

HANDBOOK OF POULTRY SCIENCE AND TECHNOLOGY

Volume 1: Primary Processing

Editor

Isabel Guerrero-Legarreta, Ph.D.

Consulting Editor

Y.H. Hui, Ph.D.

Associate Editors

Alma Delia Alarcón-Rojo, Ph.D., Christine Alvarado, Ph.D.,
Amarinder S. Bawa, Ph.D., Francisco Guerrero-Avenidaño, Ph.D.,
DVM, Janne Lundén, Ph.D., DVM, Lisa McKee, Ph.D., Yoshinori
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CONTRIBUTORS

Editor

Isabel Guerrero-Legarreta, Departamento de Biotecnología, Universidad Autónoma Metropolitana, México D. F., México

Consulting Editor

Y.H. Hui, Science Technology System, West Sacramento, California

Associate Editors

Alma Delia Alarcón-Rojo, Facultad de Zootecnia, Universidad Autónoma de Chihuahua, Chihuahua, México

Christine Alvarado, Department of Animal and Food Sciences, Texas Tech University, Lubbock, Texas

Amarinder S. Bawa, Defence Food Research Laboratory, Siddartha Nagar, Mysore, India

Francisco Guerrero-Avendaño, Archer Daniels Midland Co., Mexico

Janne Lundén, Department of Food and Environmental Hygiene, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland

Lisa McKee, Department of Family and Consumer Sciences, New Mexico State University, Las Cruces, New Mexico

Yoshinori Mine, Department of Food Science, University of Guelph, Guelph, Ontario, Canada

Casey M. Owens, Department of Poultry Science, University of Arkansas, Fayetteville, Arkansas

José Angel Pérez Alvarez, Grupo Industrialización de Productos de Origen Animal (IPOA Research Group), Departamento de Tecnología Agroalimentaria,

Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández, Orihuela, Alicante, Spain

Joe M. Regenstein, Cornell Kosher and Halal Food Initiative, Department of Food Science, Cornell University, Ithaca, New York

Marcelo R. Rosmini, Faculty of Agricultural Sciences, Universidad Católica de Córdoba, Córdoba, Argentina

Jorge Soriano-Santos, Departamento de Biotecnología, Universidad Autónoma Metropolitana–Unidad Iztapalapa, México D.F., México

Jong-Yi Eddie Wu, Foster Farms, Turlock, California

Contributors in Addition to the Editors and Associate Editors

Liliana Alamilla-Beltrán, Departamento de Graduados en Alimentos, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, México D.F., México

Jason K. Apple, Department of Animal Science, University of Arkansas, Fayetteville, Arkansas

Beatriz Caballero-Santos, INNOFOOD I+D+I S.L., Granada, Spain

María de la Concepción Calvo Carrillo, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, México D.F., México

María Elena Carranco-Jáuregui, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, México D.F., México

Silvia Carrillo-Domínguez, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, México D.F., México

José Jorge Chanona-Pérez, Departamento de Graduados en Alimentos, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, México D.F., México

Kevin Chao, Food Safety Laboratory, U.S. Department of Agriculture, Henry A. Wallace Beltsville Agricultural Center, Beltsville, Maryland

Yaakob B. Che Man, Department of Food Technology and Halal Products Research Institute, Universiti Putra Malaysia, Selangor, Malaysia

Lorenzo Antonio Durán-Meléndez, Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua, Chihuahua, México

José María Fernández-Ginés, INNOFOOD I+D+I S.L., Granada, Spain

Juana Fernández-López, Grupo Industrialización de Productos de Origen Animal (IPOA Research Group), Departamento de Tecnología Agroalimentaria, Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández, Orihuela, Alicante, Spain

José Arturo García-Macías, Facultad de Zootecnia, Universidad Autónoma de Chihuahua, Chihuahua, México

Miguel González Lozano, Coordinación de Medicina Veterinaria y Zootecnia, Universidad Autónoma Metropolitana, Unidad Xochimilco, México D.F., México

José Fernando González-Sánchez, Departamento de Graduados en Alimentos, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, México D.F., México

