiotics in animals and humans selects for antibiotic resistant bacteria. This resistance can be transferred among certain types of bacteria, especially those that inhabit the intestinal tract.

If an individual becomes infected with disease-causing bacteria that are resistant to antibiotics, then the initial therapy may be ineffective. An alternative antibiotic may then be used that could be more expensive or have increased side effects. Futher, this situation can delay effective treatment which could prove critical in some cases.

Exposure of humans to antibiotic residues in animal products can contribute to sensitizing an individual to a particular antibiotic. For example, penicillin sensitivity is quite common in humans. When combined with natural penicillin molds that grow in the environment, the presence of penicillin residues in animal products may contribute to the development of a sensitivity. Subsequently, an allergic or hypersensitivity reaction may occur when penicillin is taken for an infection.

Present regulations on the use of antibiotics in animals prohibit the marketing of products for a specified time period following the use of an antibiotic. Such regulations help to ensure that any residues remaining in marketed products are so small that they will cause no harm to consumers. Additionally, certain antibiotics, such as chloramphenicol, are reserved mainly for human treatments and are not licensed in the United States for use in food-producing animals. When regulations are followed, pharmaceuticals residues in animal products are insignificant and of no risk to consumers.

### Pesticides

The presence of small quantities of pesticide residues in animal products is common. Some of these are from pesticides used on the animals, while others are from environmental uses that cause direct contamination of the animal or its feed. Regulations governing the use of pesticides on animals are similar to those governing the use of antibiotics and commercial steroid products on them. Products derived from animals treated with pesticides may not be marketed for human food until a sufficient withdrawal period has passed, ensuring that any remaining residues are of no threat to consumers.

Many crop by-products such as cottonseed, tomato pumice, and almond hulls are fed to livestock in California. These products may contain pesticides used in crop production or in processing that can enter animals through their feed. Residues may then occur in animal products which ultimately reach the consumer.

### Hormones

Steroidal hormones are used to enhance growth and feed efficiency and for managing the reproductive performance of food animals. In certain situations, these agents are of concern to some consumers since they may promote carcinogenesis. Other consumers are concerned about possible changes in secondary sexual characteristics from consuming products from treated animals. However, residue levels in treated animals are within the range of hormone values found in normal animals. The only conceivable danger would be if the injection sites, usually the tissues discarded at slaughter, were to be repeatedly consumed.

Livestock may also gain high levels of steroids from eating certain types of plants containing them (for example some clovers) or by eating foods contaminated by molds producing estrogenic compounds. This can have adverse effects on livestock, such as mammary enlargement, reduced fertility, and abortion.

Peptide hormones, such as growth hormone, may also be used on livestock. Because they are broken down into inactive compounds in the intestinal tract if eaten, these hormones are of no threat to humans.

### Summary

Chemical residues in animal products are of some consumer concern. Potentially, there are numerous compounds present which cannot be detected or avoided by the consumer, and the risks from them are generally not well understood. To date, no cases of human disease have been diagnosed from normal levels of residues resulting from animal health products, but the threat of the unknown sometimes causes more concern than known threats such as those from bacterial contaminants.

This report develops model systems for various commodities—dairy, beef, poultry, and pork. A case study for each includes a description of a particular chemical, when and how problems occur, and alternative practices and their economic consequences.

### References

Anonymous. "Gastronomy Confronts Contaminated Foods." *American Society of Microbiology News* 53 (1987): 470.

Center for Disease Control (CDC). "Food-borne Disease Outbreaks." Annual Summary, 1982. In: CDC surveillance summaries 1986, U.S. Department of Health and Human Services, Atlanta, Georgia. 1986.

Food Safety and Inspection Service (FSIS). *The Safe Food Book: Your Kitchen Guide.* U.S. Deparment of Agriculture, FSIS. June, 1985.

Menning E. L. "Danger Lurks in Your Supermarket Meat Cases." *Journal of the American Veterinary Medical Association* 192 (1988): 494-497..

Mossel D. A. A. "Impact of Foodborne Pathogens on Today's World, and Prospects for Management." *Animal and Human Health* 1(1988): 13-25.

Stowe C. M. "Life Before and After Residues. *Journal of the American Veterinary Medical Association* 192(1988): 622-624.

Young F. E. "Food Safety and the FDA's Action Plan Phase II." *Food Technology* (November 1987): 116-124.

# Antibiotics in Dairy Production

*L.J. (Bees) Butler and Rick Bennett*

## Introduction

Milk is produced and distributed with outstanding attention to protecting its quality and wholesomeness. Only healthy cows are allowed to produce marketable milk, and great care is taken in obtaining the milk from the cow. Milk standards are set by state and local ordinances. Every batch of milk collected from a farm is examined for compliance with these standards. Since unacceptable milk is not taken by the creamery, dairy personnel have a great incentive to produce a good product. As a result of these precautions, U.S. milk is rarely involved as a cause of illness.

The milk supply in the United States is closely inspected and regulated to ensure that the consumer receives a safe and high quality product. Milk is examined not only for its solids content (fat, protein, lactose and minerals), but also for a wide variety of other constituents. In California, most of the milk is tested for residues from commonly-used cattle antimicrobials. Microbiological standards set for both raw and processed milk are very high, since these organisms can cause milk to rapidly deteriorate in quality. California milk is also routinely tested for other chemicals such as pesticides, radioactivity (including strontium, caesium, and iodine), fungal toxins (aflatoxins), halogens, and heavy metals.

Despite federal statutes which set the legal tolerance for antibiotic residues in milk nearly at zero (less than 16 mm inhibition zone on test plate), recent studies found such residues (above tolerance) in a significant percentage of retail milk samples. In a western study, 33 percent of the commercial milks tested contained antibiotic residues, while in a midwestern study the residue rate was 60 percent (Wehr, 1987; Brady and Katz, 1988). Sulfa drugs constituted a portion of the residues—a drug not usually associated with mastitis treatment, but commonly used for lameness in cows. The other drugs detected were antibiotics of the penicillin group, the aminoglycoside and cephalosporin groups. Chloramphenicol, which has never been approved for use in food producing animals, was regularly found in the milk samples.

The health implications due to antibiotic residues in food products were outlined in the introduction of this report, and will not be discussed further here. This case study examines how antibiotics enter milk on the farm, and considers existing and potential alternatives to reduce antibiotic use.

## Mastitis

Mastitis is a condition that causes inflammation of the mammary gland and reduces both the quality and quantity of milk produced. It is a widespread problem in U.S. dairy herds. In herds where mastitis control is not effectively practiced, up to 50 percent of the cows are commonly infected with mastitis, while the disease has been virtually eliminated from herds with properly managed programs.

The manifestation of mastitis may be clinical, where inflamed udders and abnormalities in the milk are visible, or subclinical, where detection is possible only by culture tests. In its many forms mastitis requires an integrated program to achieve effective control.

Mastitis has many causative agents including a variety of bacteria, other microorganisms and injury. The disease can be contagious (passed from one animal to the next, or between quarters of the same animal), or induced by environmental organisms. The susceptibility of the dairy cow to mastitis varies with its life cycle and environment. During lactation, animals are exposed to both contagious and environmental pathogens.

Contagious bacteria such as *Streptococcus agalactiae* and *Staphylococcus aureus* are commonly spread from infected udders to noninfected udders on contaminated milking equipment. These pathogens can also be spread on the hands of machine operators and wash cloths used to clean the udders. Some infections are subclinical in nature, and therefore go undetected and untreated for some time.

The dairy environment hosts many bacteria such as *Escherichia coli* and enterobacter which cause mastitis. Pathogens are commonly present in water, soil, plants, animal feces, and bedding materials.

During the 60 day dry period, between the time milking is stopped and the birth of a calf, there

is increased incidence of new infections from certain pathogens, particularly of the coliform variety. Susceptibility is highest between the first two weeks of the dry period and the two weeks immediately before calving. In the interim the animals typically develop an increased resistance to coliform infections.

