



Poultry Science

Fifth Edition

Colin G. Scanes

with

Karen D. Christensen

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*Dedicated to the outstanding present, past, and future students
studying poultry science
and to the excellent faculty teaching this.
May the pursuit of truth and service be your watchword.*

ABOUT THE AUTHORS

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Preface

The production of poultry continues to make tremendous advances. This book is thoroughly revised to reflect this.

The book is intended for multiple audiences:

1. A textbook for introductory poultry classes for undergraduate students (overlooking the “Deeper Dive” sections), particularly in North America, but also throughout the world.
2. A textbook for senior undergraduate/graduate students (embracing the research-based “Deeper Dive” sections).
3. An overview of poultry production for business and engineering students entering the poultry industry.
4. A useful compendium for poultry professionals, small- and medium-sized producers of poultry and game birds, and future farmers.

The utility of this textbook for introductory poultry classes is enhanced by the “Points for Discussion”

sections. Moreover, the effectiveness of class instructors is undergirded by the research-based “Deeper Dive” sections.

Areas covered include global poultry production; commercial poultry production; poultry business organization; and production of meat chickens (broilers), turkeys, eggs, ducks, geese, game birds, and other poultry. In addition, chapters cover poultry biology, genetics, behavior, diseases/health, housing, ventilation, and processing. New or greatly expanded sections cover biosecurity; poultry stress/welfare; feed additives; food safety; incubation; controlling pests; poultry waste and environmental issues; brooding; internships and applying for positions; and organic, free-range, and niche poultry production.

Colin G. Scanes
2019

A Global Perspective on Poultry

□ CHAPTER SECTIONS

- 1.1 Introduction
- 1.2 Domestication and Early Use of Chickens
- 1.3 Domestication of Turkeys, Ducks, and Geese
- 1.4 Global Growth of Poultry and Egg Production
- 1.5 Nutritional and Other Attributes of Poultry Meat and Eggs
- 1.6 Health Consequences of Consuming Poultry Meat and Eggs
- 1.7 Efficiency of Poultry Production
- 1.8 Nonfood Uses of Poultry
- 1.9 Projections on the Future of Poultry Production

□ OBJECTIVES

After studying this chapter, you should be able to:

1. Define the term poultry.
2. Describe the domestication of the chicken.
3. Describe the domestication of the turkey.
4. Understand the importance of poultry in the world.
5. Know what the top countries and regions are for the production and export of chicken, turkey, duck, goose (meats), and eggs, both chicken and other eggs (essentially duck and goose eggs).
6. Understand why poultry production has increased globally.
7. Understand why the efficiency of poultry production has improved.
8. Comprehend the nutritional advantages and disadvantages of eating eggs and poultry meat in the diet.
9. List the nonfood uses of eggs, poultry, and coproducts.

1.1 INTRODUCTION

Poultry (see Figure 1.1) have been a part of human lives since at least the Neolithic Revolution. There has been tremendous growth in poultry and egg production globally (see section 1.4). There is high global consumer demand for poultry meat and eggs due to the following:

- The taste, flavor, texture, juiciness, and overall enjoyability of eating poultry meat.
- The versatility of eggs cooked as meals, into cakes, and in the manufacture of processed foods.
- Excellent nutritional content with high-quality protein, vitamins, and minerals together with relatively low fat (see section 1.5).
- Low price. Due to improvements in the efficiency of production, the price of poultry meat and eggs has declined relative to the ability of people to buy (see section 1.6).



Figure 1.1 Day-old chicks drinking from nipple drinkers. (Source: Omjai Chalard/Shutterstock)

TEXTBOX 1A

Word Origins Related to Poultry

The English language derives from a mixture of predominantly two languages: Old English (itself derived from Anglo Saxon, a West Germanic language) and Middle French (a Romance language derived from Latin). Both Germanic and Romance languages are Indo-European languages dating back to a common language (Proto-Indo-European) more than 5000 years ago.