María Pilar González-Santiago, INNOFOOD I+D+I S.L., Granada, Spain

Gustavo F. Gutiérrez-López, Departamento de Graduados en Alimentos, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, México D.F., México

Héctor Janacua-Vidales, Universidad Autónoma de Ciudad Juárez, Instituto de Ciencias Biomédicas, Medicina Veterinaria y Zootecnia, Juárez, Mexico

Nina Kaario, Finnish Food Safety Authority Evira, Department of Food and Veterinary Control, Helsinki, Finland

Martha Yarely Leal Ramos, Facultad de Zootecnia, Universidad Autónoma de Chihuahua, Chihuahua, México

Mallika Manral, Defence Food Research Laboratory, Siddartha Nagar, Mysore, India

Luis E. Marti, Veterinary Public Health Department, Faculty of Veterinary Science, Universidad Nacional del Litoral, Esperanza, Provincia de Santa Fe, Argentina

Geoffrey Mead, Consultant, Bathampton, Bath, Somerset, UK

Daniel Mota Rojas, Department of Animal and Crop Production, Universidad Autónoma Metropolitana, Unidad Xochimilco, México D.F., México

Jean-François C. Muellenet, Department of Food Science, University of Arkansas, Fayetteville, Arkansas

Sarah Padilla, Department of Family and Consumer Sciences, New Mexico State University, Las Cruces, New Mexico

María de Lourdes Pérez-Chabela, Departamento de Biotecnología, Universidad Autónoma Metropolitana-Unidad Iztapalapa, México D.F., México

K. Radakrishna, Defence Food Research Laboratory, Siddartha Nagar, Mysore, India

Marjatta Rahkio, Finnish Meat Research Institute, Hämeenlinna, Finland

Carrie E. Regenstein, Computer Services, Carnegie Mellon University, Pittsburgh, Pennsylvania

Yuan Ren, Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada

Robert Renema, Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada

- Estrella Sayas-Barberá**, Grupo Industrialización de Productos de Origen Animal (IPOA Research Group), Departamento de Tecnología Agroalimentaria, Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández, Orihuela, Alicante, Spain
- Awis Qurni Sazili**, Department of Animal Science and Halal Products Research Institute, Universiti Putra Malaysia, Selangor, Malaysia
- Carita Schneitz**, Orion Corporation, Espoo, Finland
- Esther Sendra-Nadal**, Grupo Industrialización de Productos de Origen Animal (IPOA Research Group), Departamento de Tecnología Agroalimentaria, Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández, Orihuela, Alicante, Spain
- Gabriel J. Sequeira**, Veterinary Public Health Department, Faculty of Veterinary Science, Universidad Nacional del Litoral, Esperanza, Provincia de Santa Fe, Argentina
- Vandana Sohlia**, Defence Food Research Laboratory, Siddartha Nagar, Mysore, India
- Alfonso Totosaus-Sánchez**, Tecnológico de Estudios Superiores de Ecatepec, Laboratorio de Alimentos, Ecatepec de Morelos, Estado de México, México
- Magdalena Tudela-Carrasco**, INNOFOOD I+D+I S.L., Granada, Spain
- Carol Turner**, Department of Family and Consumer Sciences, New Mexico State University, Las Cruces, New Mexico
- Chitra Wendakoon**, Southwest Center for Animal Health, Food Safety and Bio-Security, College of Agriculture, Consumer and Environmental Sciences, New Mexico State University, Las Cruces, New Mexico
- Jianping Wu**, Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada
- Marie Yang**, Department of Food Science, University of Guelph, Guelph, Ontario, Canada

PREFACE

Poultry has been and still is a major animal product in our diets. With the advances in preservation techniques for fresh poultry and processed products, consumer preferences for poultry and poultry products are higher than ever. Information on the science and technology of processing this important food commodity is essential to the work of government, academia, and industry.