There are several other factors which affect the incidence of mastitis in individual animals and dairy herds. Heredity appears to play a role as evidenced by an observed positive relationship between high yielding animals and the prevalence of mastitis. In selecting for animals with higher yield traits, producers have seen increased mastitis as well. The probability of mastitis also increases with age and with the incidence of previous infections—an issue which bears on the decision to treat or cull an infected animal.

**Economic Importance of Mastitis**

The main reason for discussing mastitis here is that it is a disease that is often treated with antibiotics—and antibiotics therefore become a major source of contaminant residue in milk. However, mastitis is not simply another infection that occurs in dairy cows. There are significant economic losses to both producers and processors (and, therefore, to consumers) associated with mastitis. It has been estimated that in 1985, the annual loss to mastitis in the United States was about $181 per cow or about $2 billion, representing 11 percent of the total value of farm milk sales (National Mastitis Council, 1987). The factors that are the source of loss and their estimated costs are shown in Table 1.

About two-thirds of the estimated losses are due to reduced production, while the rest of the loss is due to discarded milk, cow replacement costs, reduced sales value of infected cows, and costs of drugs and veterinary services. These estimates *do not* include the substantial economic losses associated with mastitis related to: antibiotic residues in milk, milk quality control, dairy manufacturing, and degradation of milk for processing.

Mastitis infection can change the composition of milk constituents because of elevated somatic cell counts in mastitic milk. Changes in the composition of milk due to elevated somatic cell count associated with mastitis are shown in Table 2.

While total protein does not change dramatically, there are marked changes in the types of protein present. Casein, a protein of high nutritional importance and of necessity for making cheese, is

Table 1. Estimated annual losses caused by mastitis[a]

| Source of loss | Loss per cow | Percentage of total |
|---|---|---|
| Reduced production | $ 116.10 | 64 |
| Discarded milk | 24.44 | 14 |
| Early cow replacement cost | 13.60 | 8 |
| Reduced cow sale value | 9.94 | 5 |
| Drugs | 9.68 | 5 |
| Veterinary services | 4.84 | 3 |
| Labor | 2.42 | 1 |
| Total | $ 181.02 | 100 |

Assumptions: 38 percent of cows infected in an average of 1.5 quarters; milk loss 1,600 pounds per infected quarter; milk price $12.73 per hundredweight.

[a]These estimates are for 1985 and were updated from estimates made in 1979. Losses may be somewhat lower than indicated because of lower prevalence of infection in 1985.

Source: National Mastitis Council, 1987.

Table 2. Compositional Changes in Milk Constituents Associated with Elevated Somatic Cell Counts[a]

| Constituent | Normal milk | Milk with high SCC | Percentage of normal |
|---|---|---|---|
| | percent | | |
| Solids-non-fat | 8.9 | 8.8 | 99 |
| Fat | 3.5 | 3.2 | 91 |
| Lactose | 4.9 | 4.4 | 90 |
| Total protein | 3.61 | 3.56 | 99 |
| Total casein | 2.8 | 2.3 | 82 |
| Whey protein | .8 | 1.3 | 162 |
| Serum albumin | .02 | .07 | 350 |
| Sodium | .057 | .105 | 184 |
| Chloride | .091 | .147 | 161 |
| Potassium | .173 | .157 | 91 |
| Calcium | .12 | .04 | 33 |

[a]Examples of compositional changes found in various studies.

Source: National Mastitis Council, 1987.

substantially lower. Lower casein content lowers the cheese yield of milk significantly. Sodium and chloride also increase causing a disruption in casein and calcium synthesis in milk, thus lowering the levels of both.

As if the losses from mastitis were not enough, there are also significant economic losses associated with antibiotic residues, if present, in milk. Some antibiotics cause allergenic reactions in some humans, and in addition, expose humans to the potential development of resistant bacterial strains, making antibiotics used for human infection less effective. Antibiotics are also strong inhibitors of bacteria used in the production and manufacturing of many dairy products. Yogurt and cheese starters may be significantly inhibited. And antibiotics may affect the acidity, flavor and quality of yogurt, buttermilk and cheese and decrease their shelf-life. While there are not estimates of the actual cost of these losses in the United States, they are thought to be significant.

**The Practical Control and Treatment of Mastitis with Antibiotics**

Because various mastitis pathogens differ in their response to antibiotic treatment, identification of the specific causative agent is important. For example, some varieties of coliform bacteria are particularly resistant to the antibiotic products currently on the market. However, antibiotics have been quite successful in eliminating other types of mastitis from some herds. Because clinical mastitis causes visible abnormalities in the animal or milk, individual cows or quarters can be diagnosed and treated.

Antibiotic therapy is rarely used to treat subclinical mastitis in lactating animals. A somatic cell count of the bulk tank milk can indicate the prevalence of the disease at the herd level, but because there are no visible symptoms, individual cultures of all quarters of all animals are required in order to implement selective treatment. Because of the expense, this type of comprehensive testing is not done unless the bulk tank somatic cell or bacteria counts are high enough to prevent marketing of the milk.

More often producers practice comprehensive dry cow therapy, where antibiotics are administered to the entire herd during their respective 60 day dry period. This is a preventative measure that has been successful with certain types of infection. There are antibiotics on the market, approved by the Food and Drug Administration, that are slow release products administered at the beginning of the dry period. These are not effective for the whole dry period, having cleared by the time calving occurs so the risk of residuals when lactation resumes is low.

To protect consumers from harmful residues, all milk from treated cows must be withheld from the market for a specified time period depending on the product and dosage used.

**Antibiotic Residues**

The most likely source of residues in dairy products is the milk from cows treated for clinical mastitis who were returned to the milking string before the antibiotic was completely cleared from their bodies. There are several reasons why this might occur:

- insufficient withdrawal period observed,
- antibiotic dose too large for the specified withdrawal period,
- cows treated with custom formulations of one or more antibiotics for which an appropriate withdrawal period has not been determined,
- cows treated with antibiotics for which no residue tests exist,
- residue tests lack sufficient sensitivity and/or specificity, and
- the surveillance rate is low.

Treatment of cows with antimicrobials for other infections, such as uterine infections, lameness, and intestinal diseases, may result in above-tolerance levels of health products in the milk if the cow is accidentally milked into the marketable tank prior to the withdrawal time.

Normally antibiotics used for dry cow therapy are fully cleared from the system of the animal by the time lactation resumes. In some cases, however, late term abortion or inaccurate breeding dates can initiate lactation prior to the clearance of the antibiotic. This animal may be prematurely returned to the milking string while excreting antibiotics in her milk.

Culled dairy cows are another potential source of residues in the human food chain. Residues may result from mastitis treatments and from other injections or oral treatments given to the cows for disease treatment. If the animals are sold for slaughter before the antibiotic has cleared, the meat products may be adulterated.

**Dairy Model for Antibiotic Adulteration of Milk**

A summary of the causes of mastitis and factors predisposing animals to the disease are given below.

**A. The Lactation Cycle**

**1. Parturition (calving)**

During calving a cow is at high risk for infectious diseases, especially mastitis. Mastitis is often expressed during this time due to increased exposure to infectious agents and to reduced resistance.

**2. Lactation (average 305 days)**

Clinical mastitis may occur at any time during the lactation cycle. The incidence depends on many factors, most of which are associated with dairy management. However, certain types of mastitis are more common in high producing cows. Cows culled due to mastitis may have been medicated so that their meat may contain antibiotic residues.

**3. Dry period (non-lactating —about 60 days)**

During this period there is a high incidence of new infections from certain pathogens. Comprehensive dry cow therapy with antibiotics effective in preventing certain types of infection are commonly given to all cows in some herds. Multiple dosing with "dry cow" products may be associated with milk residues. Antibiotic residues may also be present from "dry cow" products if late term abortions or incorrect calving dates initiate lactation prior to the clearance of the antibiotic.

**B. Age Factors and Multiple Lactation Cycles**

Heifers can begin lactation with a mammary infection; however, clinical mastitis increases with age and with previous occurrence of mastitis—factors which are apparently independent. Increasing parity is also associated with increased clinical mastitis.

