

Chapter 10

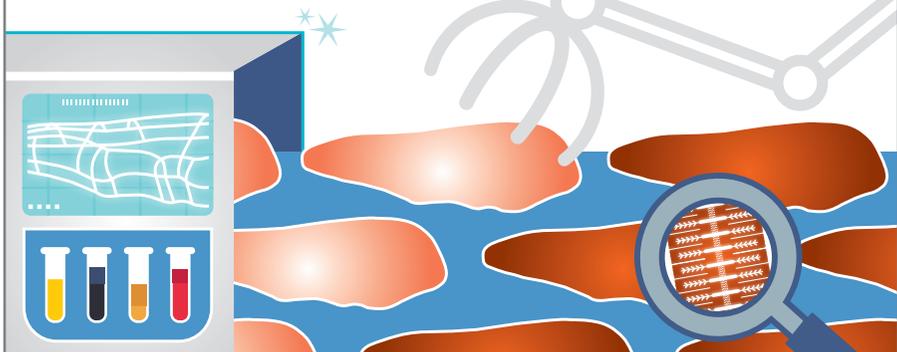
FURTHER PROCESSING – EQUIPMENT



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.

© 2015 Shai Barbut

This work is licensed under the Creative Commons licenses noted below. To view a copy of these detailed licenses, visit creativecommons.org. Briefly, this license allows you to download the work and share with others as long as you credit the copyright owner.

You can't change the content in any way or use it commercially. Other than as provided by these licenses, no part of this book may be reproduced, transmitted, or displayed by any electronic or mechanical means without the prior written permission of the copyright owner, except in the case of brief quotations embodied in critical reviews and certain other non-commercial uses permitted by copyright law.



Effective July 1, 2015, this book will be subject to a CC-BY-NC-ND license. This book contains information from authentic and highly regarded sources and a wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the author cannot assume responsibility for the validity of all materials or for the consequences of their use.

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

10

FURTHER PROCESSING – EQUIPMENT

10.1 Introduction

The meat industry produces a large variety of meat products ranging from whole muscle to ground and comminuted products, each of which requires different equipment. This chapter explains the principles of operating modern meat processing equipment, which has evolved over the centuries to help processors and butchers perform different tasks (e.g., cut, inject brine, stuff, cook, slice). Variations exist in equipment design, size, and configuration, but most operate under fairly similar principles. Previously, equipment was designed for individual, single tasks (e.g., mixing) but today many processing lines are designed to accommodate continuous, automated operations.



Figure 10.1.1 Large scale fully automated lines producing nuggets. Courtesy of Townsend.

This is part of a large scale move towards automation (see Chapter 1), where fully automated lines produce thousands of nuggets/sausages per hour (Fig. 10.1.1), with minimal manual labour (i.e., employees might perform quality control functions or adjustments). Such continuous lines speed up manufacturing, move more product through a given plant, permit more centralized control, reduce potential cross contamination problems, and as a result, create cost savings.

The basic steps involved in meat processing are illustrated in Table 10.1.1.

Table 10.1.1 Unit operations used in meat further processing*.

Section	Activity	Action(s)
10.2	Cutting – Size Reduction	Grinding Chopping (coarse, fine) Flaking
10.3	Mixing/Blending (meat, salt, water, etc.)	Mixing (paddle, ribbon mixer) Brine Injection Massaging/Tumbling
10.4	Forming/Stuffing/Netting	Forming (patties, meat balls) Stuffing (regular casings, co-extrusion) Netting Equipment Cooking in Bag
10.5	Smoking	Smoking (smoke house)
10.6	Cooking/Heating	Water Cooking Hot Air Cooking (linear, spiral oven) Microwave Frying in Oil
10.7	Cooling	Air Chilling Water Chilling Cryogenic Chilling
10.8	Peeling	Sausage Peeling
10.9	Slicing	Slicing Cubing
10.10	Packaging	Flexible Packaging Rigid Packaging
10.11	Safety Checks	Metal Detector X-Ray Detector
10.12	Labeling	High Speed Labeling
10.13	Storage and Distribution	Cold/Frozen Storage Distribution Channels
* General sequence of production; not all activities are included in the manufacturing of an individual product		

Depending on the product (e.g., whole muscle roast, ground sausage), the operator will select steps to be used. Generally speaking, all processes performed prior to cooking are carried out at a refrigeration temperature to minimize microbial growth. In addition, good manufacturing practices and adequate HACCP programs are used to enhance the safety of the products (see Chapter 12).