Many good professional reference books are available. The preference for any particular one depends on the needs of the users. Most are single-volume books, with some covering general and others specific topics. Excluding encyclopedias, multivolume reference books in the discipline are uncommon for many reasons, such as cost, wide coverage, and standard technical challenges, including but not limited to the involvement of a large number of professionals and pressure of a timely publication. On the other hand, most big technical libraries in the world (government, academia, and industry) prefer comprehensive multiple-volume books because they reduce the needs for several books. From this perspective, our two-volume set is designed especially for libraries, although books of this nature will always serve as useful reference sources for students, researchers, instructors, and R&D personnel. The first volume covers the primary processing of fresh poultry and preservation of raw poultry meats. The second volume covers the secondary processing of raw poultry meats to processed retail products.

Volume 1 emphasizes primary processing and covers poultry and their slaughter practices, with an emphasis on classification, biology, production, transportation, slaughtering, pre- and postmortem handling, and carcass evaluation and cutting. The preservation methods for raw poultry meat are also described, such as heat, cold, chemical compounds, irradiation, and high pressure. Emphasis is placed on refrigeration and freezing since these preservation techniques are of major importance. The remaining topics include the engineering principles of packaging, quality attributes of poultry meat (taste, texture, tenderness, juiciness), safety of products and workers, sanitation, and government requirements for hazard control and risk analyses. Details are also provided for Jewish and

Muslim practices for slaughtering and processing poultry and poultry products. Eggs are always an integral part of a discussion related to poultry and poultry products. Coverage related to eggs includes health, nutrition, and the science and technology of processing eggs. Accordingly, the coverage in Volume I is divided into five sections. The table of contents provides the topics for the 38 chapters.

Volume 2 deals with secondary processing of poultry and poultry products covering the transformation from basic raw poultry meat into safe and wholesome products tailored for consumers. These products are available in many forms, including but not limited to such popular poultry items as sausage and deli meats. Some of these items are raw, some cooked but not ready to eat, and some cooked and ready to eat. Thus, the major goal of this volume is to present the technical knowhow needed for manufacturing such products. To do so, this volume presents a sequence of topics divided into seven sections.

Volume 2 begins with the basic principles in formulating and processing poultry products, including mechanical deboning, marination, emulsion basics, formulation, and breading. Many processed poultry products for consumers contain nonmeat ingredients, and this topic is discussed in detail. This is followed by the practical applications and techniques in manufacturing patties, sausages, bacon, ham, luncheon meats, nuggets, pâté, and other products. To produce a high-quality poultry product, one must be familiar with the color, flavor, and texture of raw and cooked poultry meats, and these quality attributes are described in detail. Obviously, the wholesomeness and safety of the product is a primary concern for all government agencies around the world. Because of the many outbreaks of foodborne diseases from contaminated poultry products, 9 of 39 chapters in this volume are devoted to sanitation and food safety system in the United States, covering topics such as contaminants, microbiology, pathogens, analytical techniques, and the requirements for sanitation, hazards identifications, and risks factors involved.

Although many topics are included in these two volumes, we do not claim the coverage to be totally comprehensive. The work is the result of the combined expertise of more than 150 people from industry, government, and academia: professionals from Argentina, Brazil, Canada, Finland, India, Italy, Japan, Malaysia, Mexico, Spain, and the United States. An international editorial team of 15 members from six countries led these experts. Each contributor or editor was responsible for researching and reviewing subjects of immense depth, breadth, and complexity. Care and attention were paramount to ensure technical accuracy for each topic. In sum, these two volumes are unique in many respects. It is our sincere hope and belief that they will serve as essential references on poultry and poultry processing.

We wish to thank all the contributors for sharing their expertise throughout our journey. We also thank the reviewers for giving their valuable comments, leading to improvements in the contents of each chapter. In addition, we thank members of the production team at John Wiley & Sons, Inc., for their time, effort, advice, and expertise. All these professionals made this two-volume treatise possible. You are the best judge of the quality of their work and we trust that you will benefit from the fruits of their labor.

