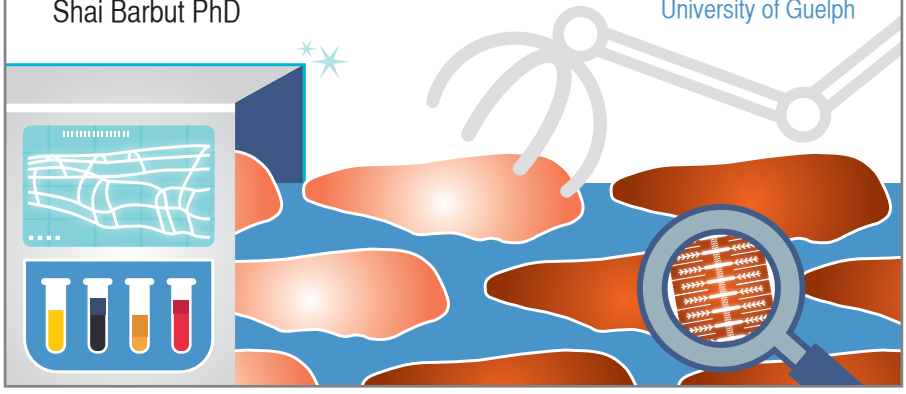
Chapter 5

PRIMARY PROCESSING OF POULTRY

The Science of Poultry and Meat Processing

Shai Barbut PhD

University of Guelph



Chapters

1. AUTOMATION
2. GLOBAL PERSPECTIVE
3. STRUCTURE* AND MUSCLE PHYSIOLOGY
4. LIVE BIRD HANDLING*
5. PRIMARY PROCESSING OF POULTRY*
6. HACCP IN PRIMARY PROCESSING*
7. INSPECTION AND GRADING*
8. STUNNING*
9. PORTIONING, DEBONING AND FRESH MEAT COMPOSITION*
10. FURTHER PROCESSING – EQUIPMENT
11. HEAT PROCESSING, COOLING AND PRESERVATION METHODS
12. HACCP IN COOKED MEAT OPERATIONS
13. PRINCIPLES OF MEAT PROCESSING
14. BATTERING AND BREADING – PRODUCTION UNDER HACCP
15. MICROBIOLOGY AND SANITATION
16. EVALUATING TEXTURE AND SENSORY ATTRIBUTES
17. EVALUATING WATER/FAT BINDING AND COLOUR
18. WASTE TREATMENT AND BY-PRODUCTS

* Topics focussing on poultry. Rest of the chapters are related to both red meat and poultry.

Preface

The aim of The Science of Poultry and Meat Processing book is to provide students and industry personnel with a comprehensive view of the modernized primary poultry meat industry and further processing of both red meat and poultry. An emphasis is placed on basic concepts as well as recent advancements such as automation (e.g. increasing poultry line speed from 3,000 to 13,000 birds per hour over the last 40 years) and food safety (e.g. HACCP in primary and the further processing areas). The book also includes chapters explaining basic muscle biology, protein gelation, heat and mass transfer, microbiology, as well as meat colour and texture to help the reader understand the underlying scientific concepts of meat processing. The Science of Poultry and Meat Processing book is based on over two decades of university teaching experiences, and is designed to be used as a course textbook by students, as well as a resource for professionals working in the food industry. The book is available online, at no cost, to any interested learner. Using this format has also allowed me to include many colour pictures, illustrations and graphs to help the reader.

The book is dedicated to my past and current students who have inspired me to learn more and conduct challenging research projects. I see this as an opportunity to give back to the field that I have received so much from as a student and as a faculty member. Looking back, I have learned a great deal from my MSc and PhD advisor, Dr. A. Maurer, who was the student of Dr. R. Baker - the father of poultry processing in North America. I would also like to thank Dr. H. Swatland with whom I worked for almost 20 years, for the many challenging scientific discussions.

Writing The Science of Poultry and Meat Processing book was a long process, which also included having all chapters peer reviewed. I appreciate the help of my colleagues, but I still take responsibility for any inaccuracy in the book. If you have comments or **suggestions,** I would appreciate hearing from you (sbarbut@uoguelph.ca), as I am planning to revise and update a few chapters on a yearly basis.

I would like to thank the many people who have helped me during the writing process. To Deb Drake who entered all of the material for the book, to Mary Anne Smith who assisted in editing, and to ArtWorks Media for the design and desktop publishing of the book. I greatly appreciate the help of my colleagues who reviewed chapters and provided useful discussions. They include Mark B., Ori B., Sarge B., Gregoy B., Joseph C., Mike D., Hans G., Theo H., Melvin H., Myra H., Walter K., Roland K., Anneke L., Massimo M., Johan M., Erik P., Robert R., Uwe T., Rachel T., Jos V., Keith W., and Richard Z. I would also like to thank my family for their love and support during the entire process.

About the Author

Shai Barbut is a professor in the Department of Food Science at the University of Guelph in Ontario, Canada. He received his MSc and PhD at the University of Wisconsin in meat science and food science. He specializes in primary and further processing of poultry and red meat. His research focuses on factors affecting the quality of meat, as well as protein gelation with an emphasis on structure / function relationships, rheological properties and food safety aspects. He has published over two hundred peer reviewed research papers and is the author of the Poultry Products Processing – An Industry Guide textbook. He is a fellow of the Institute of Food Technologists and has received awards from the Meat Science Association, Poultry Science Association, and the Canadian Institute of Food Science and Technology. He is involved in a number of government committees as well as academic and industrial research projects.

Library and Archives Canada Cataloguing in Publication

Barbut, Shai, author

The science of poultry and meat processing / Shai Barbut, PhD.

Includes bibliographical references and index.

Issued in print and electronic formats.

ISBN 978-0-88955-625-6 (bound).

ISBN 978-0-88955-626-3 (pdf).

1. Poultry--Processing. 2. Meat industry and trade. I. Title.

TS1968.B37 2016 664'.93

C2015-903906-1 C2015-903907-X

5

PRIMARY PROCESSING OF POULTRY

5.1 Introduction

As the poultry processing industry has matured, dedicated large scale plants have been built around the world. As indicated in Chapter 1, automation has helped to improve efficiency and line speed. Fifty years ago, maximum line speed was about 2,000 birds/hr (bph). In comparison, modern plants with automated evisceration and cut-up lines (Figs. 5.1.1a and b) can handle 13,500 bph on a single line. In contrast, manual lines usually handle fewer birds and the output for workers is drastically lower (see Chapter 2). New technologies such as computerized machine vision are finding their way to processing plants and can be used for grading and sorting birds as well as for veterinary inspection. Some government agencies are currently evaluating this concept, which can be performed to a high degree of accuracy and can help increase human performance with this kind of repetitive task. A significant price reduction of sensors, control units, scales, and cameras has assisted in introducing computerized equipment and monitoring systems into poultry processing plants to help improve performance. Information, captured by a machine vision system (Fig. 5.1.2), can be also used to make decisions about the way each bird will be marketed (e.g., whole, cut-up), or the way it should be portioned (e.g., deboned breast, bone in thigh meat) to best match inventory available and daily market demands. One of the big advantages of such a system is that a manager can make a decision three hours before the bird gets into the cut-up department. Such in line computer systems are already available to the processor (see also Chapter 1). In the future, the use of in-line computer systems is expected to increase as is their degree of sophistication and application in traceability.

Modern dedicated poultry plants are designed to process a certain type of poultry (e.g., broilers, turkey, duck, ratite) and include slaughtering, de-feathering, evisceration, chilling, portioning, and packaging operations specified to the type of bird processed. In many cases the primary processing plant is built adjacent to a secondary meat processing plant so shipment of fresh meat is not an issue.

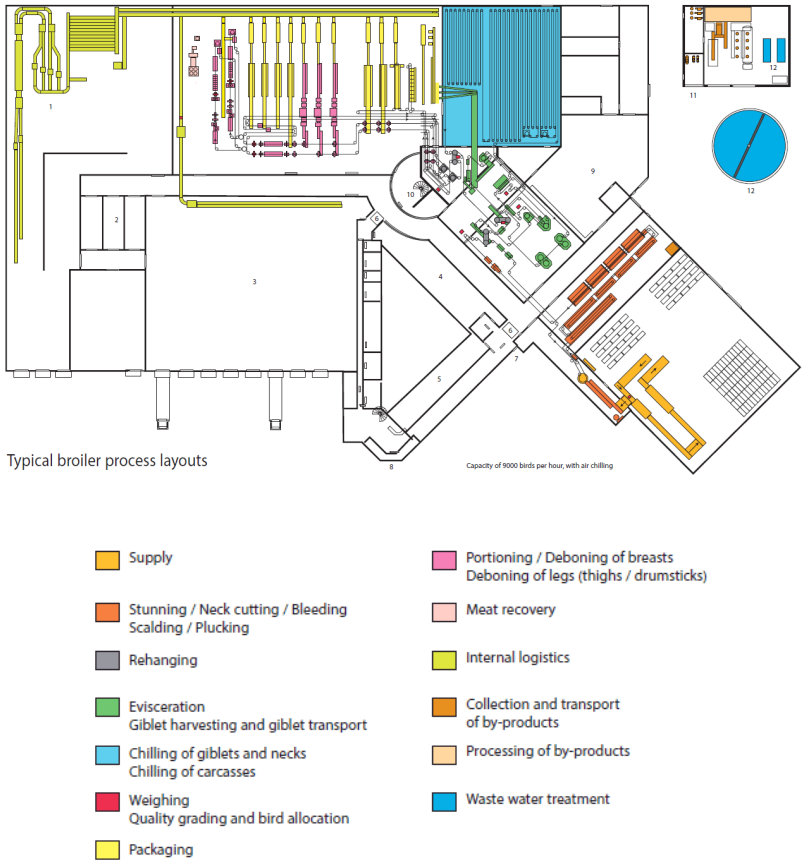


Figure 5.1.1.a Floor plan design for a broiler processing plant handling 9,000 birds per hour. Courtesy of Stork.

The steps involved in a typical poultry processing plant are illustrated in Fig. 5.1.3; modifications of this arrangement can be seen (e.g., unloading before or after stunning, a hot wax bath to remove pin feathers in a duck processing operation), but the basic steps are similar in all plants. Another diagram showing the overall process and focusing on the HACCP program is provided in Chapter 6. As will be described below, the whole operation can be automated to varying degrees depending on factors such as capital investment, local labour costs and availability, and processing volumes.

Figure 5.1.1.b Inside view of a modern poultry processing plant designed to handle 13,500 birds per hour. Courtesy of Marel.

Figure 5.1.2 Machine vision of broiler operation. Courtesy of Marel.