Word origins related to poultry fall into three groups: (1) Derived from Old English, (2) derived from Middle French, and (3) others.

1. Poultry-related words derived from Old English.
 - Chicken, from Old English word *cicen* (chicken).
 - Chick (“baby” chicken), a diminutive¹ of *chicken*.
 - Cock (adult male chicken), from the Old English word *kok* (male chicken).
 - Cockerel (male chicken), a diminutive of *cock*.
 - Duck, from the Old English word *duce* (duck) (from the Germanic *ducan*, meaning “to dive”).
 - Dove, from the Old English word *dufe* (dove).
 - Fowl, from the Old English word *fogul* (a bird or to fly).

The term **poultry** applies to domesticated birds. These are both a source of meat and eggs. Poultry include chickens, turkeys, ducks, geese, pigeons, guinea fowl, pheasants, quail, and other game birds, together with the ratites, ostriches, emus, and rheas. In the past, other species of birds such as swans and peafowl were eaten and included in the term poultry. For the etymology (origin of words) of poultry-related words, see Textbox 1A. Our understanding of domestication has greatly expanded through the application of the techniques of molecular biology to existing populations of domesticated and wild birds together with knowledge derived from archaeology. The domestication and early use of chickens and turkeys are considered in sections 1.2 and 1.3, respectively.

Definitions

Domestication: When people take wild animals or plants and breed them over multiple generations such that their characteristics are meeting human needs.

Poultry: Domesticated birds. Globally, the term today predominantly consists of chickens, turkeys, ducks, and geese. In addition, there is production of minor poultry species such as guinea fowl, pheasants, quail, and other game birds, together with the ratites, ostriches, emus, and rheas.

- Goose, from the Old English word *gos* (goose).
 - Hen, from the Old English word *henna* (female chicken).
2. Poultry-related words derived from Middle French.
 - Ostrich, from the Middle French word *ostrice* (ostrich).
 - Pigeon, from the Middle French word *pigon* (pigeon) (from the Late Latin *pipion*, meaning “a young bird,” and from the Latin *pipire*, meaning “to chirp”).
 - Poultry, pullet, and pout, from the Middle French *poult* (female chicken) (itself from the Latin *pullus*, meaning “small chicken”).
 - Quail, from the Middle French word *caille*.
 3. Poultry-related words derived from other languages.
 - Emu, from Portuguese *ema*.
 - Rooster (adult male chicken), from American English (bird that roosts). A replacement for the arguably offensive word *cock*.

¹ A diminutive is a nickname or shortened form of a name. For example, Kate and Sam are the diminutives for Katherine and Samuel.

Poultry science: The study of all aspects of poultry, including production.

Poultry biology: The study of the biology of poultry and a facet of poultry science and avian biology.

Ornithology: The study of birds. This is derived from *ornis*, the Greek word for “bird.”

Avian science: Another term for the study of birds. This is derived from the Latin word for bird, *avem*, and its plural, *aves*.

TEXTBOX 1B

Points for Discussion

1. Should we be eating meat and eggs?
2. Rather than eating poultry, meat, and eggs, we could be eating the ingredients of poultry feed (corn or other cereals, and soybeans as a source of protein). After all, they are highly nutritious. This is called the “food versus feed” argument.
3. What customs, traditions, or occasions are associated with poultry and eggs?
4. Do we eat only for nutrition? Do we eat only to sate our hunger? Do we eat for pleasure?
5. Share your favorite recipes and dishes.
6. Share some common dishes at restaurants.