I. GUERRERO-LEGARRETA
Y.H. HUI
A.D. ALARCÓN-ROJO
C. ALVARADO
A.S. BAWA
F. GUERRERO-AVENDAÑO
J. LUNDEN
L. MCKEE
Y. MINE
C.M. OWENS
J.A. PÉREZ-ALVAREZ
J.M. REGENSTEIN
M.R. ROSMINI
J. SORIANO-SANTOS
J. EDDIE WU

PART I

POULTRY: BIOLOGY TO PREMORTEM STATUS

1

POULTRY BIOLOGY, CLASSIFICATION, AND TRADE DESCRIPTIONS

Y.H. HUI

Science Technology System, West Sacramento, California

ISABEL GUERRERO-LEGARRETA

Departamento de Biotecnología, Universidad Autónoma Metropolitana, México D.F., México

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COMMERCIAL PRODUCTION OF CHICKEN

This book is not the proper forum to provide details on the commercial production of chickens. However, a general introduction is provided here as a frame of reference for discussion in all chapters.

Most commercial production of broiler chickens involves intensive and highly mechanized operations that use small areas in which the birds run on litter floors in large open poultry sheds. This differs from other forms of animal farming that use cages. However, a small percentage of broilers is now produced in larger areas in which the birds can run more freely. These birds are produced for specific markets.

Receipt of Chicks

Fertile chicken eggs are hatched in rooms with control for temperature and relative humidity. A yolk sac containing residue nutrients and moisture will sustain chicks for 2 to 3 days. However, it is important that the birds be kept warm, with feed and water available within easy reach. Within 72 h after hatching, chicks in ventilated boxes should be transported to broiler farms in specially designed air-conditioned trucks.

Housing Structure

On arrival at the farm, the newly hatched chicks are housed in open buildings called *units*, *sheds*, or *houses*. They vary in size, with a typical unit measuring 15 m × 150 m, holding about 40,000 adult chickens; some units can contain up to 60,000 broilers. There are usually three to 10 sheds or units on one farm. A typical new chicken farm has eight sheds holding about 40,000 birds each, with a total of about 320,000 chicken.

Ventilation by Mechanical Means In some countries, traditional broiler sheds are ventilated, with the sides of the sheds open to fresh air. The amount of fresh air is regulated by opening one or more vents or by leaving curtains open or closed accordingly. Other manual ventilation methods include the use of fans or a water-misting system to implement evaporative cooling in very hot weather. Newer chicken houses use tunnel ventilation: Fans at one end draw cool and fresh air over the chickens and fans at the other end blow it out. Heat sensors regulate the fans to heat and cool the structures at a desired rate of time and speed.

In some countries, including Canada and the United States, modern technology is used to air-condition such units in addition to other computerized systems to optimize management of the birds. Such operations are possible when chickens are mass-produced by multinational corporations under all environmental conditions. Chickens always have easy access to feed and water. Depending on the facility, silos on the outside supply feed into feed lines and pans from end to end of the unit. Drinkers are available at regular

intervals and connected to the water lines running from end to end of the shed.

Grow-out Phase

Key points to remember in the grow-out phase:

1. Provide suitable bedding, such as sawdust, wood shavings, or other material, such as rice hulls.
2. Preheat the unit.
3. Provide proper water and feed lines.

When the day-old chicks arrive at a broiler farm, routine procedures are as follows:

1. The chicks are initially confined to 30 to 50% of the floor space in the unit, usually referred to as the *brooding area*.
2. *Brooders*, gas heaters or heat lamps, are used to provide supplementary heat in addition to the shed heating system.
3. Extra feeding pans and water dispensers are added to assure sustenance. Additional paper is added on top of the bedding to prevent dropped feed from soiling the bedding.

Depending on several factors, including the business environment, a farm or company specializing in rearing male or female chicks for chicken meat may include both sexes in one plant or separate sexes in different plants in the same or different locations. The baby checks must enjoy comfort and good health to maximize their survival rate. The temperatures for proper rearing of baby chicks can be adjusted as follows:

- For the first few days, the optimal ambient temperature is 31 to 32°C.
- Growth is accompanied by less heat to keep them warm. After the first 2 days, the ambient temperature is decreased by about 0.5°C each day, until it reaches 21 to 23°C at 21 days.