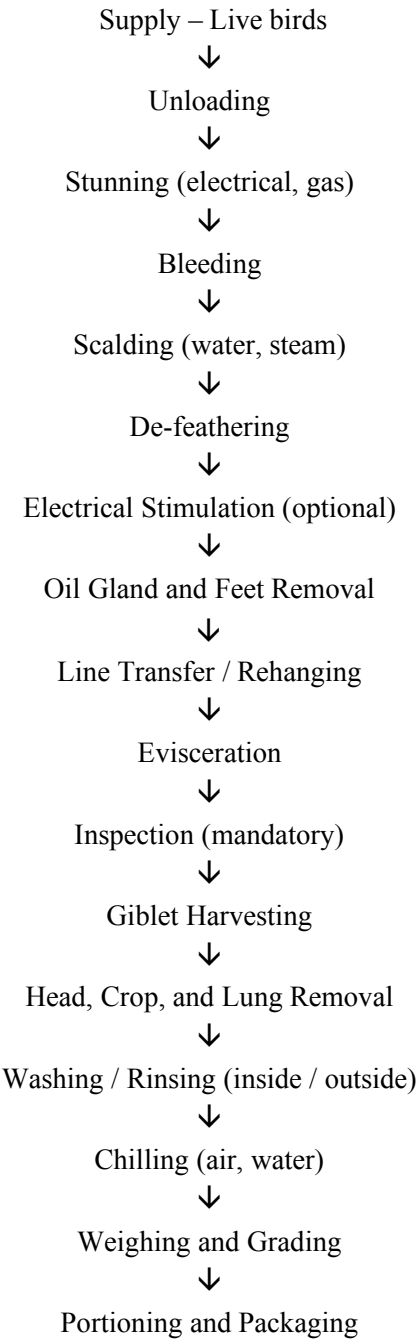


Figure 5.1.3 Typical sequence of steps in poultry primary processing.

This chapter focuses on the different steps involved in the primary processing of poultry. The microbiological and hygienic aspects of the various steps are further explained in Chapters 6 and 15. Overall, there has been a lot of development over the past half century and today more automation has been introduced in countries where labour costs are high (e.g., Western European countries). However, regions with traditionally low labour costs are also seeking increased automation as worker availability becomes a major issue (e.g., competition with other industries).

5.2 Supply – Live Birds

Birds usually arrive to the plant by truck in crates or cages (see Chapter 4). At the plant, the process starts with a bulk weighing of the birds either on the truck when it enters the processing plant or in the cages prior to unloading. The live weight is used as a basis for calculating the payment to the grower. In some places, the eviscerated weight is subtracted from the liveweight (minus the weight of the condemned birds) and, together with the grades assigned, is used to calculate the payment to the grower. When the birds arrive at the plant, it is recommended to allow them some rest time. This is especially important for birds that have been exposed to harsh environmental conditions such as extreme heat, cold, and/or a long journey. Reducing their stress level and providing time for the birds to return to their normal breathing and heart rate is very important for reducing problems on the processing line. For example, in the case of controlled atmosphere stunning (CAS), it is recommended that birds be placed in a quiet, cool area for 1-2 hrs prior to processing because factors such as breathing rate and muscle glycogen levels are crucial in preventing meat quality defects that result from convulsions (see Chapter 8 for more details).

5.3 Unloading

Traditionally, unloading the birds from the crates and placing them on the shackle line has been done manually and is still done this way in many places around the world (Fig. 5.3.1). The crates can be unloaded onto a conveyer belt, which then passes by employees who remove the birds and place them on a moving shackle line. If the crates are built into the truck, the birds are unloaded and placed directly onto the shackle line by employees who stand on a scissor lift. Automated unloading systems have also been developed and are usually part of a large modular crate system (Fig. 5.3.2). In this case, the whole module is lifted and tilted so the birds can walk onto a conveyor belt. Since this process is fully

automated, motion or light sensors are used to verify that no bird is left in the crate after tilting. If a bird is detected, the crate is tilted again and/or an alarm is sounded so an employee can come and check the crate.

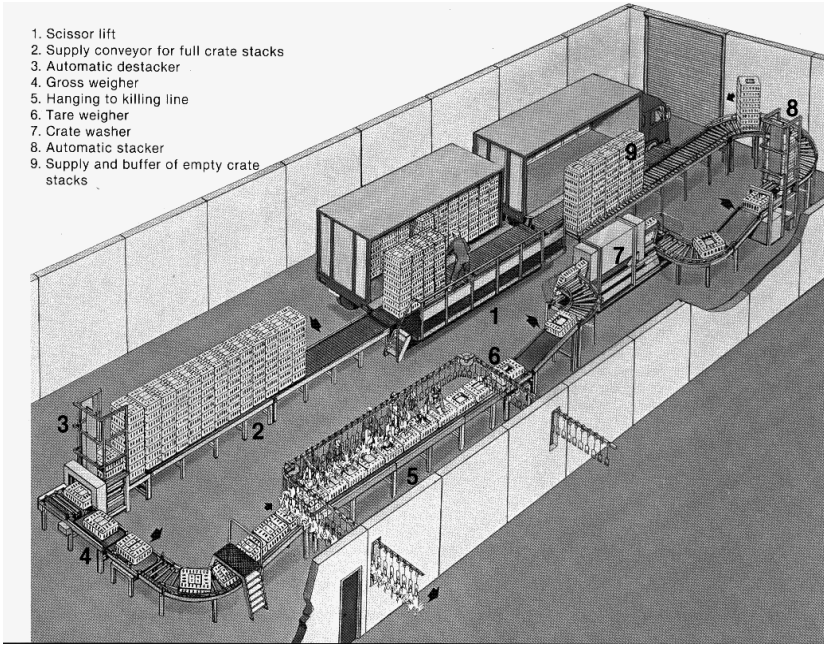


Figure 5.3.1 An example of manual bird unloading system: Courtesy of Stork.

In plants where electrical stunning is used, birds are manually placed on the shackle line. If CAS is employed, the birds are commonly unloaded onto a conveyor belt (usually by tilting. Note this step can also be done where electrical stunning is used) and then moved to the stunning area where they are stunned by CO_2, argon gas, or a mixture of gases. In other CAS systems the birds are left in their crates during stunning and are then easily removed and placed on the shackle line. Handling unconscious birds is much easier and helps reduce bruising as compared to the removal of conscious birds from crates. When birds are stunned prior to their placement on the line, birds should be moved quickly before they regain consciousness. There are some exceptions when deep and irreversible CAS or electrical stunning is used. Regardless of the unloading operation, special care should be taken to minimize bruising of the birds. Several large companies are now introducing additional measures to minimize the stress birds are exposed to during

catching, transporting, holding, and unloading. In the latter two phases measures can include showers, air conditioning, special lighting (mainly blue light, which does not excite the birds), and ventilation systems that reduce dust and decrease the noise level. Various research publications have shown that excited birds are more likely to be active, flap their wings, and get hurt during the process than relaxed birds (McEwen and Barbut, 1992).

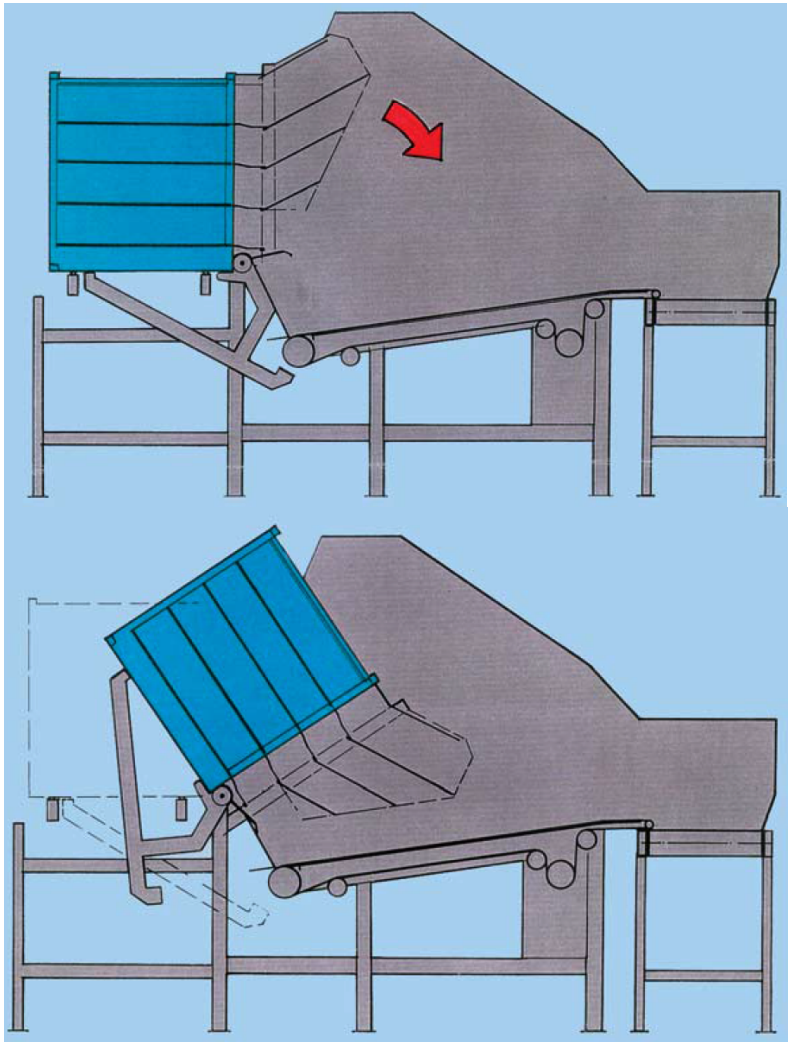


Figure 5.3.2 Automated tilting system for unloading birds. Courtesy of Stork.

5.4 Stunning

Stunning is done to render the animal unconscious prior to slaughter. When stunning is used, it can be done by an electrical current, gas, or by mechanical means. It was originally done to immobilize the animal to allow for easier and safer handling. This was especially true for large, red meat animals. More recently, stunning has been used primarily as a means of improving animal welfare by minimizing the pain and suffering associated with the process. From this point of view, stunning should result in the rapid onset of a stress free insensibility of sufficient duration to allow the animal to remain unconscious until death (Fletcher, 1999). The settings used for stunning are commonly prescribed by strict government regulations. These also include any exemptions that arise from special religious considerations (e.g., the Jewish and Islamic laws known as Kosher and Halal, respectively). More detailed information is provided in Chapter 8, which is devoted to the different methods of poultry stunning.