TEXTBOX 1C**A Deeper Dive: Hunger across the World**

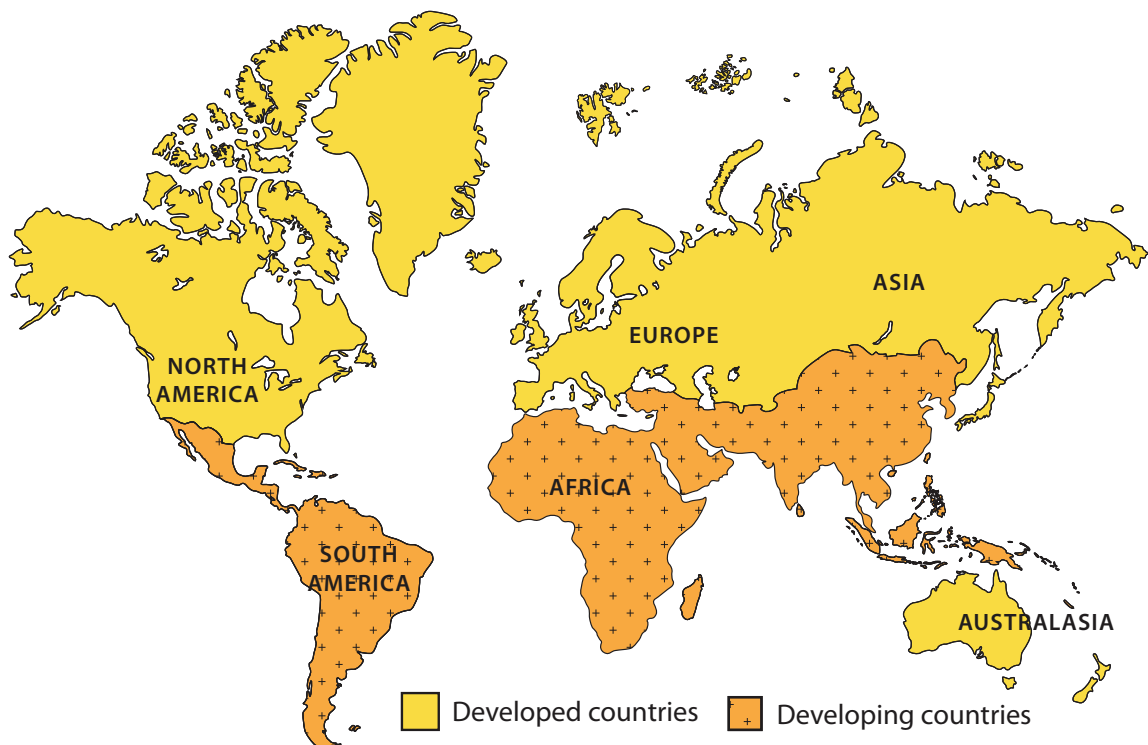
According to *The State of Food Security and Nutrition in the World 2017*, published by the United Nations Food and Agricultural Organization, between 1990 and 2016 there has been a decline in the percentage of people who are hungry. The magnitude of these improvements varies considerably between different regions of the world (see Textbox 1C Figure 1).

- Developed regions remained at < 5%.
- Developing regions declined from 23.3% to 12.9%.
- Africa declined from 27.6% to 20.0%.
- Latin America declined from 14.7% to 5.5%.
- Asia declined from 27.6% to 12.1%. More specifically, Central Asia declined from 14.2% to 7.0%, Eastern Asia from 23.2% to 9.6%, Southern Asia from 23.9% to 15.7%, South Eastern Asia from 30.6% to 9.6%, and Western Asia from 14.2% to 8.4%.

There are low rates of hungry people in developed regions but higher rates in developing regions. From 1990–2016, there were declines in the percentage of hungry people with particularly large decreases in Latin America and Eastern Asia.

The prevalence of underweight children is a major global problem as it is the underlying cause of 45% of deaths in young children and cannot be fully corrected even if sufficient nutrition is provided later. The prevalence of underweight children in 2016 were the following: Southern Asia 27%, Western Africa 20%, Eastern Africa 18%, Southern Africa 11%, Latin America < 10%, and Eastern Asia < 10%. The cause of underweight children is childhood malnutrition, which can be due to suboptimum breastfeeding together with a lack of protein in the diet and deficiencies of vitamin A and zinc. Other nutritional deficiencies (such as protein, iodine, and iron) also impair childhood development and result in physical and mental stunting. The decreases in underweight children under 5 years old between the early 1990s and 2014–2016 generally align with the declines in the percentage of people who are hungry.