**C. Pathogens**

The pathogens associated with mastitis are generally considered in two groups:

(1) Contagious organisms passed from cow to cow, usually through the milking machine and the milking personnel—their major source is the infected udder.

(2) Environmental organisms that grow and reproduce in the dairy environment.

**D. Environment**

The physical and management environment has a profound influence on the incidence of clinical mastitis, including:

- Sanitation systems
- Milking machine functioning
- Employee performance
- Management of infected cattle
- Use of subclinical mastitis detection and milk quality information
- Animal nutrition

**Alternatives to the Use of Antibiotics**

Research data and field experience of dairy professionals clearly indicate that virtually all mastitis can be prevented using currently available information and technology. In commercial and research herds, the incidence of clinical mastitis has been reduced to two cases per month per 1000 cows.

The dairy herds with normal to elevated incidence of clinical and subclinical mastitis often resort to antibiotic therapy as the principal means for mitigation of the disease problem. Even before antibiotics are used, the farm has experienced major economic losses from reduced milk production from diseased udders. Milk yield loss due to mastitis in a herd of 200 cows can exceed $60,000 per year. Additional losses are incurred when antibiotics are utilized, since the milk is then unsalable for a legally defined withdrawal period ranging from 3 to 14 days, depending on the extent of medication. Losses also occur when animals leave the herd prematurely due to early culling or death.

The economics of mastitis prevention have been shown in a number of studies to be very cost effective. Estimates of the return on prevention expenditures range from 8:1 to 16:1.

**Prevention Technology, Systems, and Economics Applied to the Lactation Cycle**

**Sire Selection**

Genetic selection has produced tremendous improvement in milk production. The same techniques can be applied to select for traits that provide mastitis resistance. Research data suggest that this emphasis will result in a net gain in milk production, despite a reduced genetic emphasis on milk yield. This technique may also increase natural antimicrobials in the milk, such as lactoferrins and peptides.

**Heifer Raising**

The mechanisms of mammary infection in non-lactating heifers is not clearly understood. General recommendations to prevent mastitis in heifers include not feeding mastitic milk to them as young calves, preventing heifers from suckling each other, and controlling flies that may transmit the bacteria to the heifers.

**Preparturient Period**

This is a time when animals are particularly

susceptible to mastitis. As calving approaches udders become distended, increasing the potential for exposure to environmental pathogens, particularly in bedding materials. There is a decrease in the level of lactoferrin, a protein which inhibits growth of coliform bacteria, and the effects of any dry cow therapy have worn off by this time. Additionally, cows suffer from increased stress just before calving, making them more susceptible to infections.

A number of control measures can be implemented to reduce the development and spread of mastitis before parturition:

1. The design and maintenance of housing systems can affect the incidence of disease. Poor ventilation can promote the growth of bacteria which thrive in damp, humid conditions. Overcrowding of animals can lead to increased injury and stress.
2. Maintenance of sanitary dairy conditions is an essential aspect of mastitis control. Provision of fresh bedding and the frequent removal of manure and urine can reduce the risk of environmental exposure.
3. Vaccines have been developed for use against mastitis, but the effects of immunization are still under investigation.
4. Nutrition can play a role in mastitis prevention, and in some cases diets have been supplemented with vitamins A and E as well as selenium; animals are typically deficient in these throughout the dry period. The correct calcium-phosphorus ratio must also be fed.
5. Researchers are currently experimenting with intra-mammary devices. A plastic loop has been developed which is inserted during the dry period to enhance the animal's natural ability to fight the growth of bacteria. While preliminary tests suggest some success, further research is required to assess the effectiveness of these devices.

**Lactation**

The spread of most contagious pathogens occurs during the milking process. There are many management opportunities at this point to enhance disease control:

1. Teat sanitation practices can have a tremendous impact on the incidence of contagious mastitis, particularly post-milking teat dips to disinfect udders. Studies show that the incidence of new infections can be reduced by 50 percent with this practice. Teat sealants may be useful in some herds, and pre-dipping teats (prior to milking) has reduced mastitis in some herds.
2. Maintenance of the teats in good condition is important since injured or chapped teats are more susceptible to infection.
3. Use of individual paper towels to wash and dry udders prior to milking reduces the spread of pathogens from cow to cow on wash cloths. Proper hand sanitation is essential as well.
4. Disinfection of milking machines between milking reduces the spread of bacteria from one milking to the next. Disinfection of the machine between each cow (back-flushing) is also used in some dairies to reduce cow-cow transmission of organisms.
5. Keeping machines in good condition helps to reduce mastitis. Poor vacuum control can cause bacteria in the milk lines to be flushed up into the udder; old rubber parts can harbor bacterial colonies; poorly working machines can cause injury to the teats thereby predisposing the udder to infection.
6. Culling diseased animals or placing them in a separate milking group, and the milking of heifers first, can help to reduce the spread of disease in a herd.
7. Limited introduction of replacement animals protects the herd from new infections. Under this regime, replacement cows may be home-raised heifers or purchased pre-lactating heifers.
8. Treating all the cows during lactation to eliminate obligate mammary pathogens from the herd may be performed if the milk is severely affected and non-marketable.
9. The environment can be controlled to reduce the numbers of environmental bacteria that can contact the udder. This involves:
   - regular cleaning of the bedding areas,
   - choice of bedding that does not support rapid bacterial growth,
   - housing designed to keep the cows clean,
   - proper design of sprinkler systems that wash the udder prior to milking,
   - clipping hair from around the udder to reduce dirt accumulating near the teats.
10. Animals identified with a potential problem can be prevented from producing milk for commercial sale. There are several existing and potential systems of identifying animals at risk including:
    - somatic cell counts of milk,
    - electrical conductivity of milk,
    - body weight and condition of the cow,
    - milk/body temperature.

11. Information and data summary systems can aid the producer in making management decisions, and in assessing the effectiveness of disease control programs. Useful information includes data on cyclical and seasonal trends at the herd level, as well as clinical histories, milk culture results, milk yield and milk loss data on individual animals.
12. Enhanced diagnostics—cow side antigen detection and cow side antibiograms—will aid in the identification of the infecting organism and facilitate timely and effective treatment.
13. Research on the economics of treating versus culling diseased cows is needed. There are indications that the probability of infection is partly a function of age and the incidence of previous infection. Economic analysis may show that the producer is better off in the long run culling a cow rather than treating her with antibiotics (thus eliminating the risk of antibiotic-contaminated meat products). In the future, computer programs may be able to help make the most economical decision for each cow based on her record.

**Dry Period**

During the dry period, a cow varies in her susceptibility to mastitis.

1. Researchers are currently exploring the possibility of extending that portion of the dry period when the animal has an increased natural resistance to disease. This enhanced resistance is partially due to the increased presence of lactoferrin in the system which helps to arrest coliform growth. Another contributing factor is the formulation of a protective plug in the teat opening which serves as a barrier to disease.
2. The use of chemical or mechanical teat barriers is being tested.
3. The use of vaccines to increase a cow's immunity to mastitis organisms is being investigated.
4. The efficacy of comprehensive dry cow therapy is being assessed, bringing into question the cost effectiveness of treating all cows every time.
5. Nutrition of the dry cow may be closely related to the incidence of mastitis; vitamin supplements may improve resistance.
6. Biotechnology products with antimicrobial properties may be developed.

**References**

Brady, M.S., and S.E. Katz. "Antibiotic/ Antimicrobial Residues in Milk." *Journal of Food Production* 51 (January 1988): 8-11.

National Mastitis Council. "Current Concepts of Bovine Mastitis." Arlington, VA, 3rd ed., 1987.

Wehr, Michael. "The Incidence of Antibiotics Other than Penicillin in Producer Raw and Finished Milk Products." *Proceedings of the International Association of Milk, Food, and Environmental Sanitarians*. Oregon, August 1987.