10.2 Cutting/Size Reduction

Reducing the size of meat cuts is a common process involved in the manufacture of sausages and patties. Depending on the desired particle size in the finished product, different equipment can be used. The three basic procedures that are used include: grinding (coarse/medium/fine), flaking, and chopping (coarse/fine).

10.2.1 Grinding

Grinding is probably the second oldest method of reducing meat particle size; the first being manual cutting/chopping. In this process, meat is forced through a grinding plate preceded by a rotating blade. Grinding plates have different size openings and shapes (Fig. 10.2.1.1) and an auger is used to push the meat through a moving set of blades and a grinding plate (Fig. 10.2.1.2). The size of the equipment varies depending on volume and ranges from small, manual grinders that can process a few kg/hr to large electrically driven grinders capable of processing thousands of kg/hr. Pump driven grinders also exist where the meat is pushed by a pump (e.g., positive displacement) directly into the grinding head (Fig. 10.2.1.3). This kind of equipment has some advantages when it comes to maintaining particle definition in products such as dried salami, or when a “home style” grind appearance is required for retail sold ground meat. However, it should be noted that most grinders used by the industry are the auger type. In order to minimize heat build up, especially at the pressure building area of the head, the blades should be kept sharp and the plate maintained in good shape (e.g., not worn out). It is common to keep a blade and plate paired together. If, during production, the operator notices an uneven pattern of meat coming out of the grinder, the machine should be stopped and the connective tissue (or any other obstacle) trapped behind the plate removed. Some of the medium/large grinders have a special system that continuously collects and removes sinew, connective tissue, and bone residues through an opening in the center or the side of the plate. This material is carried away by a pipe or hose connected to the opening so it does not get mixed again with the ground meat. This is an important part of the operation as it can significantly reduce the time needed to open and clean the accumulating tough residues at the surface of the plate. In addition, it reduces heat build-up

(caused by friction of the material clogging the plate's opening), and eliminates fat smearing within the ground meat. In order to increase efficiency, some grinders are built with two or three sets of knives and plates (Fig. 10.2.1.2). The first set is for a coarser grind while the subsequent sets grind the product finer. By doing so, one can eliminate the need to move the meat mass to a second grinder for a finer grind. The size and number of blades, as well as the plates' openings, vary depending on the degree of grinding required. In a single set grinder, the meat is usually first ground through a large opening plate (e.g., kidney plate with openings of about 50×20 mm), followed by a smaller plate (e.g., 5 mm holes). Regrinding meat that has been mixed with spices (in a mixer), is also common practice in products such as summer sausages where a good mixing of the spices and starter culture is desired.



Figure 10.2.1.1 Rotating blades, grinding plates with different size opening and shapes. Courtesy of Speco Inc.

An important aspect of the grinder operation is preventing “back-up”, which can happen when too much meat is driven towards the plate. Back-up results in an inefficient operation, overheating of the meat mass, and fat smearing. In a small, manual operation this is controlled by the operator, but on a large scale line automatic controls should be set to avoid this problem.



Figure 10.2.1.2 Main parts of a meat grinder. Note that the auger’s pitch is changing from large to small. The blade and plate have to be kept sharp at all times to result in good grinding, avoid smearing and temperature build up. Some grinders have a set of 2-3 blades and plates on the same shaft; i.e., meat is gradually moved to a smaller plate. This configuration can save time and labour, but requires a bigger motor to drive the system. In some models sinew and bone particles can be collated, from the inner surface of the grinding plate, and removed from the side/center of the grinder. Photo by S. Barbut.

Pre-breaking frozen meat blocks is also considered part of size reduction and grinding. There are two general approaches. The first is a ‘chipper’ type, which is a rugged grinder that can handle frozen blocks without damaging the texture of the meat. It usually comes with a powerful slow speed rotor that chips away pieces from the block. Size of the pieces can be controlled by using different size rotors. The second approach is employing a blade/guillotine type that moves down and cuts the frozen meat block to predetermined portions.



Figure 10.2.13 Meat grinder utilizing a positive displacement pump (on the left hand side) to push the meat to the cutting plate (on the right hand side). Courtesy of Marlen.