5.5 Bleeding

Bleeding is done by opening the blood vessels in the neck (Fig. 5.5.1). There are several ways of cutting the blood vessels in poultry: a single blade to sever one carotid artery and one jugular vein, a single or double blade to cut both carotid arteries and jugular veins, or severing one or both vertebral arteries. The so-called "Modified Kosher" is one of the most common methods and results in cutting the jugular vein just below the jowls so that the trachea and esophagus remain intact. Leaving these parts intact is important when automated equipment is later used to pull out the trachea. Other, less common methods include decapitation and a mechanical stunning that consists of piercing the brain and cutting the veins in the roof of the mouth. The "Modified Kosher" is easy to perform manually or with automated equipment and results in a good bleed out while leaving the head, trachea, and esophagus intact (Mountney, 1989). High speed automated bleeding equipment employs a railing system that positions the neck of the suspended birds in such a way that the blood vessels can be opened with precision. In the case of the traditional Kosher and Halal slaughter, only manual cutting of the blood vessels is permitted. This is done by a specially trained person who cites a blessing during the operation.

The bleed out phase can take anywhere between 2-5 min depending on bird size and type. During the process, about 35-50% of the total blood volume is removed. Considerable variation can exist between animals and flocks. Using the Modified Kosher method has been reported to result in higher bleed out than decapitation

or piercing (Mountney, 1989). Other factors affecting blood loss include pre-slaughter stress, stunning method, and the time interval between stunning and bleeding.

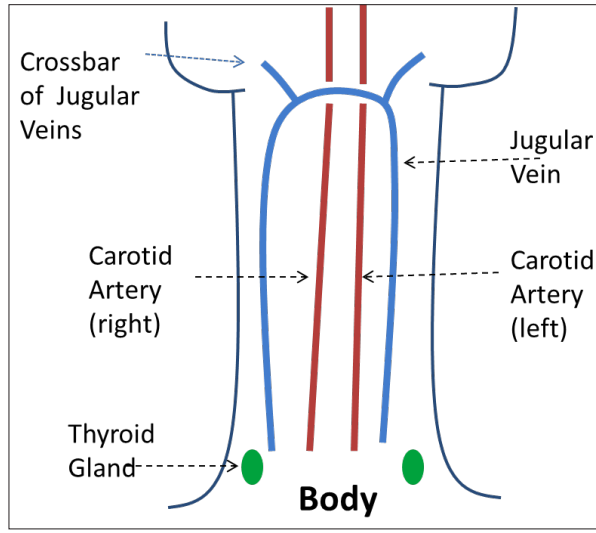


Figure 5.5.1 Ventral view of the main blood vessels in the chicken neck.

Table 5.5.1 shows some of the differences between four different stunning methods. Overall, it shows that bleed out can be significantly affected by stunning method and the length of time before the neck is cut. It is important to note that a poor bleed out can increase the prevalence of carcass downgrading due to blood spots and, in particular, engorged or hemorrhagic wing veins (Gregory and Wilkins, 1989; Raj and Johnson, 1997). The data in Table 5.5.1 indicates that the highest bleed out was achieved with high frequency electrical stunning. Fifty Hz, which is commonly used in some countries, resulted in adequate bleeding when blood vessels were ruptured 1 min after stunning; a delay of 3 min resulted in lower bleed out. A controlled atmosphere stunning with a CO_2+ argon mixture resulted in slightly less bleed out compared to the 50 Hz electric current. The bleed out was not affected by ventral or unilateral neck cutting methods; however, delayed cutting resulted in lower values. In the argon stunning, a delay of 3 or 5 min did not cause a significant difference. The authors concluded that CO_2+ argon stunning, as compared to 50 Hz electrical stunning, provided satisfactory results. See additional discussion on gas stunning in Chapter 8.

Table 5.5.1 Results of stunning treatments on bleed out. Adapted from Raj and Johnson (1997).

Treatment	Time until neck cut (min)	Method of cutting	Bleed out (g/kg)
			Mean (SE)
Electrical 50 Hz (120 mA)	1	V	34.2 (1.88)^{de}
		U	29.7 (1.74)^{e}
	3	V	26.0 (1.41)^{ab}
		U	28.4 (1.79)^{abc}
	5	V	29.1 (2.19)^{abc}
		U	24.8 (1.33)^{a}
Electrical 1500 Hz (120 mA)	0.3	V	36.1 (0.93)^{e}
90% Argon	1	V	31.0 (1.56)^{cd}
		U	29.8 (1.11)^{bc}
	3	V	26.5 (1.46)^{abc}
		U	29.8 (1.68)^{bc}
	5	V	30.0 (2.13)^{bcd}
		U	29.7 (1.89)^{bc}
Carbon Dioxide + Aargon mixture	1	V	30.0 (1.01)^{bc}
		U	28.7 (1.76)^{abc}
	3	V	26.1 (1.67)^{ab}
		U	28.1 (1.50)^{abc}
	5	V	26.0 (1.00)^{abc}
		U	25.0 (0.98)^{a}

V = Ventral cut, both carotid arteries and jugular veins.
U = Unilateral cut, one carotid artery and one jugular vein.
$^{a-e}$ Means without a common letter differ significantly ($P < 0.05$)

5.6 Scalding

Loosening the feathers by immersing the birds in hot water is an important step that provides for easier de-feathering. Traditionally hot water has been used but recently steam scalding has been introduced and is now being installed in various large scale operations. In a small plant scalding can be performed manually (i.e., placing and removing the carcass from a stationary scalding tank). Large plants use a continuous line where birds are submerged in a long hot water tank while suspended from a moving shackle line. The water bath can consist of a single long bath, a multistage scalding water bath system (Fig. 5.6.1), or a steam scalding system (Fig. 5.6.2). There are three commonly employed scalding schemes:

a. Soft/semi-scalding: 50-53ºC for 1-3 min, used for broilers and young turkeys.
b. Sub/medium scalding: 54-58ºC for 1-2 min, used for mature birds.
c. Hard scalding: 59-61ºC for 0.75-1.5 min, used commonly for waterfowl.

Selecting a scheme depends on factors such as the degree of difficulty in removing feathers, the subsequent chilling method (e.g., water, air), and the bird's age (Barbut, 2010; 2014). A higher scalding temperature better loosens feathers from their follicles (see histological sectioning through a broiler's feather follicle in Chapter 3) but is also harshest on the skin. In the case of hard scalding, the outer layer of the skin (see Chapter 3; skin structure and especially epidermis) becomes loose and is later removed during the plucking operation when rubber fingers are used to rub the skin. The removal of the epidermis can result in the skin becoming lighter in colour as the typical yellow pigmentation that comes from feed (e.g., corn) is lost. In some markets, however, a preference for white skinned birds mandates the use of hard scalding. Hard scalding can also be used for certain chicken parts, such as in China where a separate hot water scalder is used for feet and paws (i.e., peeling the outer skin layer is part of the traditional process). When considering the whole bird, hard scalding can result in skin discolouration if dehydration occurs during a subsequent air chilling operation. In any case, hard scalding is a common way to release the feathers from waterfowl. Generally speaking, hard scalding does not cause as much discolouration in the thick skin of waterfowl as it does in young broilers. In very young broilers even a milder treatment of medium scalding can remove part of the outer skin layer, which leaves the skin sticky; however, it will not result in excessive discolouration if the birds are kept in a moist environment (e.g., water chilling, spray chilling).

In general, soft/semi-scalding is commonly used for young broilers and turkeys because it does not damage much of the outer layer of the skin but it still allows for relatively easy de-feathering. In a water scalding tank, adequate water agitation and uniform water temperature ensure good heat penetration for subsequent feather removal. By introducing air bubbles at the bottom of the tank or using pumps to create jet streams, the water currents will force feathers to separate and not form an insulating layer (Fig. 5.6.1). To improve meat hygiene, careful scalding equipment design is required. A single gram of soil material (e.g., dirt, fecal material) attached to feathers can contain 10^8-10^9 microorganisms per gram, and it is therefore important to minimize cross contamination in this common tank.

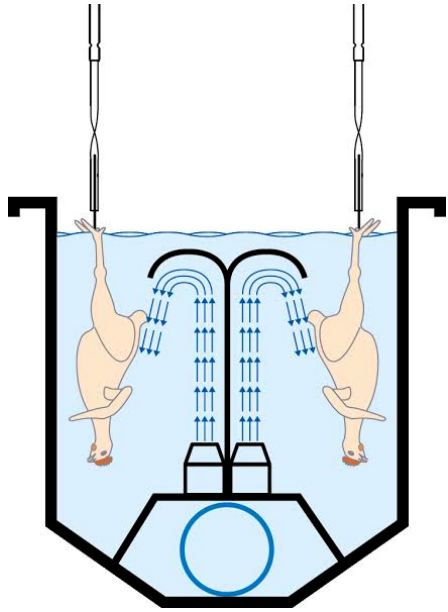


Figure 5.6.1 Hot water scalder used to loosen the feathers. A water jet system is used to improve circulation and enhance water – skin contact. Courtesy of Meyn.

Maintaining and controlling the water temperature is one of the key parameters that can control bacterial load. Another means is the use of a counter flow design whereby clean water is introduced at the exit end of the scalding tank and water flows toward the entrance where the birds are introduced. Installing a multistage scalding tank operation can further reduce contamination problems. A multistage operation can include 2 to 4 water tanks separated by transfer zones, where excess water on the birds is allowed to drip off. Carcasses are moved from an initial, more contaminated tank, to subsequently cleaner tanks while the transfer zones drippings are collected and discharged separately (see also Chapters 15 and 18; dealing more specifically with microbiology and waste water, respecitvely). The scalding operation is a high energy and water consumption process. Newer systems feature steam as the heat transfer medium (Fig. 5.6.2). A steam scalder can save up to 70% of the water used by a traditional hot water scalder, which results in large savings in both water and energy.

It should also be mentioned that in true Kosher processing scalding is prohibited. Because hot water is not used to loosen the feathers, a more aggressive plucking operation is required that can result in more skin tears.

Figure 5.6.2 A new steam scalding system showing the shackle line (top) and the strategic location of the vents for the steam discharge (sides). Courtesy of Marel.

5.7 De-feathering

Feather removal in modern plants is done by mechanical pickers/pluckers equipped with rubber fingers that rub the feathers off the carcass. In a continuous operation, this is done while the birds are hanging upside down on a moving shackle line and go in between two to three sets of drums or rotating disks covered with rubber fingers. Figure 5.7.1 shows a rotating disk design used to obtain good coverage of the bird. The de-feathering equipment is composed of many of these disks that are mounted on a special frame. The height and spacing arrangement of the disks can be adjusted to accommodate different sizes of birds. The fingers can also be mounted on drums. The fingers (Fig. 5.7.2) are made of rubber and contain different levels of a lubricating agent to control their hardness and elasticity. All chemicals used in making the fingers have to be approved for food contact; any modification should be approved by the appropriate regulatory agency. The elasticity and length of fingers vary depending on the type of bird, task required (e.g., pulling tail feathers), machine speed, etc.