# Antibiotics in Beef Production

*Fred Troutt, Ben Norman, and Anita Edmundson*

### Introduction

There is substantial evidence that the public is alarmed about, and will not tolerate, the presence of chemical residues in food. The perception is that a variety of chemical residues—antibiotics, pesticides, steroid hormones—are present in our meat and milk supply, and pose a threat to human health.

Neither the concept of a tolerance level of a chemical nor that of the associated risks is well understood by the general public. The information that a chemical is toxic when fed in high concentrations to laboratory animals is often taken to mean that foods containing minute quantities are poisonous to humans. Government testing to ensure a safe food supply is frequently mistrusted, possibly because inspection and testing procedures used are not understood.

In 1985, the Center for Veterinary Medicine, Food and Drug Administration, conducted a tissue residue study from 134 violative residue reports. Fifty-eight of these reports could not be followed up fully; the remaining 76 were used in the analysis. Forty-six percent of the violative residue problems investigated were in cull dairy cows, and 32 percent were in veal calves (29 percent "bob" veal and 3 percent fancy veal). The balance, or approximately 22 percent of the detections, was distributed among market hogs, 12 percent; heifers and steers, 5 percent; turkeys, 4 percent; and rabbits, 1 percent (Paige and Kent, 1987). If these figures accurately depict the violative residue problems in the United States, the principal components of the beef system responsible for the bulk of the violations are cull dairy cows and bob veal calves. Cull dairy cows contribute approximately 25 percent of the total U.S. beef supply, mostly as hamburger.

The U.S. system of beef production is complex. In the primary beef system, feeder cattle are selected, congregated, transported to feedlots, fed, and marketed at approximately 1,100 pounds weight. The stress of shipment, congregation of large numbers of animals, and alterations in the environment and diet cause cattle in feedlots to be at high risk for illness. The feedlot can be a focal point for several food contaminants because large numbers of animals from differing environments interact there. Large numbers of cattle may be treated for illness or administered animal health products to prevent illness.

In the beef system there is a variety of sources of food contamination. The principal ones are due to microbial contaminants; 80-90 percent of these occur at the food preparation stage in the home or restaurant. The primary bacterial contaminants of concern to humans are *campylobacter, salmonella, escherichia coli, shigella, yersinia,* and *listeria.* Bacterial contamination may occur at the time of processing, from bacteria in or on the animal, equipment, personnel, and in the environment. Chemical residues in beef may be from antimicrobials, pesticides, herbicides, and a variety of other chemicals. However, human disease has not been proven to result from consumption of the levels of these chemicals generally allowed in meat.

Marketing unwanted dairy calves also presents problems with residues. Male dairy calves are routinely removed from the dairy farm very early in life for marketing as veal. These calves may be exposed to enteric pathogens including *salmonella, cryptospordium, campylobacter,* and possibly *yersinia.* The calf may have been treated for infections or fed medicated or hospital cow milk containing antibiotics, before leaving the farm. These calves may be poorly prepared for the diseases they are exposed to when bought, congregated, and shipped—a condition leading to the frequent use of animal health products to prevent their suffering and/or death. If these young calves are marketed as bob veal (less than three weeks or less than 150 pounds), they are too young to have undergone the withdrawal period for several antibiotics that may have been administered to them.

Fancy veal calves are usually purchased and congregated as a load, before entering a production unit—a "veal barn." During congregation, the calf may be exposed to many pathogens, antibacterial agents, pesticides, and other chemicals. Because of an associated high rate of illness, calves are often treated with animal health products. Carcasses at the processing plant may also be exposed to bacterial and chemical contaminants.

The principal sources of violative levels of chemical residues in beef and possible alternative to reduce their presence are outlined below.

**Beef-type Cattle**

Violative levels of chemicals are rarely found in beef-type cattle. Any residues found in beef are generally below tolerance levels and have not been shown to cause harm to humans. The principal reason for any violative level of chemical residues in these animals (mostly steers and heifers) is that inappropriate withdrawal times were observed after treatment with antimicrobial injections or orally-administered antibiotics. Some cases of chemical contamination of our beef-cattle supply have resulted from feed accidents.

A few large livestock producers are labeling their products residue free. This is in a contract with a federal meat inspection program in which producers, at their own cost, do added testing beyond that required by the government. They are subject to spot checks by federal inspectors. In 1985, about 3 percent of the beef fed were labeled to indicate their residue-free status. The effects of this on the producer and the rest of the market are currently being investigated.

**Alternatives to Reduce Violative Levels of Residues**

1. Develop improved biotechnological, chemical, or biological detection methods for antimicrobial residues to use on the farm and in processing plants. Current detection methods can take several days, so that products are often marketed before the results are obtained.
2. Hold producers liable for costs associated with violative levels of residues as an incentive to provide residue-free products.
3. Identify all animals given medication along with the date of administration, to ensure that cattle are not accidentally sold before the drug withdrawal period has passed. Many large feedlots use this system. They move treated cattle to a special pen, returning them to the regular pens only after the withdrawal period.

**Veal**

The veal industry obtains most of its animals from the dairy industry's culling unwanted calves. During fiscal year 1986, 2,181 calf carcasses were condemned in the United States (4.2 percent of the total condemned), because of residue problems. Also in 1986, 16,232 calf carcasses (4.7 percent of the total retained) were retained because of residues (FSIS, 1986).

The source of violative antimicrobial residues levels in veal calves is generally the result of inappropriate withdrawal times which may have been either unknown or ignored. These calves often change ownership several times making trace-back difficult and enabling dealers to disclaim responsibility for problems. Bob veal calves are the main source of violative residues in beef animals in California. Fancy veal units do not routinely feed antibiotics to calves, but only use them with disease outbreak to prevent suffering and death loss.

Animal health products can enter veal animals at several points—on the farm, at points of calf congregation, or during the housing-feeding phase of veal production. On the farm, calves may be fed hospital pen milk from cows receiving medication or medicated milk replacer, may receive injections and/or oral administration of antimicrobial agents, or may acquire antibiotics from colostrum from a cow treated during her dry period (believed not to be of high incidence). Sometimes these are extra-label drugs for which the withdrawal times are not known. After leaving the farm, calves may also be given injections and or oral administration to treat illness.

**Alternatives to Reduce Violative Levels of Residues**

1. Offer educational programs to inform and motivate producers, marketers, packing houses, veterinarians, and consumers. Suitable milk replacers free of antibiotics should be available to feed to the bob veal calf, so that hospital cow milk or medicated milk replacer is not used.
2. Purchase veal calves at processing plants subject to a residue free status. All calves could be tested at the time of processing.
3. Increase the level of testing and deliver a mandatory fine for violations.
4. Develop biotechnological, chemical, or biological methods that are rapid, reliable, and economic for on-farm or processing plant detection of antimicrobial residues. The technology is available for the development of these systems. Indeed some chemical and biological processes are used, but have limitations such as low sensitivity, reliability, and repeatability. Additional research is needed to develop processes and procedures that are accurate and highly reliable.
5. Use efficacious and relatively inexpensive antimicrobial agents that have rapid clearance, and hence minimal or essentially "zero" withdrawal periods. Such agents are now used to a limited degree, but more need to be developed.

6. License veal producers, and only allow veal calves with official license tags to be processed. This system would provide a trace-back method. Warnings, fines, license suspension and/or revocation for violations could provide an incentive for compliance with antimicrobial withdrawal times.
7. Stop slaughtering bob veal calves, since these animals are too young to have full withdrawal times for several antimicrobials they may have been given.
8. Hold sellers of contaminated animals fully liable.

### Cull Dairy Cows

The cull dairy cow is probably the greatest single source of violative antimicrobial residues in meat in the United States. Residues result from intramuscular injections with a variety of animal health products and intra-mammary infusions (extra-label or approved uses) for mastitis. Problems arise if withdrawal times are not observed and medicated cattle are slaughtered.

**Alternatives to Reduce Violative Levels of Residues**

1. Offer educational programs to inform and motivate producers on the risks associated with antimicrobial residues in dairy cows to be culled.
2. Sample all cull dairy cows presented for slaughter, and make purchase subject to a residue-free status.
3. Develop biotechnological, chemical, or biological methods that are rapid, reliable, and economic for on-farm or processing plant detection of antimicrobial residues. These could prevent the slaughter and marketing of animals containing residues.
4. Use antimicrobial agents designed specifically for the dairy cow, with rapid clearance, minimal residues, and essentially a "zero" withdrawal time.