At the World Food Summit (WFS) in Rome in 1996, 182 governments committed “to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half their present level no later than 2015.” Some countries, but by no means all, have achieved this goal.



Textbox 1C Figure 1 Developed and developing countries.

Birds are a successful class of vertebrates, with billions living from the Arctic to the Antarctic. There are almost 20,000 species of birds across the globe, with a greater number of species of birds than mammals but less than those of fish or insects (birds 18,000; mammals 5,415; fish about 30,000; insects about 1,000,000).

Human population is continuing to expand but, despite the efforts of the global community with the Millennium Development Goals, the number of hungry people remains about the same. Changes in the world's population and the number of hungry people are summarized in Table 1.1.

Earth's human population continues to rise and agricultural production is more than keeping pace with the growth. There are also decreases in the number of people who are hungry. Taken together, agriculture fully met the needs of over 1.5 billion more people in 2015–2017 than 1992–1994. An alternative viewpoint is that the decline of undernourished people is due to the large decrease of the number of very poor and the ability of more people to buy food.

Table 1.1 Changes in the world's population and the number of people getting insufficient nutrients.

	1994	2014
World Population in Billions	5.8	7.5
Number of Hungry People in Millions²	1011 ¹	795
Percentage of World's Population Who Are Hungry²	18.6 ¹	10.9
Number in Billions (%) of World's Population Who Are Poor³	1.85 (32.5)	0.77 (10.7)
Percentage of Children under 5 Years Old Who Are Underweight	25	14

¹ 1990–1992

² Undernourished people receiving caloric intake below the minimum dietary energy requirement.

³ Living on \$1.90 or less per day.

Data from the United Nations (Population Office, FAO, and WHO) and World Bank.

1.2 DOMESTICATION AND EARLY USE OF CHICKENS

Chickens were domesticated for food (eggs and meat) and/or for cockfighting. In addition, they were used for religious or ceremonial purposes. Chickens were domesticated from junglefowl (genus: *Gallus*). The species of junglefowl are (1) Red junglefowl (species: *Gallus gallus*) from Southeast Asia (Figure 1.2); (2) Green or Javan junglefowl (*Gallus varius*) from islands of Indonesia; (3) Sri Lankan junglefowl (also known as Ceylon or Lafayette's junglefowl) (*Gallus lafayettii*) from Sri Lanka; and (4) Grey junglefowl (also known as Sommerat's junglefowl) (*Gallus sonneratii*) from the Indian subcontinent.

The principal ancestral stock for the chicken is the Red junglefowl (*Gallus gallus*) (see Figures 1.2 and 1.3). There are thought to have been multiple domestications of junglefowl in Southeast Asia and present day Southeast and Northeast China. These occurred around 10,000 years ago, with chicken bones at archaeological sites in northeast China dated to about 7,500 years ago based on radiocarbon dating. Chickens then spread to the Indian subcontinent, present day Iran and the Fertile Crescent (the areas from present day Egypt through Israel, Jordan, and Palestine to Syria and Iraq), Europe (probably via the Silk Route), and to Africa. In the Indian subcontinent, there was crossing of early domesticated chickens with wild Grey junglefowl, with today's chicken including genetics of both the Red and Grey fowl.



Figure 1.2 Wild Red junglefowl (*Gallus gallus*)—the ancestor of domestic chickens. (Source: Silverfoxz/Shutterstock)



Figure 1.3 Chickens were domesticated from wild Red junglefowl. (Source: andrea lehmkuhl/Shutterstock)

Polynesians took chickens along with pigs and Pacific rats as they spread across the islands of the Pacific, even reaching as far as the west coast of South America (Figure 1.4). European colonists took chickens to the Americas. The first recorded chickens were on the island of Cuba in 1495. From their introduction until the advent of large-scale commercial production techniques, chickens were raised as scavenging chickens in backyards and farmyards (Textbox 1E discusses village chickens). There is still considerable potential for the continuation and expansion of this small-scale approach in many communities in developing countries. The addition of egg and meat protein to protein-deficient diets, together with cash income, can make small-scale poultry production very appealing.

