HANDBOOK OF POULTRY SCIENCE AND TECHNOLOGY

Volume 2: Secondary Processing

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Handbook of poultry science and technology/editor, Isabel Guerrero-Legarreta; consulting editor, Y.H. Hui; associate editors, Alma Delia Alarcón-Rojo . . . [et al.].
p. cm.
Includes index.
ISBN 978-0-470-18537-7 (2-vol. set)
ISBN 978-0-470-18552-0 (v. 1)
ISBN 978-0-470-18553-7 (v. 2)
1. Poultry–Processing. 2. Poultry plants. I. Guerrero-Legarreta, Isabel.
TS1968.H36 2009
664′.93–dc22

2009014025

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

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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.

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PART I

SECONDARY PROCESSING OF POULTRY PRODUCTS

1

PROCESSED POULTRY PRODUCTS: A PRIMER

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INTRODUCTION

For centuries, poultry and poultry products have been a popular food for human beings. Similar to other foods, we have been able to preserve them from spoilage by salting, drying, smoking, and fermenting. Eventually, sugar or another sweet raw ingredient was used as a preservation tool. Then canning, refrigeration, and frozen storage became available. For the last 30 years, advances in science, technology, and engineering, accompanied by intensive research and development, have resulted in an array of preservation techniques that rival our culinary

Handbook of Poultry Science and Technology, *Volume 2: Secondary Processing*, Edited by Isabel Guerrero-Legarreta and Y.H. Hui

interests. Such techniques include, but are not limited to, the use of packaging, chemical and biological agents, heat, cold, fermentation, irradiation, pressures, and reduced atmospheres. Processing and formulation of the raw materials have also improved tremendously in terms of sizing, emulsification, marination, curing, smoking, drying, and so on. Other chapters in the volume address such scientific developments and advances. In this chapter we present an overview of some economics aspects of poultry products, such as commercialization, pricing, consumer preferences, and certain special dietary needs.

TRENDS IN POULTRY PRODUCT COMMERCIALIZATION

Processed poultry meat and their fabricated products are consumed worldwide. However, sociopolitical and economic circumstances modify the scope of commercialization. Let us look at these trends in various population groups outside the United States. They will serve as a general frame of references to facilitate programs in the United States for the exportation of poultry and poultry products.

European Union Broiler imports, mainly from Brazil, are expected to increase in 2008. The European Union (EU) may become a net importer of chicken meat for the first time in 2008. Chicken meat consumption is expected to increase in 2008 as an inexpensive source of protein. France is the principal exporter of chicken meat in the EU region, but France reduced its market share in 2007, due to Brazil's successful competition in the Middle East and sub-Saharan Africa. Brazil is also the main poultry product supplier to the EU (salted, marinated, dried, smoked, cooked, etc). Thailand is the second largest exporter to the EU. Brazilian poultry meat exporters have recently purchased several European poultry processors, including some in the UK. With respect to consumption, and despite rising prices, chicken meat remains a low-cost protein source.

Canada Canadian broiler chicken imports in 2006 were 82% from the United States and 17% from Brazil. After Mexico and the Russian Federation, Canada is the third most important export market for U.S. poultry meat. The U.S. Department of Agriculture does not allow imports of Brazilian chicken; the Canadian Food Inspection Agency has strict import control procedures to ensure that Brazilian chicken in Canada does not enter the United States.

Latin America In Venezuela, chicken remains the most available and cheapest source of animal protein. About 80 to 90% of the poultry produced in Venezuela is purchased fresh by households. The rest goes to the processing sector (hams, sausages, frozen nuggets, etc.). Poultry products offered through the government's distribution network are cheaper than current controlled prices; however, the government imports poultry from Brazil.

Poultry meat exports from Argentina in 2007 were 110,000 metric tons (plus 50,000 metric tons of chicken paws, which are expected to be exported to China

and Hong Kong). Chile is the largest market, since it demands products very similar to those produced for the local market (mainly breasts and leg quarters). South Africa is also one of the country's primary buyers of frozen whole broilers, leg quarters, and mechanically deboned meat. Saudi Arabia mainly imports from Argentina individually quick-frozen breasts; the Russian Federation imports broilers, mechanically deboned meat, and wings. Exports of processed poultry products are primarily cooked poultry meat, frozen cooked or fried pieces, and hamburgers to Germany, the Netherlands, France, the UK, and Chile.