Figure 5.7.1 De-feathering disks mounted on a vertical surface. The birds are moved in between disks mounted on both sides; distance can be adjusted to accommodate different size of birds. Courtesy of Stork.

Figure 5.7.2 Examples of different fingers and disk mounting for de-feathering equipment.

As indicated before, the size of the fingers and force needed depend on the type of bird, location (wing, tail) and ease of feather removal. The feather follicle distribution on a broiler is shown in Fig 5.7.3.

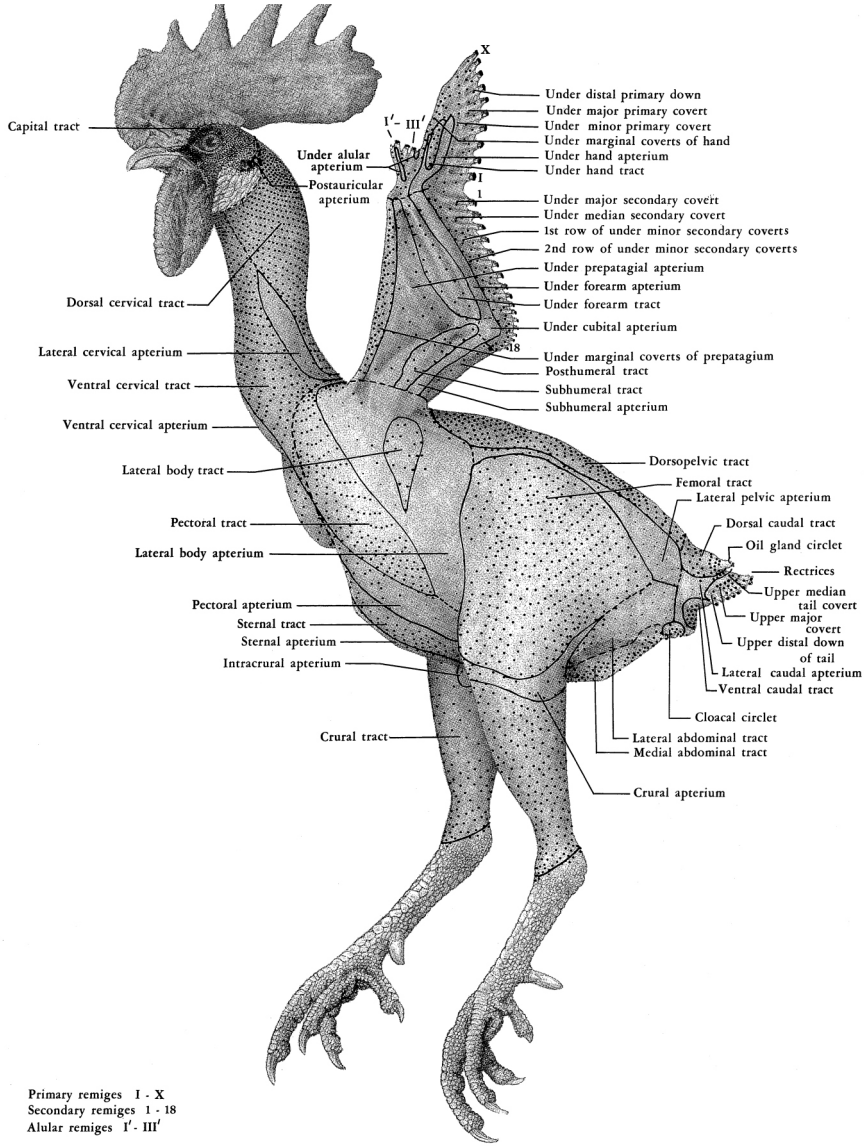


Figure 5.7.3 Feather follicle distribution in chicken. From Lucas and Stettenheim (1972).

Areas of denser feather coverage have more feather follicles. Some of the feathers are more firmly attached (e.g., wing tip) and require stronger force to remove. In order to achieve this task, the rubber fingers should be positioned closer to the carcass or additional plucker disks should be installed at strategic locations. Klose et al. (1961) reported that scalding broilers at 122°F (50°C) significantly reduced feather pulling force by about 30% compared to pulling similar feathers from a live bird. When the scalding temperature was raised to 128°F (53°C), force was reduced by about 50% and when 140°F (60°C) was used, about a 95% reduction was seen. The authors also used an anesthetic drug (sodium phenobarbital) to assist in releasing the feathers. When they measured the force reduction in live birds, they reported about a 50% reduction compared to non-anesthetized birds.

Table 5.7.1 Retention force of broiler's feathers. Adapted from Buhr et al. (1997).

		Initial post-mortem[1] (2 min)			Final post-mortem (6 min)		
Slaughter orientation	**Sample orientation**	**Feather tract**			**Feather tract**		
		Pectoral	**Sternal**	**Femoral**	**Pectoral**	**Sternal**	**Femoral**
		---------- (g) ----------					
Supine	**Supine**	425	311	618	434	338[ab]	677
	Inverted	423	363	631	424	367[ab]	649
Inverted	**Supine**	422	344	667	437	325[b]	637
	Inverted	380	366	663	405	394[a]	709
Side:							
Left		396	337	632	433	372340	667
Right		429	355	657	417		669
Pooled SEM		40	37	49	40	41	59
		---------- Probability ----------					
Source of variation:							
Slaughter-Sample orientation		0.1434	0.0524	0.2337	0.5076	0.0193	0.1570
Side		0.0557	0.2220	0.2402	0.3109	0.0515	0.9532

[a,b] Means within a column and parameter contrast with no common superscript differ significantly ($P < 0.05$), n = 4 broilers.

[1] Post-mortem 2 or 6 min after stunning and bleed out. All broilers were stunned inverted on a shackle and bled as indicated.

When they combined the anesthetic drug and scalding, there was an additional reduction below the value of the anesthetic drug used by itself for both the 50°C and 53°C scaldings. At the 60°C scalding, the difference was not so great, since scalding already resulted in a large reduction. However, the authors suggested that 60°C was too high for broilers and recommended a lower temperature. Later, Buhr et al. (1997) investigated the feather retention force in commercial broilers (Table 5.7.1). The broilers were electrically stunned (50 V alternating current, for 10 sec; average current drawn of 30 mA per bird), bled (severing both carotid arteries and at least one jugular vein), but not scalded. The results showed that the force required for feather removal was consistently greater in the femoral area than in the pectoral area, with sternal feathers requiring the least force. The carcasses were either suspended from a shackle (inverted) or placed on a table (supine). In their study, scalding was not used because "it would overwhelm the detection of minor factors such as angle of feather extraction, sampling side, stunning, spinal cord severing, or carcass orientation" that they were examining.

The feather follicle distributions in a mature turkey and in a duck are shown in Fig. 5.7.4 and Fig. 5.7.5, respectively. Overall, feather removal force is higher in turkeys and ducks than in broilers and increases as turkeys mature. Another difference is the presence of small pinfeathers in waterfowl that are very hard to remove by conventional rubber fingers. Therefore, in a waterfowl (e.g., duck, geese) processing plant, a hot paraffin bath is used to dip the carcasses after the first de-feathering operation (i.e., removal of the large feathers). The carcasses are then taken out, allowed to cool, and the hardened wax is peeled off by another set of rubber fingers. This wax is then re-melted, filtered to remove the pinfeathers, and re-used. When only minor pinfeather problems exist such as in conventional broiler processing, a singeing process (burning of small feathers) is commonly used. This is done by passing the carcass through the flame of a clean burning substance (e.g., natural gas) that does not leave any off-odours or flavours. The carcasses are then rinsed by high pressure spray nozzles while moving on the shackle line to remove any soil left after the de-feathering and singeing processes.

In a low volume operation, the de-feathering process is done in batch-type equipment where the carcasses are placed inside a large rotating drum equipped with rubber fingers. Alternatively, some operations handpick the feathers. Hand picking is also utilized if fancy feathers are to be collected for decoration, sport equipment, etc. (see Chapter 18).

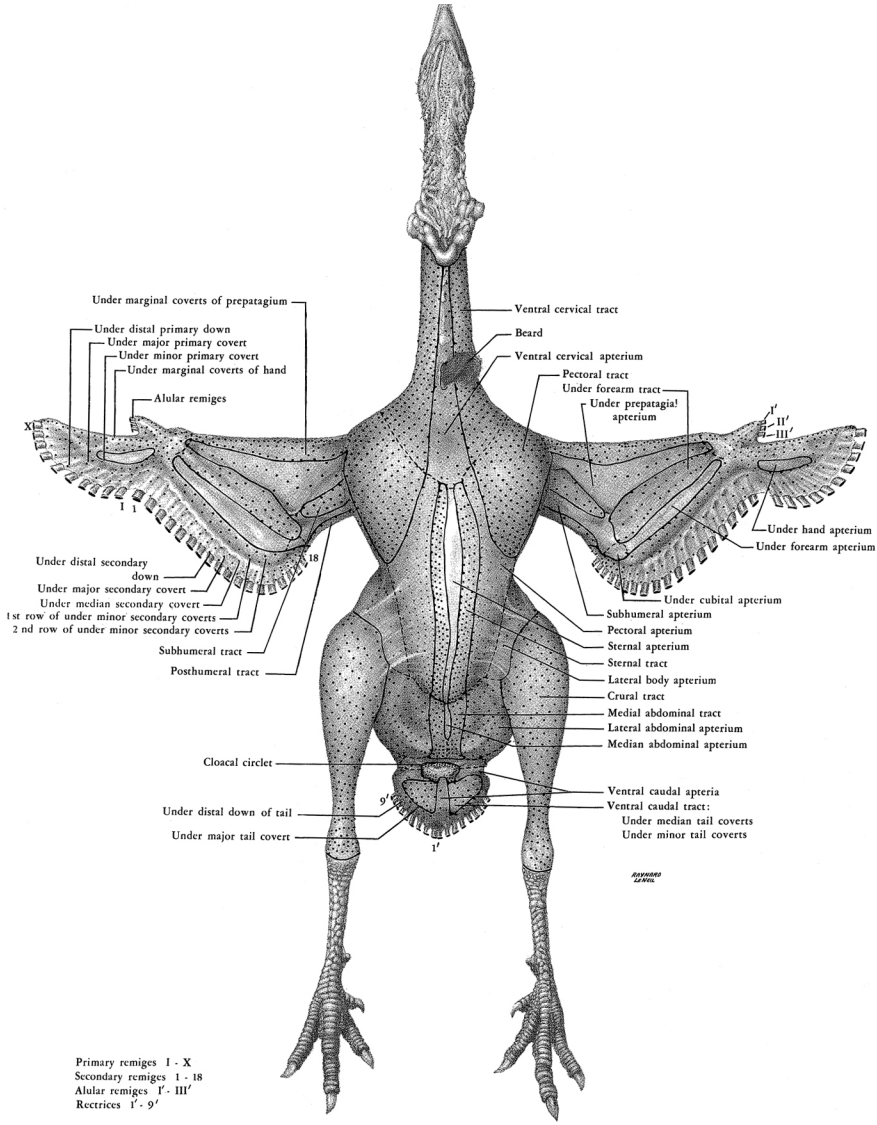


Figure 5.7.4 Feather follicle distribution in turkey. From Lucas and Stettenheim (1972).