### Comment

In all systems, the cost of testing the food supply for safety can be enormous. It is important that the burden of payment for trace-back when violative residues occur be placed on the producer. However, the cost of extensively testing our food supply will ultimately rest with the consumer, either in the product price or through taxation.

### References

Paige, J.C. and R. Kent. "Tissue Residue Briefs." *FDA Veterinarian*, November-December 1987.

Federal Safety and Inspection Service (FSIS). *Statistical Summary Federal Meat and Poultry Inspection for FY 1986* U.S. Department of Agriculture, 1986.

# Salmonellae and Other Problems in Poultry Production

*Duncan McMartin*

## Introduction

Of the many animal products available for human consumption, one of the safest is poultry. There are a number of forces, both in nature and by human design, that contribute to the safe production of poultry products. Nature pre-wraps the fresh egg in a highly efficient and biologically safe container. Other poultry products such as meat birds, especially broilers/fryers, have a relatively short production life, so that the time for entry and buildup of toxic materials in tissue is limited. And the production environment of any modern poultry operation is clean and is decontaminated and disinfected frequently.

The vertically integrated structure of the poultry industry and the small number of production units (relative to the beef and dairy industries) provide for uniform disease control methods and compliance with safety codes and regulations on a whole-flock basis. The industry also has taken advantage of biological and environmental research to create efficient production systems which incorporate many effective disease control measures. As a result, disease outbreaks are uncommon, despite a reduction in certain preventative practices such as feeding antibiotics.

Producers, researchers, and government regulators, however, still face many challenges. One of these is public education. For example, a small consumer survey conducted by a local farm advisor in the Davis vicinity indicated that some consumers are concerned about adulterants, such as antibiotics and hormones, in eggs, although the probability of this happening is low (Bradley, 1985). The comparative benefits and risks to consumers of various poultry production methods need to be explained, particularly the differences between close confinement and extensive or free range systems.[1]

The greatest challenge, however, is in terms of food safety and is presented by microbial infections and contaminants which reach susceptible humans in and on poultry products. In particular, salmonellae and campylobacter species contribute most frequently and most significantly to human disease. In addition, attention must be directed to reducing the use of pharmaceuticals with poultry. Methods which could, even in rare instances, introduce substances into poultry products that might be detrimental to human health, must be closely monitored, so that consumers can be assured of the safety of poultry products.

## Salmonellae

There are about 2,000 different strains of salmonella, but only 10 account for most of the infections reported. Although often associated with poultry, these bacteria can infect a wide range of animals, being common in the intestinal tracts and waste of livestock, poultry, dogs, cats, rats, and other warm-blooded animals. Because salmonellae can cause disease in humans as well as animals, they are of concern to processors, marketers, consumers, and regulators.

This part of the report on options in animal production focuses on the source of salmonella in poultry meat products, and considers the possible methods of its control or eradication. Other problems in poultry production are also mentioned.

Different species of salmonellae vary in their effects on poultry and humans. Some can be carried by host animals with little or no ill health effects, yet cause severe illness when eaten by humans. Other strains affect the health of poultry and represent a significant economic threat to producers. The industry has traditionally directed its eradication

[1]To reduce severe losses, those infectious diseases which are amendable to chemical treatment are usually combatted by this method when they occur in large dense poultry populations. Poultry raised under extensive or semi-intensive conditions, without the use of animal health products, have a market appeal for some consumers. Such poultry and poultry products can generally be sold at a premium to this market segment. However, because of the relatively uncontrolled growing conditions, meat birds may vary more in size and uniformity than birds raised under intensive conditions, and certain diseases may be more difficult to control.

and control efforts toward this latter class of bacteria.

The commercial poultry industry in the United States has reduced to almost insignificant levels the two salmonellae species which can cause severe disease in the poultry themselves, that is *Salmonella pullorum* and *Salmonella gallinarum* (fowl typhoid). Both pullorum and typhoid disease can be contracted through ovarian transmission. Typhoid, generally thought to be the more dangerous of the two, can also be passed from one infected bird to another and can cause illness in both young and adult animals.

The response was to emphasize eradication rather than control of these bacteria that affect poultry health. Some major factors in the eradication of these salmonellae were improved education of the industry, more accurate diagnostic tests, the vertical integration of the industry, elimination of infection at the breeder level, and the fact that there are relatively few alternative hosts for these salmonellae (limiting the possibilities for re-infection).

Blood tests and monitoring programs on breeder flocks are used to identify infected animals which are removed and whose hatching eggs are discarded. This program has been very successful in reducing losses due to these diseases and has drastically reduced the prevalence of these organisms in commercial flocks. However, the current extremely low level of infection was reached only after some 30 years of effort.

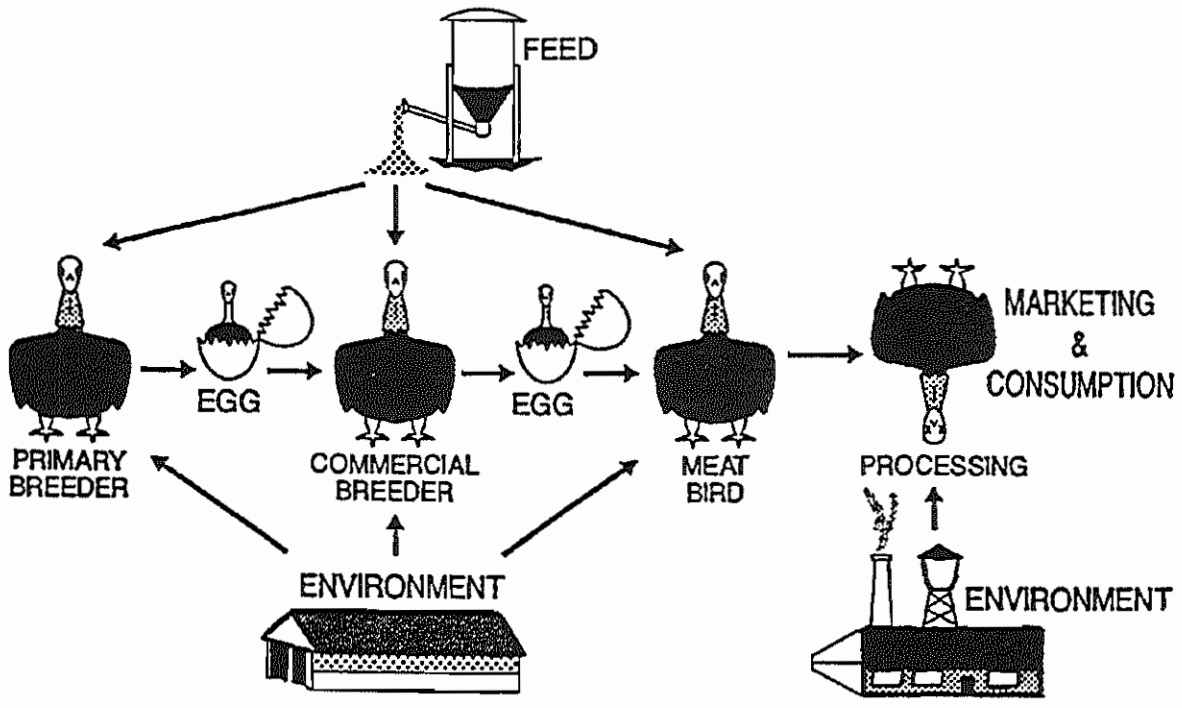
By contrast, infection of poultry with other salmonellae (known as paratyphoid organisms) which may have little or no effect on the health of the poultry, yet cause disease in humans, continues to occur. The disease particularly affects infants, the elderly, and the immunologically deficient.