The outlook in 2007 for Brazil's export of broiler and turkey meat was expected to be an increase of 4 and 10% over the preceding year, mainly to the United Arab Emirates, the EU, Hong Kong, and Saudi Arabia. This consists primarily of broiler cuts and processed meat. As for domestic consumption, competition of other meats does not affect broiler consumption, since it is more affordable than beef and pork. In addition, it is expected that the demand of the food-service industry, institutional, and fast-food sectors for products such as frozen chicken meals, precooked meals, and chicken burgers will increase; an increase in consuming more highly processed broiler products has also been observed. Large Brazilian poultry processors are responding to these changes by shifting their sales strategies toward broiler parts (mostly leg quarters and breast meat) and further-processed value-added products such as precooked meals, chicken nuggets, and chicken burgers.

The Chilean poultry production has expanded significantly during the last decade. Poultry meat availability for domestic consumption has grown over 200% during the last two decades; it has become the most important source of animal protein in Chile since 2006, mainly as a result of the higher prices of beef. Chile exports poultry products to 26 different countries. In 2007 two new markets have been opened for the Chilean poultry industry: the Russian Federation and the United States.

Guatemala has the capacity to cover all domestic demand; the U.S. exports provide almost 30% of local consumption. Seventy-eight percent of Guatemala's broiler production plants are technically advanced, including the biggest producer, which also owns the largest chicken fast-food franchise covering the Central America market; 93% of chicken imports are U.S. products, and 75% of the turkey imports are also American. Processed products such as ready-to-fry fillets and patties are starting to build a market. Poultry cuts have a very efficient distribution chain, being sold directly to markets, hotels, restaurants, and supermarkets.

Mexican consumers' concerns about cholesterol and other health issues are creating more marketing opportunities for chicken meat. Poultry meat is cheaper than other protein sources. Consumers prefer fresh whole chickens rather than chicken cuts; however, purchases of chicken cuts are increasing, primarily in supermarkets. Chicken and turkey meat are the primary poultry products imported by Mexico. The processing industry imports most mechanically separated poultry (chicken and turkey) and poultry cuts as inputs for the domestic sausage and cold-cut industries. Imports of chicken cuts (mainly leg quarters) and mechanically separated chicken is decreasing due to high international chicken prices, which

have diverted much of the U.S. exportable supply to other markets, such as China and Russia. The United States is the main supplier of chicken meat to Mexico, although Chilean imports are increasing. In recent years, the Mexican export trend toward value-added products has been increasing, mainly chicken and turkey sausages.

India India broiler meat production grew at over 15% per annum in recent years. Due to wide acceptance and affordable prices, poultry meat is the major meat consumed in India. High mutton prices, religious restrictions on beef and pork, and the availability of fish in coastal regions made poultry the preferred meat. Indians typically prefer fresh chicken meat. The processed poultry meat market (chilled/frozen dressed/cut chicken) is limited, confined primarily to institutional sales. Poultry meat exports are negligible; in recent years, some southern Indian industries have been exploring the possibility of exporting poultry meat to the Middle East and Southeast Asian markets.

Thailand Thailand imports cooked chicken from the EU and Japan; China is likely to reduce its exports to Thailand as a result of growing domestic consumption. The volumes of Thai uncooked items, such as boneless leg and skinless boneless breast, exported to Japan will increase. Cooked chicken products are normally made-to-order meat products that are processed or prepared by heat, such as grilling, steaming, and boiling. Some of these cooked meat products are seasoned with salt, Japanese sauce, and other flavorings.

Japan Broiler meat makes up about 90% of the Japanese poultry meat market, including both domestic production and imports. Spent laying hens account for about 10% of the poultry meat market; consumption of ducks, turkeys, and other poultry is limited. In general, leg meat (boneless) is preferred over breast meat. The Japan food-service sector utilizes large quantities of imported generic cuts, mainly from Brazil, including cuts to be processed into prepared products after entry into Japan. Some U.S. bone-in leg cuts are utilized as well in this industry. Japan also imports cooked products from Thailand and China, mainly to prepare yakitori products (skewed grilled chicken).

Republic of Korea Due to the continued oversupply of domestic broiler meat, imports were reduced in 2007. The domestic industry prefers Brazilian deboned leg meat to bone-in leg meat from the United States, due primarily to the larger size of American imports. About 80% of total imports were frozen wings, and the remainder was heat-treated meat used to fabricate a traditional product known as *samgyetang*. The bulk of imported heat-treated meat was from China, with only a small fraction originating in Thailand. Korean broiler meat exports ranged between 1000 and 3000 metric tons over the last decade. Imported chicken cuts are used primarily in the food and processed service sector, for fabricating seasoned chicken dishes, chicken nuggets, seasoned wings, patties, and so on. Local chicken is sold primarily as chilled whole birds, with a smaller amount as cuts

to both the food-service sector and retail markets. Meat derived from domestic spent hens is used mostly as raw ingredients in further-processed products such as sausages and hams.