1.3 DOMESTICATION OF TURKEYS, DUCKS, AND GEESE

Turkeys (*Meleagris gallopavo*) were domesticated in the New World by the pre-Columbian civilizations (Aztecs and pre-Aztec peoples) of present-day Mexico and Central America about 2,000 years ago (see Figures 1.5 and 1.6). It is possible that other populations of turkeys (also of different subspecies) were domesticated by the American Indians of the Southwest of what is now the United States of America. The Spanish colonists of Mexico transported domesticated turkeys to Spain as documented in 1501. Later, these were distributed to the Mediterranean countries, to



Figure 1.4 Domestic chickens were transported across the Pacific Ocean by the colonizing Polynesians. (Image courtesy of Wikipedia)



Figure 1.5 Wild turkey (*Meleagris gallopavo*)—the ancestor of domestic turkeys. (Source: Tory Kallman/Shutterstock)

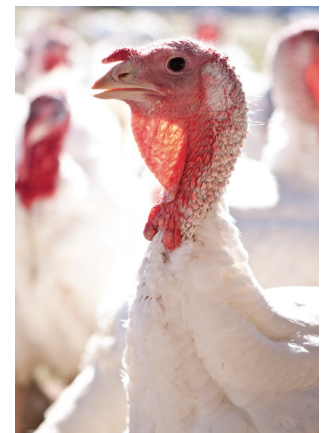


Figure 1.6 Turkeys were domesticated from wild turkeys. (Source: Richard Wozniak/Shutterstock)

other countries in Europe, and by the colonists of what became the United States of America. Domesticated turkeys were reared on a small scale by farmers and fanciers particularly in Europe and North America.

Ducks and geese were domesticated multiple times in different places. The two major species of domesticated ducks are Pekin ducks (*Anas platyrhynchos*) and Muscovy ducks (*Cairina moschata*), respectively. Pekin ducks were domesticated at least 3,000 years ago in what is today China (see Figures 1.7 and 1.8) and possibly also in the Fertile Crescent, while Muscovy ducks domesticated in the Northern Andes (present day southern Peru) about 2000 years ago.

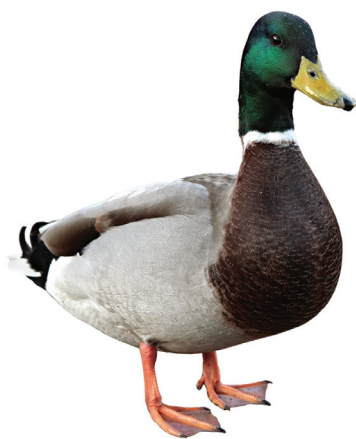


Figure 1.7 Wild mallard ducks (*Anas platyrhynchos*) were the ancestors of domesticated ducks. (Source: Aksenova Natalya/Shutterstock)



Figure 1.8 Ducks were domesticated from wild mallard ducks. (Source: Gumpanat/Shutterstock)

1.4 GLOBAL GROWTH OF POULTRY AND EGG PRODUCTION

Chicken meat is a major source of meat globally and there have been large increases in the production of chicken and other meat species around the world (Table 1.2). Chicken production today surpasses that of beef, lamb, and goat meat (Table 1.2; Figure 1.9). Production of chicken globally is now only exceeded by production of pork (Table 1.2). China is by far the largest producer of pork with 55 million metric tons produced in 2016. When meat production is ranked across the globe excluding China, production of

Table 1.2 Importance of poultry meat production as indicated by changes in global production of poultry with livestock meats (in million metric tons) over 20 years.