Because of the numerous strains of salmonellae involved, the emphasis is on control rather than eradication of this disease. Current control practices include:

- sanitation to reduce contamination of breeding, hatching, and brooding premises;
- destruction of salmonellae on the surface of hatching eggs laid by infected breeding flocks, by disinfection and/or fumigation;
- medication of hatching eggs and flocks during the early days of life.

Several sources of infection and re-infection exist (Figure 1), so the challenge of producing salmonella-free poultry, as distinct from *S. pullorum*- and *S. gallinarum*-free, is much greater. For example, producing salmonella-free primary breeding stock may reduce the prevalence of contamination of poultry products, but it will not completely eliminate contamination.

Figure 1. Turkey Salmonellosis—Points Where Contamination May Occur



### Control Measures

Studies over the past several decades have clearly shown that three factors are responsible for most introductions of salmonellae into live bird populations: feed contamination, environmental contamination, and egg transmission. Effective control programs require action to prevent infection from all three. Figures 2, 3, and 4 highlight the important control points in the production systems of poultry and feed, and at the processing plant. It is critical that monitoring occur at each of these points.

Attempts to produce and maintain chicken and turkey breeding stock free of salmonellae have had mixed results (Snoyenbos, 1984). Success or failure depends to some extent on the properties of the particular strain to which a flock is exposed. Adequate monitoring of large commercial flocks is an enormous task, and translation of laboratory results to field conditions is unreliable.

Researchers have found that under the right conditions it is possible to raise salmonella-free breeding stock. A six-year study in a new primary breeding facility produced three generations of turkey breeders free of paratyphoid salmonellae over a period of four years (Ghazikhanian, Kelly, and Dungan, 1985). When salmonellae were eventually detected, the exposure was from contaminated feed, often a major source of re-infection.

#### Environment

The environment is not salmonella free, so it is very difficult to prevent salmonellae from reaching poultry. Better control in the following areas would help:

1. Feed. To date, the industry has been unsuccessful in consistently producing uncontaminated feed. This is due partly to poor sanitation conditions in feed processing plants and partly to a lack of understanding about the potential repercussions of introducing contaminated feed into the system. Certain beliefs must be dispelled: (1) low levels of bacterial contamination in feed are relatively harmless and (2) the feed production process itself eliminates most incidence of contamination must be dispelled. While the heat process used in the production of feed kills most bacteria, subsequent re-infection from bacteria on and about the premises can and does occur. The major source of re-contamination of feed is the addition of unsterilized rendered animal offal and bone meal. Fully sterilized feed would be a major advantage in the reduction of salmonellosis in poultry. Irradiation or thermal treatment of all incoming feed could prevent the introduction of salmonellae by this route.

2. Sanitation. Proper sanitation is essential on breeding, hatching and brooding premises. It requires attention to all elements of the environment, including personnel, plant, and equipment. Vehicles used to transport animals and products must also be kept in a sanitary condition.

3. Water. Only drinking water of the highest quality should be provided.

4. Pests. Control of insects and rodents that may spread the bacteria is essential.

#### Processing

Processing is probably the most important site at which poultry are contaminated. Current poultry meat processing methods tend to spread salmonellae from any infected carcass. The following control measures could help:

1. Using adequate hygiene methods with tools, tables, lines and staff clothing to avoid postmortem contamination of carcasses.
2. Avoiding contamination of the fresh product with intestinal contents.
3. Employing equipment that can be easily sanitized.
4. Controlling insect and rodent control to prevent their bringing salmonellae into the slaughter house.
5. Using clean water to rinse carcasses. Chlorine in rinse water has proven effective in preventing the spread of infection.
6. Surface treating carcasses with lactic acid solutions immediately after slaughter.
7. Controlling bacterial spread in the common chiller bath.
8. Increasing processed product testing to detect contamination sources and eliminate them.

### Other Factors in Reducing Contamination

#### *Resistance to Infection*

Developing poultry with an enhanced resistance to infection from salmonellae would reduce the overall contamination of the finished product. The poultry industry has focused on selection for features such as rapid growth, conformity of size, and high production parameters, rather

Figure 2. Critical Control Points—Meat and Hatching Egg Production

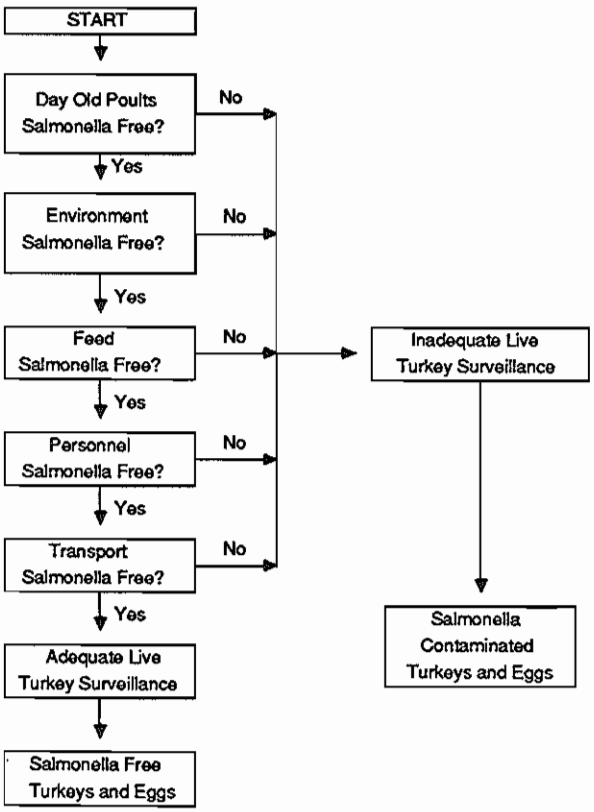



Figure 3. Critical Control Points—Feed Production

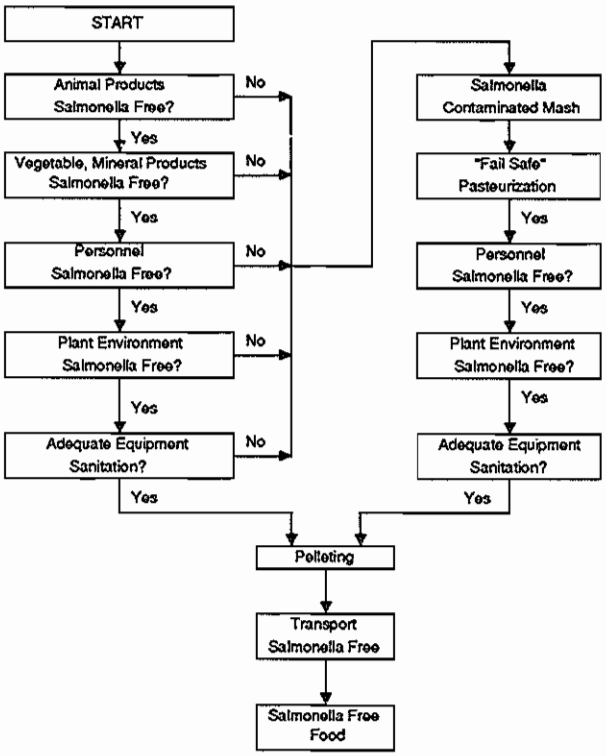
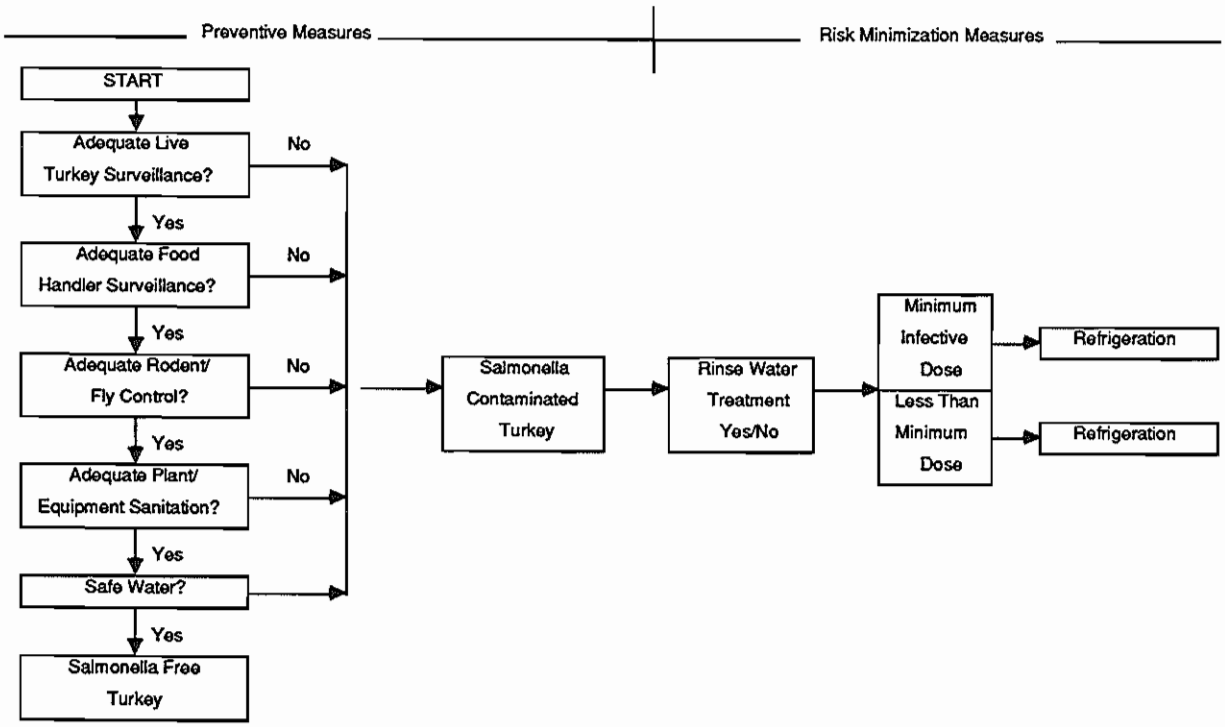