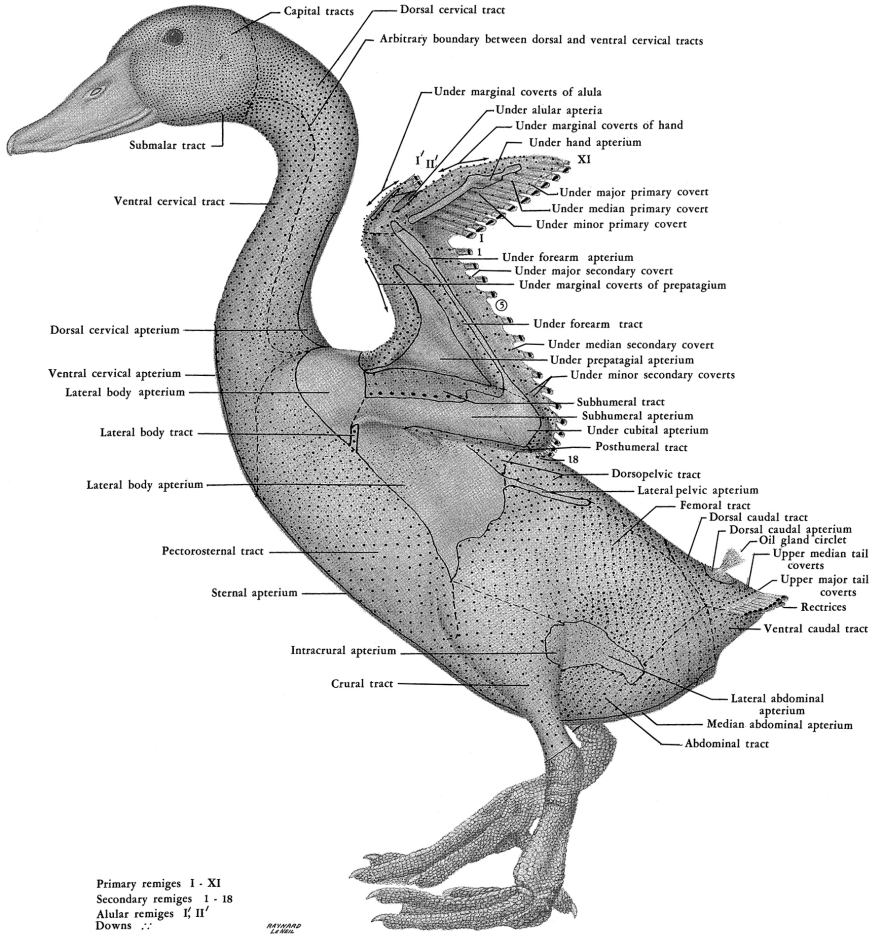


Figure 5.7.5 Feather follicle distribution in duck. From Lucas and Stettenheim (1972).

5.8 Electrical Stimulation

Electrical stimulation is an optional treatment that can be applied after either bleeding or de-feathering to trigger muscle contraction and speed up post-mortem metabolic changes (see Chapter 3 for background information on rigor mortis development). In the past, electrical stimulation has been used almost exclusively by the red meat industry but today various new poultry processing plants are using it. Originally, the lamb industry in New Zealand developed the process in order to minimize toughening associated with cold shortening. The process today also allows for the so-called "accelerated-processing" or "hot-deboning" of lamb/beef and shortens the 12-24 hr waiting period usually required for the completion of the rigor processes.

Electrical stimulation was initially tested in poultry in the early 1960s, but in the following 20-30 years did not receive much attention. A renewed interest occurred in the late 1990s when a patented process called the Minimum Time Process System was introduced. The patent described a deboning process that allowed tender meat harvest 24 min post-mortem. However, a review by Li et al. (1993) indicated that the large variation in test conditions (e.g., voltage, frequency, current, method and time of application) among researchers studying this process provided inconclusive results. In any case, the industry has showed more interest in the process and a few commercial systems have been developed. Later, Sams (1999) also reported that stimulation applied on line could provide sufficient acceleration of rigor to allow deboning right after chilling. Currently, a large portion of new poultry processing plants as well as some old ones are installing electrical stimulation in order to shorten the processing time so that tender breast meat fillets can be harvested immediately after chilling (i.e., within 3 hrs of stunning the birds). In some places in the Far East, where deboning is traditionally done 1 hr after bleeding, electrical stimulation can help (to a certain degree) reduce meat toughening. The electrical stimulation equipment is fairly similar to the equipment used for electrical stunning. The carcass is suspended from a moving shackle line and touches a metal plate (note: a saline solution is used in the stunner) through which a current is passed. Usually the equipment can deliver up to 500 V (AC) and can be set to pulse at 0.2 to 2.0 sec intervals.

5.9 Oil Gland and Feet Removal

In an automated line, oil gland removal is done by angling the birds via a set of metal bars (located along the shackle line) that position each bird such that a rotating blade can cut off the oil gland from the tail area. The cut must be precise and

remove the entire gland without damaging the underlying tissues (i.e., equipment should be adjusted when switching from large to small birds). In a small operation the oil gland is removed manually.

Feet are commonly removed by a circular blade(s) positioned along the shackle line that severs the leg at the knee joint, which has been put into position using guiding bars. It is important that the cut is done within the joint and not through a bone because bone cuts will appear dark or red in the chilled bird and, after cooking, will usually turn darker or even black. Some of the new automated leg cutters first bend the leg and then make a small incision with a stationary knife. This results in further bending of the leg, which can then be cut off at the joint with a rotating circular blade. Depending on market demand, sometimes only the foot is cut off (by cutting the hock) instead of removing the whole leg (e.g., market preference in some regions in Japan).

5.10 Transfer/Rehanging

Rehanging is done when carcasses have to be moved to another line. This can be done manually as the carcasses fall onto a sorting table, or automatically by transferring the birds right away to another line (Fig. 5.10.1). When the live birds are initially unloaded from the crates, they are placed on the line with their feet suspended from the shackle. After going through the scalding and de-feathering operations the feet are removed and the birds are re suspended from the knee joint. The transferring of birds to another line also assists in reducing contamination as semi-processed birds are moved from the dirty shackles used for the live birds to cleaner ones. The shackles used for the live birds are commonly washed before being used for the next batch. Devices for a continuous washing operation are available on the market and usually also include brushes for scrubbing.

There are different configurations for the transfer equipment. One common configuration, shown in Fig. 5.10.1, consists of a large wheel with slots for holding the birds from underneath the knee joints and then pushing them into the slots on the next line (evisceration shackles). It is important that the two lines, de-feathering and evisceration, are synchronized. This can be done by coupling the drives or establishing a buffer zone. The advantages of using automated rehanging equipment are labour savings, better hygiene (as birds do not touch each other on the sorting table), and a more homogeneous rigor mortis process. The latter is important because rehanging the birds without delay ensures that all birds are positioned at the same time interval and in the same way as rigor mortis sets in. The result is equivalent tension on similar muscles and therefore no deformation.

Figure 5.10.1 An example of an automatic bird weighing system which also includes a temporary transfer system. Courtesy of Stork.

5.11 Evisceration

Evisceration involves opening the body cavity and withdrawing the viscera (Fig. 5.11.1). The process can be done manually using a knife and scissors, semi-automatically, or fully automatically by first using a moving blade to open the cavity and a scoop-like arm to withdraw the viscera. The latter is done at high speed on lines that can process 13,500 birds per hr (Barbut, 2014). A typical carousel design is shown in Figure 5.11.2. In all cases, special care should be taken not to pierce the viscera, which would contaminate the carcass by exposing the meat to high microbial loads (e.g., 1 g of gut content may carry 10^9 bacteria). In some countries, such a contamination results in an immediate condemnation of the parts or whole carcasses exposed to the spill, whereas in other countries, moderately contaminated carcasses can be trimmed or washed.

It is important to explain the development in equipment design and layout especially when discussing the move to higher line speeds. An operation such as evisceration takes a certain amount of time, and as line speeds increase one needs more space to perform the task. For manual operations this has been resolved by lengthening the line so more people can work on the carcasses moving along the shackle line. Another alternative is to use a serpentine or a loop line (Fig. 5.11.3).

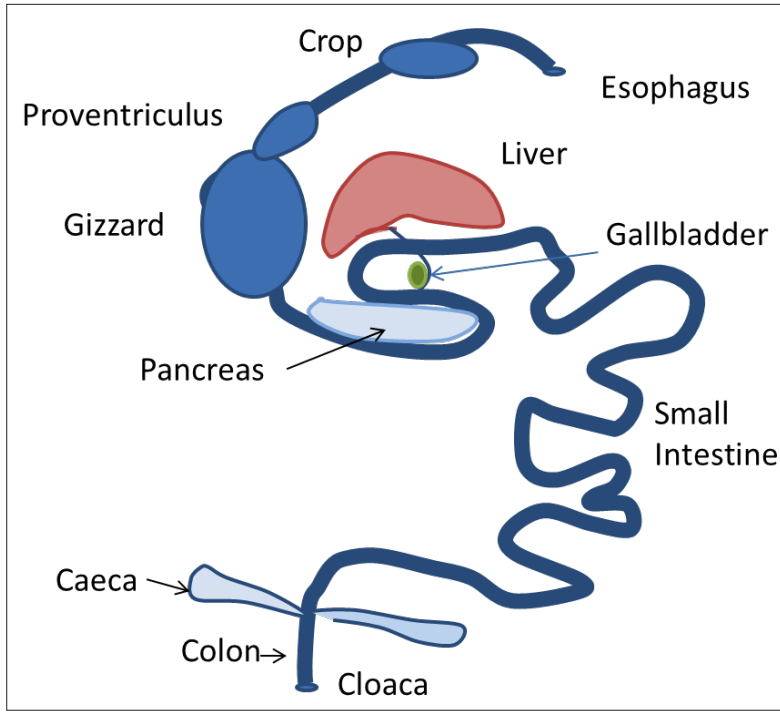


Figure 5.11.1 Digestive system in poultry. Based on Swatland (1994).