Meat	1996	2006	2016
Pork (pig meat)	79.3	100.8	118.2
Chicken meat	49.1	72.7	107.1
Beef (cattle meat)	53.6	60.5	66.0
Lamb (sheep meat)	7.1	8.4	9.3
Turkey meat	4.3	5.2	6.1
Goat meat	3.2	4.6	5.6
Duck meat	2.2	3.4	4.5
Goose and guinea fowl meat	1.5	2.1	2.5

Data from FAOStat.

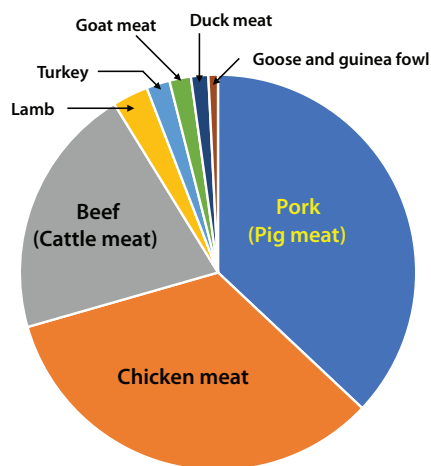


Figure 1.9 Global production of poultry (chicken, turkey, duck, goose, and guinea fowl) compared to other major meats in 2016 (data from FAOStat).

chicken meat exceeds pork, with 93.8 million metric tons of chicken meat produced in 2016 compared to 63.2 million metric tons of pork. Global production of poultry meat more than doubled, increasing by 110% between 1996 and 2016. Total production of poultry meat (chicken, turkey, duck, and goose) rose from 57.1 million metric tons in 1996 to 120.2 million metric tons poultry meat in 2016. While production of pork (pig meat) and beef rose between 1996 and 2016, the increases were markedly smaller than the increases for poultry (49.1% vs. 23.1%, respectively). In comparison, the increase in the human population was 29% between 1996 and 2016 (Table 1.1). Thus, the increase in production of pork and chicken meat greatly exceeded that of human population growth.

The regions with the highest quantities of chicken meat production are the Americas and Asia (see Table 1.3). The largest increases in chicken meat production between 1996 and 2016 were in the Americas (23.8 million metric tons) and Asia (22.2 million metric tons). The greatest percentage increases in production between 1996 and 2016 were in South America (207%), followed by Asia (154%) and Africa (143%).

Table 1.3 Changes in chicken meat production (in million metric tons) in major regions of the world.

Region	1996	2006	2016
Africa	2.3	3.4	5.6
Americas	21.7	33.9	45.5
Asia	14.4	23.5	36.6
Europe	10.2	10.9	18.1
Oceania	0.6	1.0	1.4
North America	12.9	17.3	19.9
South America	6.8	12.8	20.9

Data from FAOStat.

In contrast to the situation with chicken production, turkeys are predominantly produced in the Americas (59% of global production), mostly in North America, and Europe (33% of global production) (Table 1.4). In both North America and Europe, production of turkeys is plateauing, however there is growth of turkey production in both South America and Africa, albeit from low levels (Table 1.4). The production of ducks is focused in Asia, with the region accounting for 84% of global production (Table 1.5).

The top countries for chicken meat production for 2016 are summarized in Table 1.6 (also see Figure

Table 1.4 Changes in turkey meat production (in million metric tons) in major regions of the world.

Region	1996	2006	2016
Africa	0.05	0.09	0.20
Americas	2.8	3.2	3.6
Asia	0.10	0.14	0.16
Europe	1.4	1.8	2.0
North America	2.6	2.7	2.9
South America	0.16	0.42	0.75

Data from FAOStat.

Table 1.5 Changes in duck meat production (in million metric tons) in regions of the world over 20 years.

Region	1996	2006	2016
Africa	0.05	0.08	0.10
Americas	0.09	0.11	0.11
Asia	1.7	2.7	3.8
Europe	0.38	0.39	0.48

Data from FAOStat.