Figure 4. Critical Control Points—Whole Carcass Processing



than on selection for disease resistance. Research and development in the following areas could prove beneficial:

1. Increasing the resistance of poultry by biotechnological transfer of resistance genes. However, resistant genes for specific diseases have not yet been identified, and methods for gene transfer in poultry are not yet available.

2. Differences in resistance to specific diseases exist between breeds and strains of poultry, but probably no single strain is more resistance to *all* diseases. The selection and breeding of resistant birds would result in a slow improvement over many generations, and might slow the growth and feed conversion rates that are currently being selected for.

3. It may be possible to enhance the resistance of poultry with changes in nutrition. Currently diets are formulated for optimum production, a choice that may not create optimal disease resistance in the birds.

4. Feeding chemicals to destroy bacteria in the intestinal tract can also provide resistance.

*Irradiation*

Currently, the only short-term solution to salmonellae contamination on fresh or frozen poultry is irradiation of the products. Low-dose irradiation (radicidation) has been shown to be highly effective in destroying salmonellae on broiler carcasses (Engel and Post, 1985). However, there could be major practical difficulties in irradiating the huge volume of poultry meat produced in the United States. Besides, consumers are currently becoming concerned about the safety of irradiated products. Some chemical changes occur with irradiation which may alter the products' appearance and color. Further, even if an irradiated salmonella-free product were provided to the retail store, salmonella food intoxication can still occur at food preparation sites.

**Economics of Control**

Complete elimination of salmonellae from poultry products requires that each link in the production to consumption chain insist on salmonella-free inputs from the preceding link. This would require the joint efforts of breeders, processors, marketers, and regulators to affect successful eradication. Most producers will be guided by economics.[2] The industry has successfully developed control/eradication procedures for those salmonellae strains which threaten production, but it is unlikely that they will respond with equal effort to eradicate the remaining strains—unless there is an economic incentive to do so. Market rejection of contaminated products could precipitate such action.

It has been estimated that irradiation of poultry meat will cost approximately 3 to 5 cents per pound (Krug, 1985). Consumer acceptance of a price differential for a product labeled salmonella-free has not been investigated. And such labeling could erroneously suggest to some consumers that unlabelled poultry products are contaminated by salmonellae.

**Campylobacter**

*Campylobacter jejuni, C. coli,* and *C. lairdis* are three species, with several biotypes, found in poultry, which have been incriminated in human disease (Genigeorgis, 1986). However, the relationship between campylobacter species and human disease has not been fully determined.

*Campylobacter jejuni* has been most frequently studied. It is very common in the digestive tract of chickens, turkeys, and ducks, and on the carcasses of processed meat birds. These bacteria are also present in the digestive tracts of a wide range of wild and domestic animals and birds, and can be carried by flies.

Epidemiology studies indicate that these bacteria (1) are not transmitted in poultry eggs, (2) are not contaminants of poultry feed, and (3) survive for a relatively short time outside the host. Due to these three factors, the prospects of producing campylobacter-free poultry are better than those of producing salmonella-free poultry. However, the numerous alternative hosts of campylobacter organisms, and other epidemiologic factors, make the eradication of campylobacter from poultry unlikely in the foreseeable future. Techniques for producing campylobacter-free carcasses are not available currently. Studies indicate that *C. jejuni* is more susceptible to irradiation than is salmonella, so

[2]An estimate of the total loss in 1977 in Western Germany due to salmonellosis was 251.2 million marks—120.1 marks for human and 131.1 marks for domestic animals (Krug, 1985). Among animals, cattle suffered the greatest loss (34 percent of the animal total); poultry, the least (10 percent of animal total).

this procedure offers the best short-term prospects for eliminating human ingestion of poultry-derived campylobacter.

### Other Disease Control Measures

There are many infectious organisms which can potentially contaminate poultry. In the United States, some infectious diseases have been or are being eradicated from intensive poultry production systems. Others are largely controlled by effective immunization. Still others have been virtually excluded by successful management systems. For those diseases which do not fall into one of these three categories, producers must rely on alternative practices to prevent losses.

In some cases the use of pharmaceuticals is necessary for the treatment and control of disease. These are delivered in the feed or in the water supply. Residues from these pharmaceuticals, when used according to the regulations, are not considered to be a threat to human health. Problems have arisen only when new feed was contaminated with health products in old feed trapped in feed lines and bins, so that proper withdrawal time was not observed. The use of water-medication rather than feed-medication prevents this occurrence.

The industry currently relies heavily on treatments known as coccidiostats to control coccidiosis—an enteric protozoal disease in poultry reared on litter floors. (Birds raised on wire floors are not in contact with their feces, so don't contract coccidiosis.) Vaccines have not been successfully developed for coccidia. Pharmaceuticals are also used to treat pasteurellosis, a disease which can severely affect turkeys and for which there is no effective vaccine.

Other diseases, such as those caused by *Escherichia coli*, may be triggered by physiological and environmental stresses and fluctuations. It may some day be possible to increase nonspecific resistance of poultry so that such infections, and the subsequent need for therapy, is reduced or eliminated. However, increasing the resistance of poultry to diseases by traditional genetic methods or biotechnological transfer of resistance genes is not an immediate prospect.

Since disease control is fairly inexpensive in poultry, there has been little incentive to consider genetic selection as a practical means of disease prevention. Strain differences in response to antigenic stimulus have been noted recently, but differences are unlikely to be large enough to warrant selection on that basis, rather than on growth and production criteria.

### References

Bradley, F. "Consumer Concerns about Shell Eggs." *California Poultry Institute Proceedings.* Cooperative Extension. 1985.

Engel, R.E. and A.R. Post. "The Control of *Salmonella* and Other Bacteria Using Low-Dose Irradiation." *International Symposium on Salmonella, Proceedings, 1984.* G.H. Snoyenbos, ed. American Association of Avian Pathologists, Inc., 1985, pp. 281-288.

Genigeorgis, C. "Significance of *Campylobacter* in Poultry." *35th Western Poultry Disease Conference Proceedings.* Veterinary Extension, University of California, Davis, 1986, pp. 54-60.