The data above are suggestions only. Each farmer or company decides on the best temperature according to flock size, types of sheds, spaces available, and appropriate technical applications. Three factors are important: temperature, humidity, and air quality. All can be managed with the appropriate traditional means (i.e., fans, water vapors, ventilation, etc.) and/or modern technology (i.e., thermostats, pumps, vacuum, etc.).

The brooders are usually removed 4 or more days after the installation. In most cases they should be removed 2 weeks after installation. The space allocated to the flock increases as the chickens grow. Eventually, they are permitted to run freely over the entire shed floor. The farmer or company makes regular checks for the following:

- Is water available at all times or at a specific time?
- Is each water dispenser in working order?
- Is each feed dispenser in working order?
- Is feed available at all times or at a specific time?
- Is the ventilation system working properly?
- Is lighting adjusted to the proper intensity appropriate for the eyes of the chickens?
- Is lighting sufficient for chickens to locate water and feed?
- Is the dark period sufficient for chickens to rest?
- Are ambient temperature, humidity, and air quality adjusted and managed regularly using manual or automatic techniques?
- Is the litter clean and dry?
- Is the health of the flock excellent?
- Are dead, sick, or injured birds handled appropriately?
- Are the performance and health records of the flock acceptable?

Under proper management, a broiler flock usually suffers 3 to 4% loss during the grow-out phase. These birds may die of a variety of causes or from selective culling.

Harvesting Meat Chickens

Harvesting chicken is done several times annually or other defined period, depending on many factors, such as market needs and size of units. This collecting process is also known as *multiple pickup*, *partial depopulation*, *thinning out*, and other regional terms. In addition to being a business decision, this practice provides more space for the remaining birds and lowers the housing temperature. Several factors are involved in the actual process of harvesting:

1. *Days of growth*. The flock may be harvested at 30 to 35 days or as late as 55 to 60 days of growth.
2. *Time of day*. Night harvesting is preferred, to make sure that the birds are settled. Also, temperature plays a part during the summer.
3. *Collecting procedure*. Standard-experience crews pick up the birds in a dimmed lighting environment. This helps to settle the flock and facilitates handling. After being picked up by hand, the chickens are placed in specially designed containers for transport to a processing facility. Truck, rail, or other means of transport follows standard regional requirements.

Cleaning a Unit for a New Flock

Cleaning a unit after a flock has been harvested is essential before accepting the next batch of newborn chicks. The goals are no different from those of other businesses. Health, safety, and many other aspects are important factors

in guaranteeing that products are wholesome, marketable, and optimally cost-effective. So the following considerations are of major concern:

1. One batch of chicks stays for about 60 days, at which point it is removed from the housing unit. The period available for cleaning before the next batch arrives ranges from 5 to 15 days.
2. The extent of cleaning varies with each farmer or company and depends on the size of the flock, the size of each unit, and the types of operations (e.g., manual vs. mechanized vs. high tech). Cleaning covers bedding, floors, feed and water dispensers and accessories, equipment (i.e., fans, vacuum, pumps, etc.), and extraneous matter (i.e., rodent droppings, glass pieces, etc.). The techniques used vary depending on labor, devices, and other factors.
3. Legal requirements must be complied with in all aspects of the cleaning process: sanitation principles, use of such chemicals as disinfectants and insecticides, space allocation, and many other considerations.

Diseases: Precautions, Pest Control, and Records

At some farms, workers are responsible for diseases in the flock. Sources of contamination include hands, footwear, and vehicles. To minimize such risks, precautions include:

1. Enforcing authorized entries to sheds.
2. Enforcing the use of overalls and boots.
3. Requiring disinfection of footwear in specially equipped locations near entrances to sheds.
4. Disinfecting all equipment, including vehicles and pumps, with water or solutions.
5. Visiting flocks from youngest to oldest.