People's Republic of China Broiler production in China in 2007 was 12.5 million metric tons due to the high local demand; this year, China also imported turkey meat, a nontraditional product. Poultry meat is traditional in the Chinese culture: kungpao chicken, Peking duck, stir-fries, Cantonese-style air-dried duck, deep-fried chicken nuggets. It is expected that in 2008 China will export poultry to Japan, Hong Kong, and South Korea.

Malaysia Malaysia has one of the highest per capita consumption rates in the world for chicken. About 30% of broilers are channeled through modern processing plants; 60% are sold as dressed birds in markets. Chicken meat is the most popular and cheapest source of meat protein among Malaysians, due to the fact that there are no dietary prohibitions or religious restrictions against chicken consumption; for this reason, quick-service restaurants based on processed chicken products (e.g., battered products, hamburgers, nuggets) are popular in Malaysia; further-processed products are also distributed to wholesalers, supermarkets, hypermarkets, catering institutions, restaurants, and hotels. Consumers are very sensitive toward health and halal matters. It is important to note that the majority of Muslim consumers will not accept poultry products not certified halal by the Malaysian religious authority. The Malaysian poultry industry is well positioned to supply halal-processed poultry to other Islamic countries and Muslim consumers worldwide. Chicken parts, mainly wings and mechanically deboned chicken, are frequently imported; the major suppliers are the Netherlands and Denmark. Poultry processing is also of importance in Malaysia, where products such as chicken frankfurters, cocktail sausages, burgers, and nuggets are the most popular items. All turkey meat is imported; the United States is the dominant supplier.

Taiwan The United States is the predominant supplier of poultry to Taiwan; however, it exports only limited quantities of poultry products, mostly fresh and frozen meat and prepared chicken. During 2005, domestic production, including nonbroiler chickens, ducks, geese, and turkeys, showed a considerable decline compared to 2004, although the meat production is now recovering.

Saudi Arabia The Saudi Ministry of Agriculture classifies poultry production farms as either specialized (commercial) or traditional; 97% of poultry meat produced in Saudi Arabia consists of broiler chicken. The item consumed most is broiler meat. Brazil has been the leading frozen broiler meat supplier to Saudi Arabia, followed by France, Argentina, and South Africa. Domestically produced poultry is generally marketed fresh or chilled. During the summer months, when sales drop, major operations will freeze some production. One major operation is producing chicken frankfurters and burgers for local market. Boneless chicken

imports are dominated by Brazil, which took over the market from China and Thailand. Consumption of whole turkey is seasonal, while duck is consumed primarily in Chinese restaurants and in some Arabic restaurants.

VARIETY AND PRICES

Due to a number of possible processing methods, poultry products are available to the consumer in a wide range of products. Poultry products can be classified in various ways, depending on the specific objective of the food item: degree of comminuting (e.g., whole birds), processing characteristics (e.g., cured), shelf life expected (e.g., fresh, requiring refrigeration), and particular specifications (e.g., low fat). More details are as follows:

1. According to degree of comminuting:
   - Whole birds
   - Mechanically deboned meat
   - Products retaining their integrity, such as bone-in or deboned legs, breast, and thighs.
   - Restructured or formed products, such as cooked hams and hamburgers
   - Coarsely ground products, such as poultry summer sausages
   - Finely ground, or emulsified, products, such as frankfurters
2. According to processing characteristics:
   - Cured
   - Emulsified (sausages)
   - Battered (nuggets)
   - Marinated
   - Smoked
   - Roasted
   - Dried and semidried
3. According to expected shelf life:
   - Fresh; need refrigeration
   - Intermediate-moisture food (reduced water activity)
   - Dried and semidried
   - Fermented
4. According to particular specifications:
   - Low fat
   - Low sodium
   - Special diets
   - Religious specifications (halal, kosher)
   - Ethnic dishes (e.g., yakitori, kungpao chicken, Peking duck, Cantonese-style air-dried duck, deep-fried chicken nuggets, samgyetang, chorizo)

TABLE 1 Main Characteristics of Processed Poultry Products

Whole or Parts	Bone Removal	Preparation	Flavor	Post-Processed Products
Breasts (whole and split)	Bone-in	Canned	Asian	Bacon
Breast chops	Boneless	Cooked	BBQ	Bologna
Breast cutlets		Breading	Buffalo style	Bratwurst
Breast scaloppini		Deep fried	Cajun	Breakfast sausages
Breast strips		Dry roasted	Citrus	Burgers
Breast tenderloins		Frozen	Dijon mustard	Dinner sausages
Drumsticks		Grilled	Hickory	Ham
Ground meat (with various lean/fat ratios)		Marinated	Honey	Kebab
Necks		Ready-to-cook	Honey smoked	Luncheon meat
Thighs		Roasted	Honey-pepper	Meatballs
Whole birds		Rotisserie-like	Lemongrass	Nuggets
Wings		Smoked	Maple	Pâté
		Sun dried	Mesquite	Patties
		with gravy	Smoke	Salami
			Teriyaki	Sausages
			Zesty Italian	Sausage rolls
				Summer sausages