10.2.2 Chopping – Coarse and Fine

In chopping, the meat is passed through a set of cutting blades (Fig. 10.2.2.1). The size of the particles is controlled by the number of passes through the rotating knives and the distance of the knives from the bowl. The degree of chopping is controlled by the overall chopping time, the number of the blades and their speed. The chopping process can be designed to produce relatively large particles or very small ones. Chopping is commonly used for producing fine comminuted products, sometimes called emulsion-type products, such as frankfurters and bologna (see recipes and preparation procedures in Chapter 13). Fine emulsion-type meat products with coarse inserts can also be made by first preparing the fine emulsion and then mixing in coarse inserts by using the reverse motion of the blades (i.e., no cutting is applied). Two common chopping devices used by the meat industry are the bowl chopper (Fig. 10.2.2.1) and the emulsion mill (Fig. 10.2.2.2). In a bowl chopper, meat is placed in a cutting bowl, which moves around at a relatively slow speed [15 to 30 revolutions per minute (rpm)] while the meat is chopped by a set of sickle-shaped knives (3 to 15) at a speed of a few thousand rpm. In order to speed up the process, some new designs have two sets of cutting heads. An emulsion mill, sometimes referred to as an emulsifier, combines the principles of grinding and chopping. The pre-ground meat is fed to the mill and passed through

fast, rotating blades and later pushed through a perforated plate. The blades and plate are arranged in a similar configuration as seen in a meat grinder, and can be positioned vertically or horizontally. An in-line vacuum system can also be included to remove trapped air, which is beneficial in minimizing problems such as lipid oxidation (e.g., associated with off flavour, colour fading) and pockets or "holes" in the final cooked products (see Chapter 13). Vacuum application in bowl choppers is also popular in the industry. In that case a dome/cover is used to enclose the chopping area while a vacuum is applied (Barbut, 1999).



Figure 10.2.2.1 Meat chopper - meat is passed through a set of high speed cutting blades while the bowl is turning and moving the meat to the blades (top); the meat can also be just mixed by reversing the direction of the blades. An old meat chopper/mixer; note the belt drive mechanism (bottom). Photos by S. Barbut.

Emulsion mills operate at a very high speed (particle size is controlled by plate aperture size) and the meat is subjected to considerable friction, which results in a fairly quick increase in temperature (e.g., 5 to 8°C in a few seconds). Therefore, special care should be given to operating such equipment. A discussion on the risk of exceeding certain chopping temperatures (usually 8-12°C) during the preparation of finely comminuted meat products is provided in Chapter 13. Emulsion mills are advantageous when considering automating a production line because they can process large volumes in a continuous manner while quickly achieving a high degree of meat tissue disintegration. If air is not removed at this stage, it can be done during the stuffing operation as will be discussed later in the chapter. However, it is best to remove air during both the chopping and stuffing operations, as is done in most large plants to ensure quality.

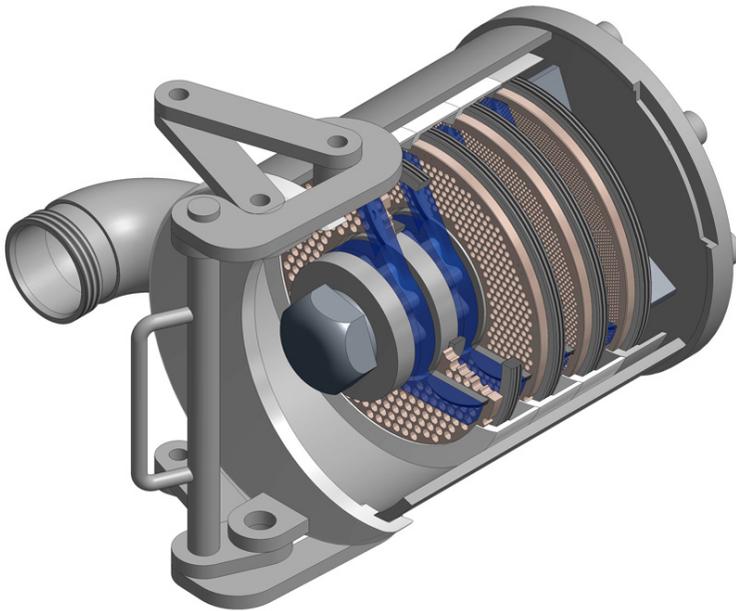


Figure 10.2.2.2 Illustration of a horizontal emulsion mill used to prepare finely comminuted meat products. Courtesy of Cuzzini.