For automated procedures the poultry industry (as well as other industries), have developed loops within the line so there is additional space and time to perform a certain task. A carousel design with devices moving with the bird (Fig. 5.11.2) is currently most popular. As will be shown below, a drawing spoon is inserted at the entrance to the carousel and continues to work while the bird is moving along. Another development has been the introduction of a conical shape carousel so the birds are more spaced out at the bottom of the carousel. If needed, multiple evisceration stations/carousels (or other equipment) can be installed on the line. Overall, this is now a common design in high speed lines. It should also be noted that the serpentine type design is common in various scalding lines as the need to reduce the equipment's footprint as well as energy consumption are important drivers in the industry. In such a case the line goes back and forth within a wider scalding tank.

Figure 5.11.2 Automated equipment used for poultry evisceration. Courtesy of Marel.

In a conventional manual operation, the abdominal skin is cut open along the midline from the anterior part of the breast bone towards the cloaca. The skin around the cloaca is usually cut in a circular pattern to minimize the chance of gut contents spilling on the carcass. In recent years vacuum cleaning of cloacal content has been added to some automated equipment in order to reduce potential contamination. After, the viscera are removed manually or by a mechanical "spoon". It is interesting to read the description for a manual process from 1962:

> "The evisceration is performed by supporting the bird with one hand and inserting the fingers of the other hand through the incision in the abdomen. The three middle fingers (and sometimes the middle finger) extended, slide past the viscera until the heart is reached. They are then partly closed in a loose grip followed by a gentle twisting action, and the viscera are slipped out of the body and released" (Childs and Walters, 1962).

The same basic operation steps are used with mechanical evisceration equipment. The mechanization of the process requires precise control of the different operations. Adjusting the equipment to accommodate variations among flocks (i.e., bird size) is of great importance since unadjusted equipment can result in damaging the intestines and carcasses and causing gut spills. Since the current equipment is not designed to be self-adjusting (i.e., no sensors to gauge pressure,

or X-ray mapping of bone location), the eviscerated birds should be monitored on a continuous basis. It should be mentioned that X-ray and other mapping devices have started to appear in red meat cutting, where larger variations among animals can be expected and where line speeds are much slower (i.e., by a factor of at least 100; see discussion and figures in Chapter 1). As indicated before, a poultry eviscerating line is designed to handle only one species (e.g., chicken, turkey) and size variations are handled by raising or lowering the devices (e.g., stunner, plucker) along the shackle line.

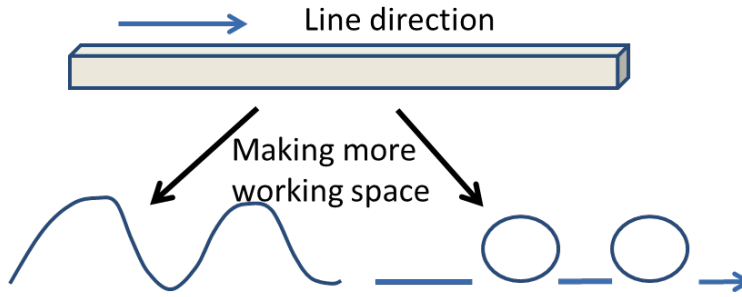


Figure 5.11.3 Illustration of "extending" workable line space.

In semi- or fully-automated evisceration lines, the first step is to cut around the cloaca using a circular rotating blade (Fig. 5.11.4). A vent cutter is placed around the cloaca by mechanical means. The blade diameter should match the size of the particular bird being processed. As indicated earlier, some of the new devices are equipped with a vacuum so the potential for fecal contamination is reduced. The cutting head is commonly rinsed after each insertion (see Fig. 5.11.4, one of the three lines reaching the device is for rinse water). The steps involved in a fully-automated evisceration process are shown in Fig. 5.11.4. Correct positioning is very important to minimize potential damage to the viscera pack and the carcass. It should be pointed out that there are different drawing spoon configurations on the market, but the main goal of the operation is the same. In some operations, the carcasses are rinsed just after withdrawing the viscera (depending on local regulations), as will be discussed later on in the chapter.

In conventional semi- or fully-automated lines, the viscera are withdrawn from the body cavity but remain attached to the body for inspection purposes. However, in some automated lines, the viscera are totally separated from the carcass after

withdrawal. This step can further improve the hygiene of the eviscerated carcasses. If the viscera pack (i.e., intestine liver, gizzard and heart) is detached from the carcass, it should be presented to the inspector together with the carcass from which it was removed. This requires precise synchronization of the two lines.

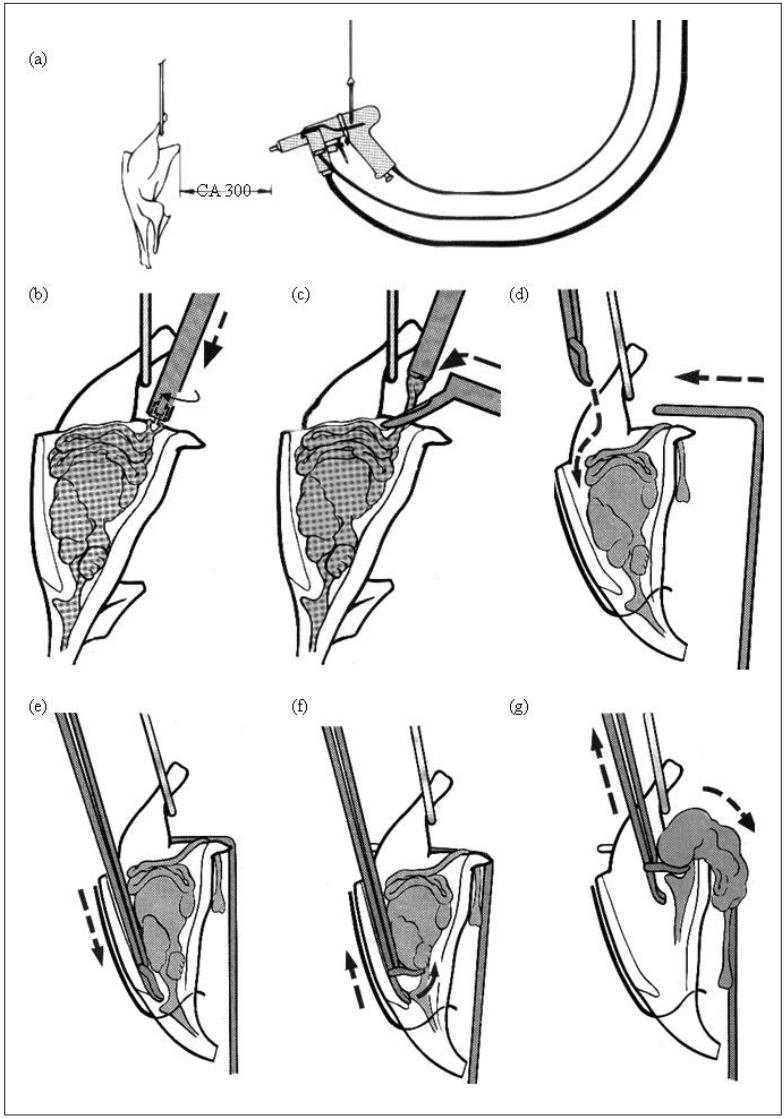


Figure 5.11.4 Schematic of unit operation used for evisceration. Shown here is a unit used for evisceration: (a) vent cutter; (b-g) steps in removing viscera. Courtesy of Stork.

5.12 Inspection

Inspection is commonly done after evisceration, as all parts are exposed at the same time. The attached or detached viscera can reveal diseases and other problems associated with the internal organs and/or outside contamination. Inspection requirements differ between countries (see Chapter 7), and the process is usually carried out by a government official. Inspection is essential to ensure that only wholesome birds that are free of disease reach the market. Some countries require individual inspection of each bird by a qualified veterinarian or government official, whereas other countries inspect flocks as a whole and only a certain number of individual carcasses. However, in the case of a wide spread disease, the inspector may choose to inspect all birds. It should also be mentioned that in some countries there is no requirement for inspection. This can cause international trade problems but not if poultry is only consumed locally. The inspection area should be equipped with adequate bright light (conditions commonly specified in the local inspection act), hand washing stations, a rake for handling suspected birds (i.e., for a more detailed inspection/trimming), and a bin for condemned birds. When individual bird inspection is required line speed should be adjusted so the inspector can check every bird. In a high speed operation, the line can also be split so several inspectors can examine the birds at once. Another alternative is using a single line with marked shackles so each inspector can be assigned certain birds (e.g., every 3rd or 4th bird; usually assigned using different coloured shackles). The carcasses should be presented in a clear way and sufficient spacing between birds should be provided. Often, mirrors are positioned such that the inspector can see both sides of the bird without touching it. An example of text from the Canadian Government Regulation is provided in Chapter 7. Computer vision systems are already available to assist and alleviate the pressure associated with examining a high speed line (see Chapter 1). However, these systems are not currently accepted for full inspection in many countries. As indicated before, a camera captures a digital picture of the carcass and compares it to a reference of a perfect carcass. After certain calculations, the system can flag any deviation as suspect and these birds are either removed from the line or are more thoroughly inspected. Several systems are already equipped with "fuzzy-logic" that allows them to "learn" as new variables are introduced. Some of the options are described in an EU supplementary document (Löhren, 2012).

5.13 Giblet Harvest

After inspection, the viscera are disconnected (i.e., if not disconnected before when special equipment is used to carry the carcass and viscera in parallel to the inspection

station) from the carcass and the giblets (liver, heart, and gizzard) are salvaged and washed in a separate line. This is an optional step, where any combination of parts can be harvested depending on market value. Previously, the process was totally manual; today, however, the process can be semi- or fully-automated. In cases where the viscera are separated to a different line for inspection (see previous section), the holder can be used as a platform for harvesting the different parts. In this case, automated equipment can be used to first remove the hearts and lungs from the hanging packs (i.e., heart and lungs at the top). This is followed by another machine that gently removes the liver, and then a module that cuts the intestines from the gizzards. Later, another unit can be used to separate the heart from the lungs. This is all done on a moving line (e.g., 12,000 packs per hour). Equipment is available for broilers, turkeys, guinea fowl, etc. The gizzard muscle (i.e., the stomach used to grind food, as birds have no teeth) is detached (manually or mechanically) from the pack, cut open, the contents are removed and the lining is peeled off. Mechanical equipment used for peeling consists of two grooved rollers (Fig. 5.13.1; right and left handed). The basic equipment is operated by a person who holds and presses the gizzard onto the rollers. The grooves/teeth catch and pull off the yellow/white lining. More automated options are also available. The gizzards are then inspected, washed and immediately chilled in order to extend their shelf lives. The hearts and livers are also inspected, washed and chilled. The giblets can be sold separately or packed in a waterproof paper bag (sometimes with the neck included) and inserted back into the eviscerated whole bird. Alternatively, parts can be sold separately (e.g., chicken livers, gizzards) or can be used by the plant for further processing.