Birds in the environment can infect farmed chickens with diseases through their presence or droppings. Routine cautionary steps include the following:

1. Removing dropped feeds promptly.
2. Keeping domesticated birds in a location far from the sheds.
3. If circumstances permit, avoiding sources of environmental water such as dams and rivers.
4. Assuring that the chickens' drinking water is sanitary.
5. Enclosing the sheds using netting or a roof, or using completely enclosed sheds with proper ventilation.

Standard pest controls must be in place to prevent diseases from rodents or insect parts. There should also be mandatory or voluntary record keeping for chicken health, growth, and behavior.

Growth and Nutrition

Many factors are involved in achieving optimal growth rate and size at harvest, such as breed, gender, nutrition, and feed. *Nutrition* is the sum of processes by which food is selected and becomes part of the body. Balanced nutrition provides the nutrients that best meet bodily requirements for growth, maintenance, and repair. This fact applies to all living creatures. The word *nutrient* refers to a broad category of organic and inorganic compounds. The essential nutrients are carbohydrates (the source of energy), protein, fat, vitamins, minerals, and water.

Supplying enough nutrients to meet the requirements for maximum poultry production can be difficult. It is not feasible economically to supply just the right amount of food to meet requirements because some of the nutrient needs must be oversupplied to compensate for the limiting nutrients in the feed: usually energy and essential amino acids such as lysine and methionine. The formulation of poultry diets considers the essential nutrients of water, energy, protein, fat, vitamins, and minerals in the proper amounts for successful operation. They are provided by animal and vegetable proteins, animal and vegetable fats, macro and micro minerals, vitamin premixes, and cereals. Each separate type of ingredient provides a specific quantity and quality of nutrients to the diet and must be formulated skillfully for maximum growth, egg production, and feed efficiency. Balancing these ingredients to produce an optimal diet for poultry requires knowledge of the needs and composition of the ingredients as well as their cost: The formulation must balance needs vs. ingredients vs. costs.

Feed efficiency refers to the amount of feed required to produce a pound of body weight or the amount of feed necessary to produce a dozen eggs. Feed accounts for 65 to 70% of the cost of production, so producers should pay close attention to the requirements of each species.

Feed

Chicken feeds can come from a variety of sources, including land and marine plants and animal products. Although most feed is made up of land plants such as grains, others may be produced from certain land animal and marine plant and animal products. For ease of reference, let us assume that major chicken feed manufacturers use such grains as wheat, sorghum, barley, oats, lupins, soybean meal, canola, and other oilseed meals and grain legumes.

The use of additives and drugs in commercial poultry is governed by laws and regulations which vary from country to country. Depending on its size and operations, a feed manufacturer offers many options for meat chicken diets formulated to optimal and strict nutritional standards: These formulations will reflect availability, price and quality of the ingredients required, and the location, season, and age of a particular broiler flock.

Other than nutritional considerations, feeds are also produced to meet other requirements, including but not limited to:

1. *Starter feed*: small crumbles for baby chicks
2. *Grower feed*: fully formed pellets for growing birds
3. *Finisher feed*: feed made available after 25 days
4. *Withdrawal feed*: feed provided just before harvest

In the last 50 years, much professional and consumer literature has been disseminated on the rearing, production, and management of poultry. Readers should consult such sources for more details. However, as an illustration, one specific topic, competitive exclusion as a natural part of poultry management, is discussed in Chapter 2.

BIRDS COMMON TO THE LIVE-BIRD MARKETING SYSTEM

For regulatory commercial purposes, the U.S. Department of Agriculture (USDA) recognizes particular birds (poultry) common to the live-bird marketing system (Figure 1). The types of common live birds in domestic and international commerce are listed in Table 1.

BIOLOGICAL AND LEGAL CLASSIFICATION OF POULTRY IN THE UNITED STATES

The U.S. Department of Agriculture (USDA) has classified major poultry and poultry products in commercial transactions (see Table 2).

Ready-to-Cook Poultry

The standards apply to individual carcasses of ready-to-cook poultry in determining the type of poultry and its class. The types of poultry are: chickens, turkeys, ducks, geese, guineas, and pigeons. The classes within each type are described below.