10.2.3 Flaking

Shaving off or flaking small pieces from partially frozen meat cuts or blocks can also reduce the size of meat cuts. The equipment (Fig. 10.2.3.1) has a circular cutting head and an impeller that spins at a high speed and pushes the meat, by centrifugal force, close to the knives. The size of the flakes is determined by the spacing within the vertical knives of the cutting head. This method eliminates the mechanical squeezing of muscle fibers seen in a conventional grinder, which can sometimes result in moisture release from the meat. However, one should also consider that the partial freezing required to keep a stiff structure might also create problems with moisture loss during thawing. The meat obtained from flaking machines has a large surface area and can serve as a good ingredient in restructured meat products where a muscle-like texture is reconstructed from small pieces of meat.

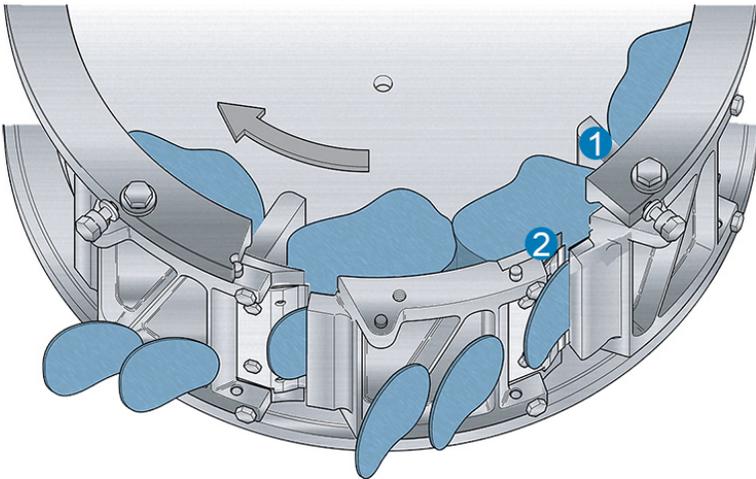


Figure 10.2.3.1 Illustration of flaking equipment. Cutting head spins at high speed and meat/food is pushed towards the blades by centrifugal force. Particle size can be determined by the size and spacing of the blades. Courtesy of Urschel Inc.

10.3 Mixing/Blending

Mixing and blending are essential steps in producing most further processed meat products as they incorporate ingredients (flavouring agents, and binders), extract myofibrillar proteins (e.g., by salt; see Chapter 13), and blend different meats.

The mixing method depends on the size of the meat particles/chunks and the desired characteristics of the final product, etc. When the meat particles are small, dry ingredients can be added to a paddle/ribbon mixer while brine injection and massage are used for large muscle portions (e.g., turkey breast, ham).

10.3.1 Mixers

Ground meat products such as sausages and meat patties are processed in a paddle/ribbon mixer that provides:

- a. good mixing of meat and non-meat ingredients (e.g., salt, spices)
- b. good uniformity when different meat sources are used
- c. absorption of a brine solution into the muscle structure
- d. extraction of salt soluble proteins from muscle by mechanical agitation.

There are different blender/mixer designs on the market. A paddle mixer (Fig. 10.3.1.1) employs paddles to mix the meat in a chamber. The blades are usually mounted on a horizontal shaft and the mixer provides a fairly gentle mixing. Another type is the ribbon blender where the diameter and pitch of each ribbon is designed to achieve maximum mixing. This type of blender usually works the product more than the paddle mixer and results in more effective protein solubility. With any mixer, blending should be precisely controlled to ensure uniform mixing action. When using a new formulation or changing the mixing schedule, uniform mixing can be checked using food colouring, mustard seeds, or small ice cubes placed at one corner of the mixer. To ensure proper mixing, the mixer should be filled according to the manufacturer's specifications as under or over filling will not achieve optimal blending. Over-mixing should also be avoided since it can result in too much muscle fiber separation and/or fat smearing.

Coarse-ground products (e.g., breakfast sausage, salami) are prepared in a mixer after grinding the raw meat to the desired size. A mixer can also be used to distribute meat and non-meat ingredients to be chopped by an emulsion mill. This ensures a uniform distribution of ingredients prior to the emulsion mill process where very little mixing takes place during a single pass through the machine.