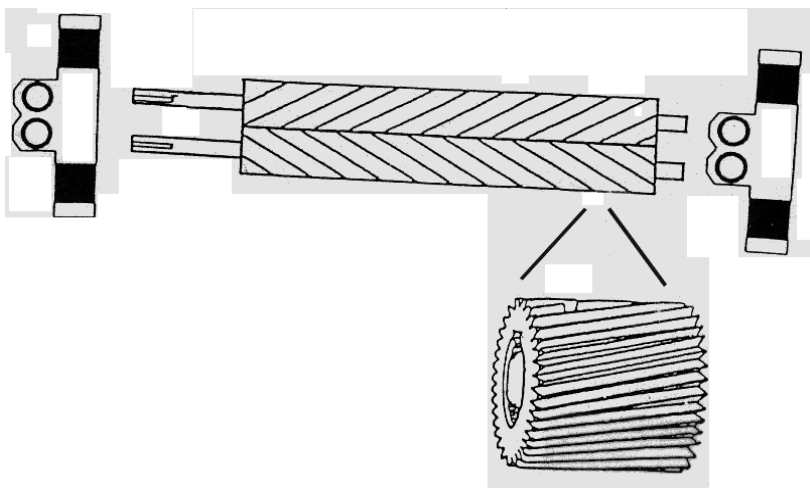


Figure 5.13.1 Illustration of rollers used for gizzard cleaning. Courtesy of DeLong Inc.

5.14 Head, Crop, Neck, and Lung Removal

The head and crop are commonly removed after inspection. However, in certain operations, one or both may be removed prior to inspection. Additionally, if the lungs were not removed during evisceration (see previous section), they have to be removed manually by inserting a rake-like device into the body cavity or by using a semi-automated vacuum gun. In high speed lines, this can require more employees than usual. The overall structure of the vacuum gun is similar to the vent cutter gun shown earlier in this chapter (Fig. 5.11.4) but it may be larger. The vacuum gun is usually attached to the plant's central vacuum system (used to transport trimmings and by-products to a central location). The equipment is commonly suspended from the ceiling by a tension cord so employees do not have to carry its weight. A fully-automated process employs the same type of equipment, but the vacuum tube is inserted by a machine after the carcass has been placed at a certain angle on a carousel as previously explained for the evisceration operation. Proper equipment adjustment is critical for obtaining a high quality product (i.e., without residues) when flock sizes change. Head removal can be done manually by using a knife. Shears operated by air pressure can be used to reduce repetitive motion injuries in workers. The mechanical shears can also be suspended from the ceiling to further improve the working conditions. Automated systems usually consist of a head puller where a guide rail first positions the head into a trough-like structure. While the carcass is moving on the shackle line, the head is pulled back and the neck is broken at the weakest point (i.e., between the atlas and the axis vertebrae). The advantage of this device is that the esophagus and trachea (windpipe) can be removed from the carcass at the same time, which saves labour. As already mentioned, care should be taken not to damage the esophagus and trachea during the bleeding operation if this method of crop and trachea removal will be used. A device to cut the neck can also be installed so the neck is separated at the shoulder area.

5.15 Bird Wash (Inside/Outside)

Various devices are used to wash the birds at different points along the processing line. They range from a simple low volume spray nozzle system to rinse the outside of the carcass after de-feathering to a more sophisticated medium/high volume water system that includes a moving shaft equipped with nozzles that is inserted into the abdominal cavity. The efficiency of the sprays in removing organic and extraneous material depends on factors such as overall coverage of the spray nozzle, spraying time, water volume and pressure used. It is important to realize that high volume and/or pressure does not necessarily provide better

washing. A common location for the washing procedure is just prior to the chilling operation. An example of an inside/outside bird wash device with multiple spray points is shown in Fig. 5.15.1.

Figure 5.15.1 An inside/outside bird washer. Courtesy of Stork.

The spray heads are positioned in such a way that debris is washed from the top down and critical areas are covered by additional spray nozzles to ensure blood and debris removal. The inside is washed by a retracting shaft equipped with high pressure nozzles that spray the abdominal cavity as it retracts. The industry has developed two methods to drain the water. The first option is draining through the neck opening (formed after removing the trachea and the crop) via a rod-type shaft with small teeth and spray nozzles that rotates while moving down and out of the neck opening. This also allows removal of any loose tissue from the neck area. The second option is tilting the carcass after spraying, which results in thorough draining of the water through the abdominal opening (created during evisceration). Different machinery variations are available depending on which draining option is desired and when the washing will take place on the line (e.g., after de-feathering or after evisceration). It is now also recognized that maintaining

a water film on the skin (by periodic spraying) while rinsing helps remove bacteria and any debris left on the carcass after scalding, plucking and/or evisceration. High pressure, low volume nozzles are becoming popular to effectively remove debris. Proper nozzle positioning (and adjusting to flock size) is very important in achieving good and efficient cleaning. Where permitted, bactericidal rinses such as chlorine and organic acids, are also used. Chlorine is one of the most commonly used chemicals and levels of up to 20 ppm are commonly employed. Bactericides, such as organic acids and phosphate dips, are sometimes used prior to chilling. See additional discussion on the different bactericides and maintaining a water film in Chapter 15.

5.16 Chilling

Regulations in most countries require that meat be chilled within a certain period of time (e.g., 2 - 6 hrs to 4°C; depending on bird size) to minimize microbial growth. In most plants thorough chilling is done prior to deboning, but in some plants carcasses are deboned before final chilling (called hot-boning or partial hot-boning). The most common methods used to chill poultry meat include immersion chilling in cold water, air chilling, spray chilling (intermittent water spraying), and combinations of the above (e.g., certain time in water and the rest in air). For immerse chilling (Fig. 5.16.1), it is common to employ long chillers (e.g., 10-50 m long) that use a counter flow of cold water, sometimes supplemented with crushed ice, to bring carcass temperatures to about 4 - 5°C within 30 - 75 min. The carcasses are placed into a trough-like structure equipped with a large diameter auger that moves the birds forward. Another design employs large paddles that slowly drag the birds forward. Parallel flow chillers (i.e., product and water flow in the same direction) and chillers with cold water/ice added along the chilling tank are still used in various plants.

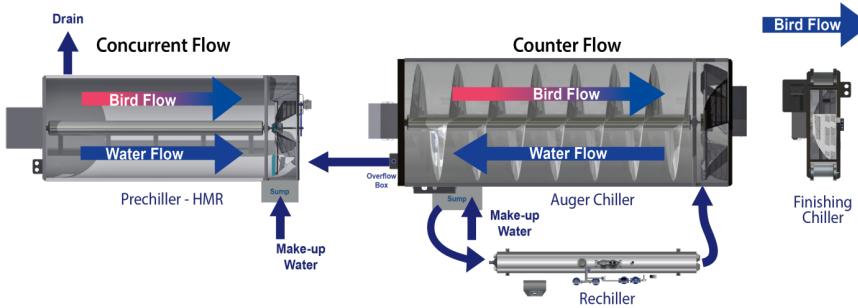


Figure 5.16.1 Water chiller system showing counter flow and a finisher chiller for possible antimicrobial treatment application. Courtesy of Morris.

However, the most common design used today is the counter-flow design where carcasses move counter to the flow of the cold clean water. This is a much more efficient way of cooling the carcasses (i.e., the coldest temperature is at the end of the tank) than the parallel flow design. This also helps to reduce the microbial load and improve the hygiene of the process. The microbial quality of the birds leaving the water chiller is usually better than those entering because the system allows bacteria to be washed away (see Chapter 15). The chilling tank length and diameter are determined by the product flow requirements where dwell time can be adjusted by modifying the auger/paddle speed. The average dwell time is 30-40 min for small to mid-sized broilers and 60-90 min for large turkeys. To increase cooling efficiency, water agitation and turbulence are used. A simple and economical way of achieving turbulence is blowing air into the bottom of the tank at various points along the line. Alternatively, a pump can be used to create water streams as described for the scalding tank. The amount of clean air (preferably from outside of the plant) and water can be adjusted so as to increase or decrease mixing. It should be mentioned that the amount of agitation could also affect the amount of water picked up by the product.

The use of a pre- and post-chiller is another improvement in obtaining a cleaner product. In the pre-chiller, water is used to chill and wash the carcasses (see diagram and additional discussion in Chapter 15). A counter-flow design helps in the gradual removal of residual blood and pieces of loose tissue attached to the product. The product is then lifted, drained, and transferred into a larger, secondary post-chiller where new clean, cold water is used to further chill the product. Ice can be added at different points, but is usually added toward the latter half of the chilling tank. The amount of water overflow in the chilling tank is regulated in some countries. For example the minimum volume required by the European Union is 2.5 liters for eviscerated birds weighing $\leq$ 2.5 kg, 4 liters for 2.5-5.0 kg, and 6 liters for $\geq$ 5 kg.

Upon exiting the chiller, the product is allowed to drain for a few minutes to remove excess water. This is done either on a perforated conveyor belt or on the next shackle line. In many countries the amount of water picked up during chilling is regulated with respect to the product's weight. For example, in the USA the maximum permitted water pickup is:

- 8.0% for chicken < 4.5 lb and turkey < 10 lb
- 6.0% for turkey 10-20 lb
- 4.5% for turkey > 20 lb
- 6.0% for all other birds types and weights

The European Union, regulations (#1538/91 EEC) are specific to chilling method and specify maximum values of: 1.5% for air chilling, 3.3% for air spray chilling, 5.1% for immersion chilling (Löhren, 2012).

Air chillers are more commonly used in Europe and some countries in the Middle East where the prices of fresh water and waste water treatment are expensive as compared to North and South America. However, it should be pointed out that air chilling is now starting to appear in North America and elsewhere. Cold air is used as the chilling medium so care should be taken not to over dry the product surface. This is usually achieved by either increasing the humidity (which also improves heat transfer), and/or wetting the product at a strategic point along the chilling process. By doing so, dehydration losses can be reduced to 0-1%. In a large plant, the setup includes an overhead railing system that goes back and forth along the chilling tunnel, which can stretch to a few km (Fig. 5.16.2).

Figure 5.16.2 Air chilling system showing overall refrigeration area. Courtesy of Marel.