Chickens

1. *Rock Cornish game hen or Cornish game hen*: a young immature chicken (usually, 5 to 6 weeks of age), with a ready-to-cook weight of not more than 2 lb, which was prepared from a Cornish chicken or the progeny of a Cornish chicken crossed with another breed of chicken.
2. *Rock Cornish fryer, roaster, or hen*: the progeny of a cross between a purebred Cornish and a purebred Rock chicken, without regard to the weight of the carcass involved; however, the term *fryer*, *roaster*, or *hen* applies only if the carcasses are from birds with ages and characteristics that qualify them for such designation under the regulations.

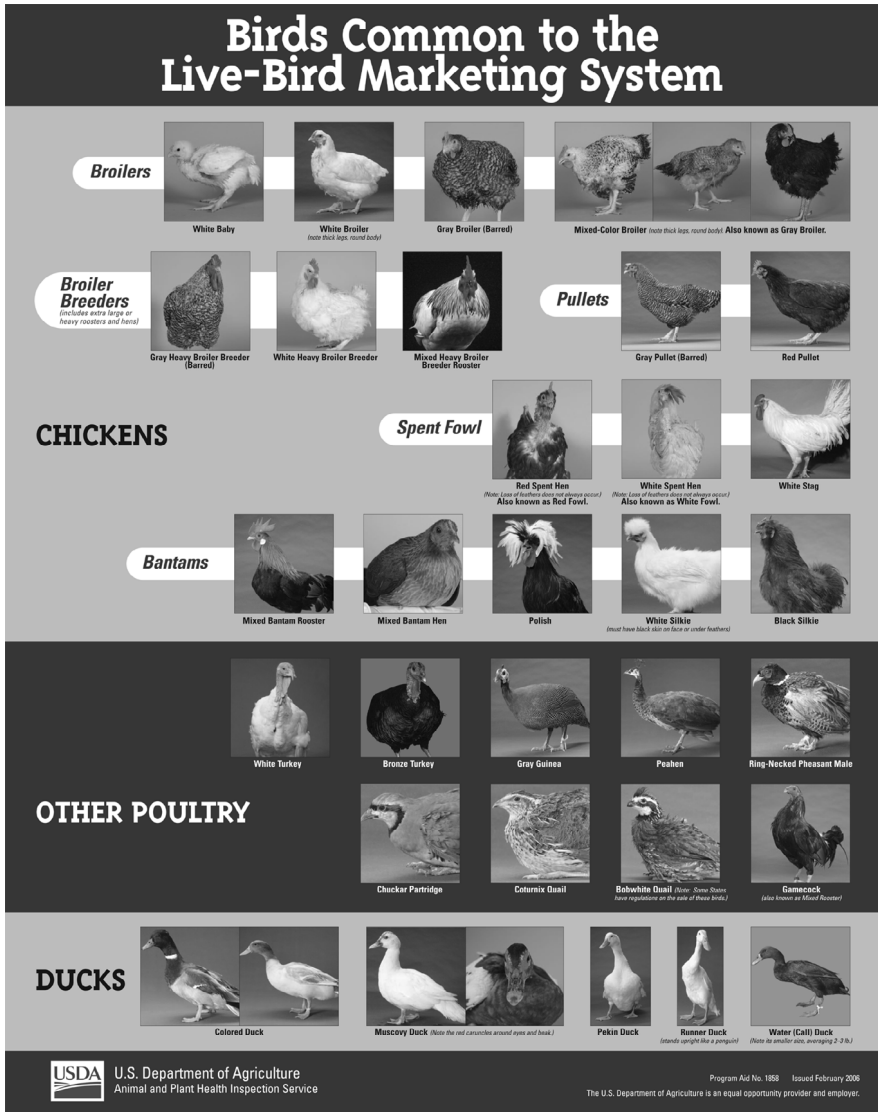


FIGURE 1 Birds common to the live-bird marketing system.