In several cases pre-blending is employed to mix in the salt prior to product creation. It usually takes 12 to 24 hrs to achieve optimum benefit from pre-blending. This allows additional time for the salt to solubilize some of the meat proteins (e.g., actin, myosin) and thereby improve the water holding capacity and binding of the individual meat particles. In some cases, salt is added only to the lean meat so the processor can obtain a high salt concentration (see Chapter 13).



Figure 10.3.1.1 Meat mixer with paddles for continuous mixing and opening the meat dough structure.
Photo by S. Barbut.

10.3.2 Brine Injection

Adding salt and spices to a whole muscle product can be time consuming and expensive (e.g., rubbing dry salt on large hams), so it is only justified for high end products. Therefore, injection equipment is used to quickly introduce the brine (water, salt, and flavourings) into large, whole muscle products. Before equipment development, the two major curing methods for large muscle products were dry curing and brine soaking. While both of these methods are still used today for selected products, brine injection is most popular. A simple injector consists of a single needle operated manually. More sophisticated injectors have a few dozen needles automatically controlled to deliver a precise volume of brine (Fig. 10.3.2.1).

A composition of a generic brine solution is:

Cold Water	75%
Salt (NaCl)	18%
Sugar/Starch	3%
Phosphate	4%
Sodium Ascorbate	0.5%
Sodium Nitrite	0.16%



Figure 10.3.2.1 Brine injector used for bone-in and boneless meat products. See text for more explanation. Photo by S. Barbut.

Delivery of the exact amount of brine is very important in meeting flavour requirements (e.g., saltiness, sweetness) and government regulations (e.g., precise nitrite level). The following examples of injection rate provide an illustration of flavour problems that might arise if mistakes occur in the delivery system:

- Intended injection of 10% pump results in 1.63% salt in the product
- Low injection of 5% pump results in 0.81% salt in the product
- Over injection of 15% pump results in 2.45% salt in the product
- Over injection of 20% pump results in 3.26% salt in the product.

A problem with under-delivery due to, for example, clogged needles, can result in lower than expected salt and nitrite concentrations. Delivering only 5% will result in half the salt flavour, but more importantly only half of the required nitrite, which can represent a serious safety issue. In the case of over-injection (e.g., 15 and 20%), the product will be too salty and also have higher than legal nitrite content. Over injection can also cause separation of the muscle bundles and the formation of pickle pockets. Uniform temperature of the injected product is also critical (e.g., previously frozen raw materials should be completely defrosted). Special care should be given to the uniformity of the injection process to prevent high salt and/or nitrite concentrations in localized areas where bones are present. This is commonly achieved with special sensors attached to the needles that can gauge

pressure and needle movement (i.e., stops movement and injection of the needle when it hits a bone). If injection continues next to a bone, high concentrations of salt and/or nitrite can cause flavour defects and some even claim nitrite burns in the final product; however the latter is extremely rare. Injectors should be constantly monitored during operation and quality control checks of pumped product should be routinely performed. The calculation for percent pump and percent yield are shown below:

Example:

Green weight (initial meat weight) 500kg

Pumped weight (meat + brine) 560kg

$$\% \text{ Pump} = \frac{(\text{Pumped weight} - \text{Green weight})}{\text{Green weight}} \times 100 = \frac{60 \times 100}{500} = 12\%$$

Example:

Finished weight = weight after cooking, smoking and/or drying 480kg

$$\% \text{ Yield} = \frac{\text{Finished weight}}{\text{Green weight}} \times 100 = \frac{480 \times 100}{500} = 96\%$$

If finished weight is: 520kg

$$\% \text{ Yield} = \frac{520 \times 100}{500} = 104\%$$

The finished product weight is used to calculate the actual salt, sugar, phosphate, and nitrite concentrations injected into the raw meat. During cooking, moisture evaporates (unless cooked in moisture proof casings), but added salt, sugar, and nitrite do not. Salt and sugar are concentrated in the product while some nitrite turns into nitric oxide gas. Therefore, knowledge of all processing parameters is crucial in developing a workable formulation and in achieving the desired concentrations of the different ingredients in the final product.

The physical shape and diameter of the needles used are also important and should match the meat. In the case of broiler breast meat (low connective tissue), the needles should be narrow enough not to cause damage to the muscle appearance. This is crucial when processing meat with a weak connective tissue structure (e.g., breast meat from large turkeys), as thick needles and/or high injection pressure will cause a lot of damage. In other cases, such as thigh meat, large needles or even small penetrating blades can be used for both injection and to tenderize (Fig. 10.3.2.2). It should be noted that the tenderizing operation can also be carried out by itself and there is equipment to do so independent of the injection process.