1.10). The three top countries for chicken meat production account for two-fifths of global production. The top chicken-producing countries are the following: (1) the United States, (2) Brazil, and (3) China, accounting for 17%, 13%, and 12% of global production, respectively. There were major increases in the production of chicken meat in the Russian Federation between 2006 and 2016 (156%).

Eggs are a major source of high-quality protein, minerals, and vitamins globally. Production of eggs has increased considerably between 1996 and 2016, increasing by 64% (Table 1.7). Production of milk globally is much higher, 9.4-fold, than that of eggs. However, if we consider the amount of protein produced, the difference is much less (2.3-fold), with global production of protein in cow's milk being 21 million metric tons of protein and in chickens' eggs being 9.3 million metric tons of protein.

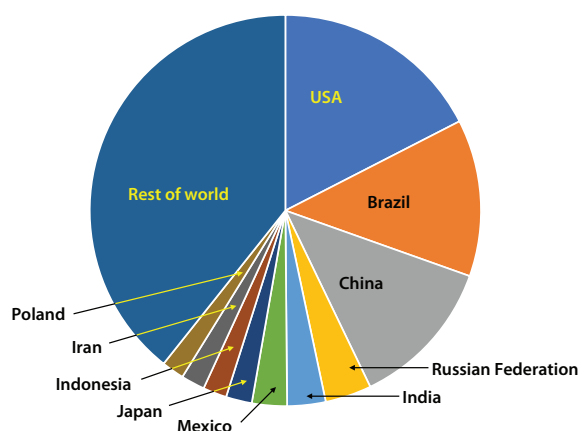
Asia produces the most chicken eggs, accounting for almost three-fifths (60%) of global production (Table 1.8).

The top countries for chicken egg production are summarized in Table 1.9. By far, China is at the top, accounting for 36% of global production. There are three groups of countries for chicken egg production

Table 1.6 Top countries for chicken meat production and changes in production between 1994 and 2014.

Ranking in 2016	Country	Production in Million Metric Tons		
		1996	2006	2016
1	United States	12.2	16.3	18.7
2	Brazil	4.1	8.2	13.9
3	China	6.1	10.2	13.3
4	Russian Federation	0.7	1.6	4.1
5	Mexico	1.3	2.5	3.1
6	India	0.6	1.5	3.4

Data from FAOStat.

**Figure 1.10** Major countries producing chicken meat in 2016 (data from FAOStat).**Table 1.7 Importance of poultry as indicated by changes in global production of eggs with the other livestock nonmeat product, milk (in million metric tons) over 20 years.**

Other Animal Products	1996	2006	2016
Milk (cows)	468	562	659
Milk (buffalo)	57.9	81.2	111
Milk (goat)	11.7	14.7	15.3
Milk (sheep)	8.6	9.3	10.4
Chicken eggs	45.1	57.9	73.9
Other bird eggs (duck and goose)	4.7	4.6	6.9

Data from FAOStat.

(Table 1.9; Figure 1.11): (1) Fast-growth countries, including in alphabetical order: China, India, Indonesia, Mexico, Pakistan, the Russian Federation, and Ukraine; (2) moderate-growth countries like the USA and Argentina; and (3) no-growth countries where production has plateaued. Countries that have plateaued are predominantly in Europe (e.g., France, Germany, and the United Kingdom) or developed countries in Asia (Japan and the Republic of Korea).

Duck and geese eggs are also produced and consumed predominantly in Asia (Table 1.8), with China and Thailand producing 5.4 and 0.4 million metric tons of these eggs, respectively. The basis of the increase in poultry and egg production is principally due to the adoption of commercial industrialized production (discussed in Chapter 2) with highly selected meat or egg-laying chickens and also to improvements in the effectiveness of village production. In many devel-

Table 1.8 Changes in egg production (in million metric tons) in regions of the world over 20 years.