3. *Broiler or fryer*: a young chicken (usually, under 13 weeks of age), of either sex, that is tender-meated with soft, pliable, smooth-textured skin and flexible breastbone cartilage.
4. *Roaster or roasting chicken*: a young chicken (usually, 3 to 5 months of age) of either sex that is tender-meated with soft, pliable, smooth-textured skin and breastbone cartilage that may be somewhat less flexible than that of a broiler or fryer.

TABLE 1 Birds Common to the Live-Bird Marketing System

<i>Chicken</i>	Type
Broilers	White baby
	White broiler (note the thick legs and round body)
	Gray broiler (barred)
	Mixed-color broiler (note the thick legs and round body); also known as gray broiler
Broiler breeders (includes extralarge or heavy roosters and hens)	Gray heavy broiler breeder (barred)
	White heavy broiler breeder
	Mixed heavy broiler breeder rooster
Pullets	Gray pullet (barred)
	Red pullet
Spent fowl	Red spent hen (note that loss of feathers does not always occur); also known as red fowl
	White spent hen (note that loss of feathers does not always occur); also known as white fowl
Bantams	Mixed bantam rooster
	Mixed bantam hen
	Polish
	White silkie (must have black skin on face or under feathers)
	Black silkie
<i>Other poultry</i>	White turkey
	Bronze turkey
	Gray guinea
	Peahen
	Ring-necked pheasant, male
	Chuckar partridge
	Coturnix quail
	Bobwhite quail (some states have regulations on the safety of these birds)
	Gamecock also known as inlixed rooster
<i>Ducks</i>	Colored duck
	Muscovy duck (note the red caruncles around the eyes and beak)
	Pekin duck
	Runner duck (stands upright like a penguin)
	Water (call) duck (note its smaller size, averaging 2 to 3 lb)

5. *Capon*: a surgically unsexed male chicken (usually, under 8 months of age) that is tender-meated with soft, pliable, smooth-textured skin.
6. *Hen, fowl, or baking or stewing chicken*: a mature female chicken (usually, more than 10 months of age) with meat less tender than that of a roaster or roasting chicken and a nonflexible breastbone tip.

TABLE 2 Poultry and Poultry Products Common in Commerce

Ready-to-Cook Poultry	Ready-to-Cook Poultry Food Products
Chickens	Poultry roast
Turkeys	Boneless poultry breasts, drumsticks, thighs, and legs
Ducks	Skinless poultry carcasses and parts
Geese	Poultry tenderloins and boneless, skinless parts
Guineas	Size-reduced poultry products
Pigeons	

7. *Cock or rooster*: a mature male chicken with coarse skin, toughened and darkened meat, and hardened breastbone tip.

Turkeys

1. *Fryer–roaster turkey*: a young immature turkey (usually, under 16 weeks of age), of either sex, that is tender-meated with soft, pliable, smooth-textured skin, and flexible breastbone cartilage.
2. *Young turkey*: a turkey (usually, under 8 months of age) that is tender-meated with soft, pliable smooth-textured skin and breastbone cartilage that is somewhat less flexible than in a fryer–roaster turkey. Sex designation is optional.
3. *Yearling turkey*: a fully matured turkey (usually, under 15 months of age) that is reasonably tender-meated and with reasonably smooth-textured skin. Sex designation is optional.
4. *Mature turkey or old turkey (hen or tom)*: an old turkey of either sex (usually in excess of 15 months of age), with coarse skin and toughened flesh.

For labeling purposes, the designation of sex within the class name is optional, and the two classes of young turkeys may be grouped and designated as “young turkeys.”

Ducks

1. *Broiler duckling or fryer duckling*: a young duck (usually, under 8 weeks of age), of either sex, that is tender-meated and has a soft bill and a soft windpipe.
2. *Roaster duckling*: a young duck (usually, under 16 weeks of age), of either sex, that is tender-meated and has a bill that is not completely hardened and a windpipe that is easily dented.
3. *Mature duck or old duck*: a duck (usually, over 6 months of age), of either sex, with toughened flesh, a hardened bill, and a hardened windpipe.

Geese

1. *Young goose*: may be of either sex, is tender-meated, and has a windpipe that is easily dented.