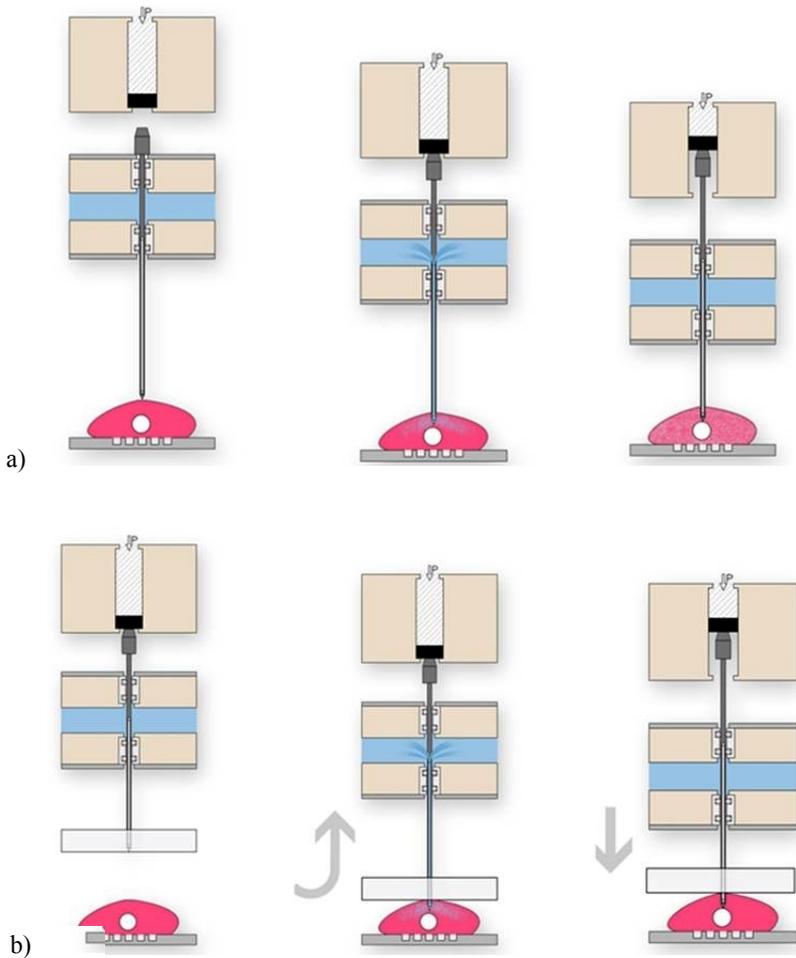


Figure 10.3.2.2 Illustration of brine injection principles (a) contact injection, and (b) forced injection. Courtesy of JBT/ Wolf – Tec.

After brine injection it is common to tumble the meat to achieve an even brine distribution, enhance absorption, and facilitate salt soluble protein extraction (Lin et al., 1991).

10.3.3 Massaging and Tumbling

Massaging and tumbling are procedures designed to help distribute brine into whole/large muscle chunks after injection, or to marinate small size meat strips in brine by tumbling. Both processes improve brine absorption and protein extraction, which later helps in binding (water added, particles' surfaces). In both processes the meat is subjected to a certain degree of agitation, which distributes the salt and other ingredients and solubilizes the myofibrillar proteins. Massaging is done in a stationary mixing vessel where a paddle(s) slowly moves the meat, whereas tumbling is done in a rotating drum that can have different baffles/ribbon designs on the sides (Fig. 10.3.3.1). The massaging action is considered gentler than tumbling since there is no lifting or dropping the meat. However, some tumbler manufacturers claim that gentle mixing, similar to a massage, can be achieved. For example, the two- and four-helical ribbon designs shown in Fig. 10.3.3.1 are claimed to provide gentler mixing than a tumbler equipped with horizontal baffles (located on the drum's side wall which help lift and then drop the meat during its continuous rotation). The helical ribbons slowly advance the meat towards the upper end of the tumbler and then gently move the meat towards the other side. This is important for meat cuts with inherently weak connective tissue structure. The capacity of tumblers and massagers ranges from a few kg (test kitchen models) to several tonnes. The degree of fill (ratio of meat volume to total volume) is also very important in adequate massaging/tumbling without damaging the meat structure. For example, low fill of a large tumbler can result in dropping the meat from a higher level and potentially breaking more connective tissue (note: this can be desirable when dealing with tough cuts, but is a problem with soft meat).