Therefore, applying one or several of the above-mentioned characteristics, a wide variety of poultry products (chicken and turkey) is obtained. The main characteristics of poultry products that have the highest market share in the United States are shown in Table 1. Combining these processing characteristics enables an enormous variety of poultry products to be produced: fresh bone-in turkey breast, hickory smoked bone-in turkey breast and honey mesquite smoked chicken breast, hickory smoked chicken ham, turkey bologna, and so on.

The possibility of diversifying products gives the poultry industry the potential to market its products to a wide variety of population sectors. In general, poultry meat is cheaper than pork or beef, making poultry, especially chicken, cheaper and more accessible to large sections of the population. However, for products that require specific processing, such as hickory smoking and honey roasts, the product price is increased considerably.

CULTURAL AND RELIGIOUS ACCEPTANCE

Because poultry meat and products are cheaper than other meats, such as beef and pork, they are widely accepted and consumed in all parts of the world. Asian countries base most of their ethnic dishes on poultry: China's Peking duck, kung-pao chicken, and steamed and grilled lemon chicken; Thailand's curry chicken, chicken Satay, and chicken macadami; India's chicken Tikka and chicken Biryani, and murg do pyaaza; Africa's roasted and barbecued chicken; Mexico's mole and pibil chicken; Brazil's Xim-xim; Colombia's ajiaco. As for new developments

in poultry processing, the wide variety of products and ready-to-cook dishes developed by transnational companies have found wide acceptance in modern societies.

Religious acceptance of food products is based on fulfilling certain laws of a particular religion, especially Jewish and Islamic requirements. In the Jewish religion, the dietary laws that govern kosher foods are found in Deuteronomy and Leviticus in the Torah; these laws have been followed for over 3000 years. Meat must come from a kosher animal, as outlined by Deuteronomy 14. Kosher birds are chickens, turkey, duck, and geese.

Halal poultry is slaughtered in accordance with requirements of the Shariah (Islamic law). Chickens are also halal birds. The animal must be slaughtered and processed with the highest standards of cleanliness, purity, and wholesomeness.

PRODUCTS FOR SPECIAL DIETS

Worldwide concern about heart disease, hypertension, and diabetes, among others, has resulted in many "healthy" new products developed by poultry meat processors. The poultry industry has developed light turkey sausages, light chicken and turkey ham, and other processed meat that fulfill consumer expectations. These products relate to a suitable dietary supply without including chemical compounds that have been reported as possibly harmful, such as saturated fats and high sodium. Among these products are low- or reduced-fat products, reduced-sodium products, and products fortified with omega-3 long-chain fatty acids.

Poultry is relatively high in polyunsaturated fatty acids, due to the fact that their diet is generally rich in these fatty acids. However, further fat reduction is highly appreciated by the concerned consumer. Low- and reduced-fat meat products are made by substituting for the animal fat a variety of carbohydrates that mimic the palatability of a fat-added product and provide a texture similar to that of fat globules in batters. Among the most common fat replacements are tapioca starch, wheat flour, and carrageenan.

It has been reported that the intake of enough omega-3 fatty acid [e.g., eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA)] prevents conditions such as atherosclerosis, coronary heart disease, hypertension, cancer, and diabetes. The omega-3 fatty acids are present in marine fishes, mainly of temperate waters. Poultry products fortified with these acids are expected to help prevent such diseases. Several turkey and chicken products, such as nuggets, frankfurters, and hamburgers, have been fortified with omega-3 acids in Canada and the European Union.

Reduction in sodium intake prevents blood hypertension, an extremely common condition in most industrialized countries that is related to cardiovascular disease. Although poultry meat itself is relatively low in sodium content, sodium is increased during further processing. At the same time, salt is an imp ortant flavoring in meat products; therefore, there is a compromise between reducing sodium content in a processed product and its palatability. About 30% of the

sodium chloride is now replaced by magnesium or potassium without notably affecting product palatability.

It is important to emphasize that the use of food additives in processed poultry products is tightly regulated in many countries, especially the United States. The information provided here explains the scientific and technical feasibility. Other resources should be used to obtain more details on government regulations.

REFERENCE

USDA Foreign Agricultural Service. 2006, 2007, 2008. http://www.thepoultrysite.com /articles.