	Region	1996	2006	2016
Chicken Eggs	Africa	1.7	2.4	3.2
	Americas	9.1	12.3	14.9
	Asia	24.9	32.9	44.5
	Europe	9.2	10.1	11.0
	Oceania	0.20	0.24	0.32
	North America	4.9	5.8	6.5
	South America	2.6	3.5	4.9
	Other Bird Eggs (Ducks and Geese)	Americas	0.04	0.08
Asia		4.6	6.6	9.2
Europe		0.07	0.08	0.09

Data from FAOStat.

oping countries, 80% of chickens are village or indigenous chickens while 20% are commercial chickens (Table 1.10). The village chicken contributes about half the chicken meat but little to egg consumption.

Table 1.9 Top chicken-egg producing countries.

Ranking	Country	Production in Million Metric Tons		
		1996	2006	2016
1	China	15.9	20.9	26.8
2	Unites States	4.5	5.4	6.0
3	India	1.5	2.8	4.6
4	Mexico	1.2	2.3	2.7
5	Japan	2.6	2.5	2.6
6	Russian Federation	1.8	2.1	2.4
7	Brazil	1.4	1.8	2.3
8	Indonesia	0.6	1.0	1.4

Data from FAOStat.

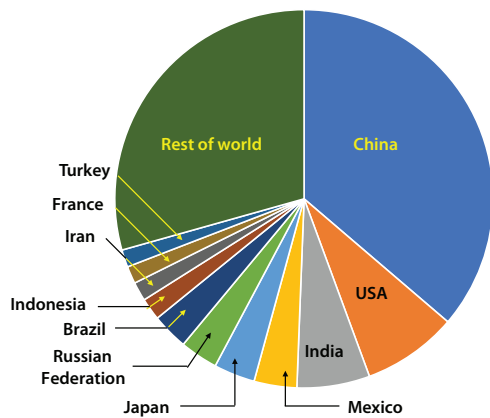


Figure 1.11 Major countries producing chicken eggs in 2016 (data from FAOStat).

Village poultry are predominantly a source of meat. This is due to low egg production, low hatchability, high mortality, high infection by parasites, and low growth rates (discussed in more detail in Textbox 1E). There are a series of approaches (outlined in Table 1.11) that can increase the efficiency of poultry production. This results in both more chicken meat and, progressively, many more eggs to be eaten or sold. Measures to improve the husbandry of village poultry include (1) controlling diseases via vaccination, (2) supplementary feed to provide sufficient key nutrients, (3) shelter to protect from the weather, (4) adding fencing to reduce predation, and (5) reducing parasites (see Table 1.11).

Commercial poultry production moves raising poultry to an entirely new level. It encompasses greatly improved genetics; formulated diets meeting the birds' needs for maintenance, growth, or egg production; control of disease and parasites; and control of the environment of the birds with control of temperature, humidity, and flooring (litter). Intensive poultry production is considered in Chapter 2.

Table 1.10 Comparison of the relative importance of indigenous/village and commercial chicken production in developing countries.

	Indigenous or Village Chickens	Commercial Chickens
National Flock in Developing Countries	80%	20%
Source of Eggs for Consumption	< 10%	> 90%
Source of Chicken Meat by Weight	50	50

Based on Pym et al., 2006; Pym, 2009.

Table 1.11 Recommendations from the United States Agency for International Development on how improved husbandry can affect the efficiency and effectiveness of chicken production.

System	Characteristics	Eggs Hen ⁻¹ Year ⁻¹	Number of Chickens for Meat Consumption	Number of Eggs for Consumption/Sale
Stage 1	Vaccination against Newcastle disease, supplementation feed, shelter.	40–60	4–8	10–20
Stage 2	Same as stage 1 plus further feeding, watering, housing; treatment for parasites, additional vaccinations.	100	10–12	30–50
Stage 3 (Semi-intensive)	Same as stage 2 plus complete diets and improved diets.	160–180	25–30	50–60