There are several air chilling technologies used by the industry. The simplest is cooling birds on a stationary rack in a walk-in cooler. Air temperature, speed and relative humidity usually depend on the particular cooler setting and are not always optimized for chilling poultry. A step up uses directed air flow and allows adjustments for air speed, temperature, and humidity to achieve the optimal

chilling rate for a particular bird size and rigor mortis stage. Dedicated chilling tunnels are constructed with a single or multi-layer overhead conveyor system (conveyors run on each tier and are offset to prevent dripping on a lower tier). Air is blown over cooling elements and then circulated in different patterns around the room at a fairly high speed. Depending on the chilling tunnel capacity and volume of the product sent through, chilling can be achieved within 60-150 min. Moisturizing at strategic points is recommended over humidifying the whole room/tunnel as better control and less cross contamination can be achieved. Usually the moisturizing units are positioned on 180º corner wheels outside the main room/tunnel. An improvement of the process is called maturation chilling and includes a system that initially directs cold air into the abdominal cavity of the carcass and onto the exterior of thick parts (e.g., breast, leg). This process can shorten the chilling time and improve the efficiency of the system. However, one should be careful to avoid cold-shortening of the muscles (i.e., chilling too quickly before rigor mortis is complete, see Chapter 3). Therefore, after the initial fast cooling of the surface, the temperature is raised and air flow is reduced. One of the benefits of air chilling is reduced moisture pick up and a drier final product that usually shows no exudation (drip loss) when packaged (Huezo et al., 2007). This is appreciated in certain markets (i.e., where people are willing to pay for it). Some processors also claim that the microbial quality of the air chilled products is better than that of water chilled products, but that is not always the case (see Chapter 15 for further discussion).

Spray chilling is a hybrid between water and air chilling. Cold water is either intermittently or constantly sprayed over the product while it moves along the shackle line. The resulting moisture pick up is less than that of water chilled products, but more than that of air chilled products. Young and Smith (2004) compared moisture uptake following water and air chilling and determined that storage decreases moisture pick up by half. In that study, air chilled carcasses lost about 0.68% weight post-chill, but did not lose any more during subsequent storage and cutting. The water chilled carcasses picked up about 11.7% moisture post-chill, but only retained about 7% through storage (24 hrs at 1ºC), 6% immediately after cutting into front-halves and leg quarters, and 3.9% after cut-up and 24 hrs of additional storage (48 hrs post-mortem). Leg quarters showed higher purge than front-halves. New air chilling systems (evaporative air chilling) now incorporate a moistening system to prevent weight loss typically associated with air chilling.

Overall, choosing one chilling method over another depends on factors such as market demand, water cost and availability, electricity costs, and capital investment available. Overall, when a new plant is built (called a "green field") the processor should consult with equipment manufacturers, inspection personnel,

and consumer groups in order to make the best decision for the new operation while recognizing that the method chosen will stay in place for many years.

The use of mathematical modeling to design new chilling options or validate the operation of an existing one, has increased over the past few years. The advantages of modeling are the ability to predict the outcome and optimize the process (see additional discussion in Chapter 11 dealing with modeling of meat cooking; i.e., another example of a heat and mass transfer modeling). Figure 15.16.3 shows the heterogeneous thermal conductivity (k) and specific heat (C_p) in different areas of a broiler carcass. This information is used in the modeling to simulate the cooling rates in different areas. Figure 5.16.4 show the simulation of an air cooling process, which in this particular case shows the effect every 30 min at the beginning and later every 3 hrs.

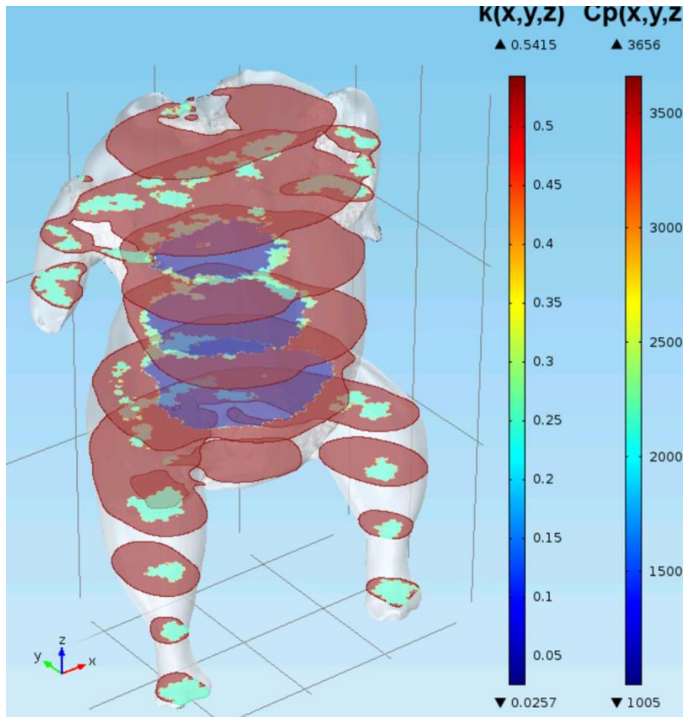


Figure 5.16.3 Slice plot of a broiler carcass showing heterogenous thermal conductivity k (W/mK), and specific heat Cp (J/kgK). From Cepeda et al (2013). With permission.

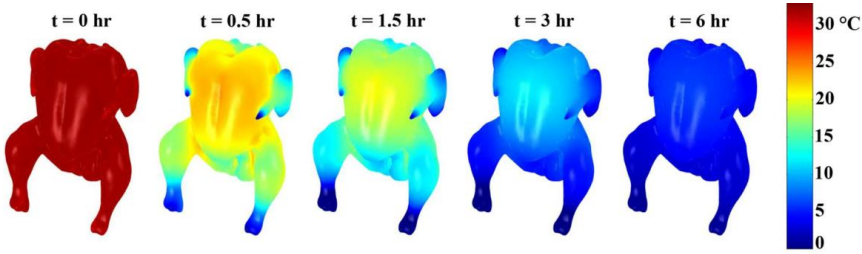


Figure 5.16.4 Simulation of air-cooling of a poultry carcass, using Comsol software. From Cepeda et al (2013). With permission.

5.17 Weighing and Grading

After chilling, the birds are weighed, graded (see Chapter 7 for more details), and either packed or deboned prior to sale and/or further processing. In most large plants, automated weighing equipment connected to a computer network is used to record the weight of each carcass/part and sort it (Fig. 5.17.1). More sophisticated computer systems can combine weight and image analysis data (previously discussed) to make a decision about the best way to market each bird (e.g., whole carcass, parts). The decision depends on input regarding price for various parts, market demands for a specific day/week, requirements for in-plant meat supply, etc. Such a process can have significant cost-savings in medium and high volume plants that process hundreds of thousands of birds per day.

Grading is done either before or after weighing. Usually, it is not mandatory but is commonly done to facilitate trade. Grading can be done by a qualified worker or with the assistance of a computerized machine vision system. See detailed discussion on grading criteria in Chapter 7. Overall, it is important to recognize that the final grade and overall meat quality can be strongly affected by the different steps described in this chapter (e.g., unloading, stunning, plucking, chilling, etc.), as well as by conditions on the farm (e.g., feeding, animal health).

Whole poultry, cut up parts or minced meat are commonly packaged in small retail packages or large combos for industrial use. The packaging material is design to protect the product form moisture loss due to evaporation, cross contamination with bacteria (e.g., on the hands of employees, consumers), dust and foreign matter, while also providing room for the processor to advertise its product (e.g., company's logo, recipes, nutritional information). See additional discussion of films' characteristics in Chapter 11.

Figure 5.17.1 An example of an automated sorting station. This is done after weighing each piece on another short segment of the belt (i.e., a standalone segment equipped with a fast weighing system). The weighing station is located about 5-10 meters in front of the sorting station, so there is enough time for data processing and execution. Courtesy of Marel.

5.18 Portioning, and Packing

Depending on the end use the birds can be portiond and/or packaged individually or in bulk; see Chapters 9 and 11, respectively.

References

Barbut, S. 2014. Review – automation and meat quality – global challenges. Meat Sci. 96:335.

Barbut, S. 2010. Past and future of poultry meat harvesting technologies. World's Poultry Sci. 66: 399.

Buhr, R.J., J.A. Cason and G.N. Rowland. 1997. Feather retention force in broilers ante-, peri- and post-mortem as influenced by carcass orientation, angle of extraction and slaughter method. Poultry Sci. 76:1591.

Cepeda, J.F., S. Birla, J. Subbiah, and T. Harshavardhan. 2013. A practical method to model complex three-dimensional geometries with non-uniform material properties using image-based design and COMSOL multi physics. Proceedings 2013 COMSOL Conference. Boston, MA. http://www.comsol.com/paper/download/180747/cepeda_paper.pdf. Accessed February 2015.

Childs, R.E. and R.E. Walters. 1962. Methods and equipment for eviscerating chickens. U.S. Dept. Agric. Mktg. Res. Report #549.

Fletcher, D.L. 1999. Recent advances in poultry slaughter technology. Poultry Sci. 78:277.

Gregory, N.G. and L.J. Wilkins. 1989. Effect of slaughter method on bleeding efficiency in chickens. J. Sci. Food Agric. 47:13.

Huezo, R., J.K. Northcutt, D.P. Smith, D.L. Fletcher and K.D. Ingram. 2007. Effect of dry air or immersion chilling on recovery of bacteria from broiler carcasses. J. Food Protect. 70:1829.

Klose, A.A., E.P. Mecchi and M.F. Pool. 1961. Observations of factors influencing feather release. Poultry Sci. 40:1029.

Li, Y., T.J. Siebenmorgen and C.L. Griffin. 1993. Electrical stimulation in poultry - a review and evaluation. Poultry Sci. 72:7.

Löhren , U. 2012. Overview on current practices of poultry slaughtering and poultry meat inspection. Supporting Publications 2012:EN-298. http://www.efsa.europa.eu/en/search/doc/298e.pdf. Accessed January 2015.

McEwen, S.A. and S. Barbut. 1992. Survey of turkey downgrading at slaughter: carcass defects and associations with transport, toe nail trimming and type of bird. Poultry Sci. 71:1107.

Mountney, G.J. 1989. Poultry Products Technology. Food Products Press, New York, NY.

Raj, A.B.M. and S.P. Johnson. 1997. Effect of the method of killing, interval between killing and neck cutting, and blood vessels cut on blood loss in broilers. Brit. Poultry Sci. 38:190.

Sams, A. 1999. Commercial implementation of post-mortem electrical stimulation. Poultry Sci. 78:290.

Swatland, H.J. 1994. Structure and Development of Meat Animals and Poultry. Technomic Publ., Lancaster, PA, USA

Young, L.L. and D.P. Smith. 2004. Moisture retention by water- and air-chilled chicken broilers during processing and cutup operations. Poultry Sci. 83:119.