Ghazikhanian, G.Y., B.J. Kelly, and W.M. Dungan. "*Salmonella Arizonae* Control Program." *International Symposium on Salmonella, Proceedings, 1984.* G.H. Snoyenbos, ed. American Association of Avian Pathologists, Inc., 1985, pp. 142-149.

Krug W. Social Costs of *Salmonella* Infections in Humans and Domestic Animals. *International Symposium on Salmonella, Proceedings, 1984.* G.H. Snoyenbos, ed. American Association of Avian Pathologists, Inc., 1985, pp. 304-309.

G.H. Snoyenbos, ed. *International Symposium on Salmonella, Proceedings, 1984.* American Association of Avian Pathologists, Inc., 1985.

Shane, S.M. "Trends in Prevention of Poultry Disease." *Animal and Human Health* 1(1988): 27-36.

# Porcine Growth Hormone

*John Glenn*

### Introduction

The major issues currently confronting the swine industry are public concern about: (1) sulfamethazine residues in meat; (2) uses of low levels of antibiotics in swine feeds, i.e., potential meat residues and the development of antibiotic resistant microorganisms; and (3) future use of porcine somatotropin (PST, porcine growth hormone) by the swine industry. Any one of these topics would be suitable for a case study; however, PST was chosen because it represents the use of emerging technology to improve the quality of food in the human food chain.

The American swine industry is confronted with a decline in pork consumption and its concomitant effect on hog prices. Consumer concern over fat content is felt to be the major cause for the decline. Genetic improvements and better feeding practices have resulted in hogs that are significantly leaner than 20 years ago. However, the public still perceives pork as "fatty." Although the industry is conducting educational and advertising campaigns to counter this image, the industry realizes that production of even leaner pork is demanded by the increasingly health-conscious consuming public. These pressures, along with recent biotechnological advances, have stimulated interest in PST.

### Porcine Somatotropin

PST is a growth regulating protein hormone produced in the anterior portion of the swine pituitary gland. The hormone is produced naturally by every pig. Current differences in swine growth rate and carcass composition are in part due to biological variation in the amounts of this hormone produced by individual pigs.

Because the digestive process breaks down the protein into its constituent metabolizable amino acids, the protein has demonstrated biological activity (i.e., exerts its hormone effect) only when injected in swine. It has no effect when given orally to any species (including humans). Thus, the hormone is completely inactive if consumed by humans or animals.

Once injected into the pig's body, the half-life of PST is less than one-half hour. As a result, the Food and Drug Administration is expected to establish a zero withdrawal time following administration of commercial PST products.

There has been research on PST since the early 1900s. For years the only source was the pituitary gland of pigs. The glands were collected at slaughter and the PST extracted in minute amounts. The expense of the process precluded any use other than for research. Recent advances in biotechnology radically altered this situation, for PST can now be produced in adequate amounts at a reasonable price. The gene for PST production is inserted into a strain of bacteria which are grown in large quantities, producing PST. When the bacteria are "harvested," the resultant PST is extracted. The PST produced by this method is biologically identical to PST produced by the pig's pituitary gland.

When PST is administered to growing and finishing pigs, it diverts a higher proportion of feed nutrients into the production of lean meat protein and away from production of fat. PST regulates the utilization of nutrients by increasing the rate of protein accretion and reducing fat accretion. Carcasses from PST supplemented pigs are larger and leaner than those from untreated pigs. In treated animals, backfat, a common index of fat content, has been reduced by more than 20-30 percent, and loin eye area increased by 1 to 5 square centimeters. There are no other changes in body protein amino acid composition, taste, or texture than those attributable to reduction in fat content.

PST also enhances the pig's growth rate and improves feed conversion efficiency. When high performing finishing pigs are treated with PST, feed efficiency has been improved by 24 percent or more and rate of gain by 16-18 percent. The net result is that 12 percent less feed is required to reach market weight and the entire process is completed in less time. After including the cost of PST and its administration, overall production costs are decreased about 7 percent. Obviously, these benefits will be best realized under good management conditions. PST enhances, rather than substitutes for, genetic potential and proper feed.

Translated into dollars, a 50-sow operation could experience an increase in average annual net worth of about $6,000. If producers received a

premium of 6 percent for producing leaner, meatier carcasses, the operator's return could increase overall about $12,500.

It is clear why widespread adoption of PST is predicted as soon as the product is licensed. Use of PST would result in a leaner product to satisfy consumer demand and increased efficiency with lower production costs to satisfy producer needs. Obviously, this scenario is based on consumer acceptance of pork produced by PST-treated pigs. Even though PST is species specific and is destroyed by digestion, the major factor influencing acceptance will be the consumer's *view* of PST safety. The swine industry is very concerned that public distrust of new technology and general suspicions about food safety could prevent utilization of PST.

PST is not currently licensed for sale in the United States or in Europe. Because of licensing requirements and production constraints, it will probably be at least mid-1990 before it becomes available for commercial use. Although alternatives for producing leaner pork are available, none of them result in such dramatic and rapid responses and/or are as safe.

**Alternatives to the Use of PST**

1. Classical genetic improvement programs require generations before significant progress can be made. In addition, selection for one trait often occurs at the expense of another, further slowing overall progress. Past experience has shown the magnitude of gains to slow as progress is achieved.
2. Gene manipulation holds the potential for establishment of lines of animals capable of naturally producing elevated levels of PST. The technology to accomplish this is currently available; however, it is very expensive and the required level of technical expertise is available only in isolated locations. Research to ascertain genetic stability and expression of the desired effect would require approximately 10 years. At that point, adequate supply and distribution of the genetic stock throughout the industry would be another major hurdle to overcome.
3. Alterations in ration composition have only a minimal effect on body fat composition since the process is primarily regulated by the animal rather than being driven by the feed. Also, many of these alternatives have detrimental secondary effects on feed efficiency.
4. Repartitioning agents (beta agonists) show promise for accelerating muscle deposition, thereby producing leaner carcasses. The mode of action of these chemicals is still unclear. Since they are not species specific, safety and withdrawal periods are of major concern. Because of all the unanswered questions and concerns, licensing of these products will probably not occur in the near future.

# SUMMARY

This report has used four case studies to illustrate the presence of chemicals in animal production: antibiotic residues in dairy products and in beef, salmonella in poultry, and growth hormone in swine. While the U.S. food supply is generally safe, chemicals and microbial agents do, on occasion, enter animal products meant for human consumption. Microbial agents in these products are the largest cause of food-borne illness. The risks from environmental contaminants and chemical residues are much lower on the list. As reported in the fourth case study, porcine somatotropin is not thought to be associated with any risks to human health.

The authors have made recommendations to reduce the incidence of chemical and microbial agents finding their way into food. While the production systems of dairy, beef, poultry and pork differ, some general recommendations are:

- Improved management practices could prevent disease and contamination at each step in the production system, from farm to processor. For example, improved methods to maintain environmental sanitation could reduce the spread of infection from salmonella.
- The development of disease-resistant animal stock, such as mastitis-resistant dairy cows and salmonella-resistant poultry, was suggested.
- The development of biotechnological, chemical and biological methods to detect violative residues earlier and more rapidly could prevent contaminated animal products from being marketed.
- Tighter monitoring and strict observance of withdrawal periods after the use of animal drugs would reduce the potential for these substances to remain in animal products. Also, the development of antimicrobials with rapid clearance and zero withdrawal periods would simplify the monitoring process or eliminate the need for it altogether.
- Making producers bear the burden of the cost of residues could become an incentive to strive for residue-free production.

In summary, effective methods must be implemented early in the production system and maintained throughout to prevent and detect contamination of animal products. Education at every step in the food supply system, from producer to consumer, is essential—education about why certain chemicals are used, the likelihood of any associated human health effects, producer's and processors' alternatives to chemical use, etc. Consumers continue to be concerned about chemical contaminants in their food—a concern that shows no signs of abating. What is needed is reliable, objective information. Hopefully, this report has contributed to this important need.