Temperature control during the operation is another important factor. Tumblers/massagers are usually placed in a refrigerated area and/or have a double wall construction that allows a fast cooling by a cooling agent. Removing the heat created by friction (moving meat pieces) and keeping the meat cold are important in protein extraction (i.e., studies show that 2-4°C is ideal) and microbial growth suppression. Agitation/movement can be applied for one to several hours (e.g., slow or intermittent overnight; see recipes for oven roasted turkey breast products in Chapter 13), and help extract the salt soluble proteins that will serve to bind meat chunks together during cooking (i.e., the proteins will gel during heating). Protein extraction can be further enhanced if the mechanical action is performed under

a vacuum. Most commercial massagers/tumblers are equipped with a vacuum pump via a hose connected to the tumbler's lid so they can turn it on without any disturbance. This also helps to remove small air pockets created during injection. The processor should validate the performance of the tumbler.

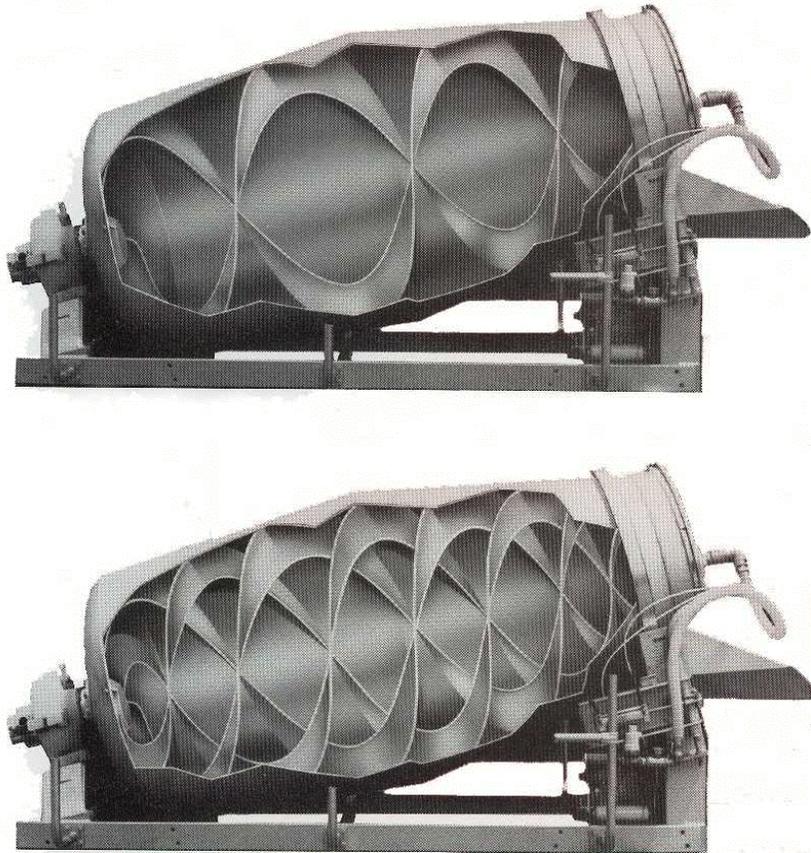


Figure 10.3.3.1 Illustration of a tumbler with a two and four ribbon configuration.
Courtesy of Challenge Inc.

This can be done with the help of the equipment supplier and/or testing batches. Figure 10.3.3.2 demonstrates the effect of tumbling time (5, 10, 14 and 18 hrs) and the NaCl substitution with KCl (0, 15, 37, 60, 75%) on ham's elasticity, which

was measured using a texture profile analysis test. Elasticity increased non-linearly with increasing tumbling time up to 13 hrs, and NaCl replacement of up to 37% (i.e., dependent on tumbler type, temperature, meat source, etc.). The authors also illustrated multidimensional optimization and indicated that 15.6 hr tumbling at 12 rpm and 15% NaCl substitution maximized cooked yield and water holding capacity. For optimal sensory attributes the conditions were 12.4 hr at 17 rpm and 18% substitution (Lin et al., 1991).

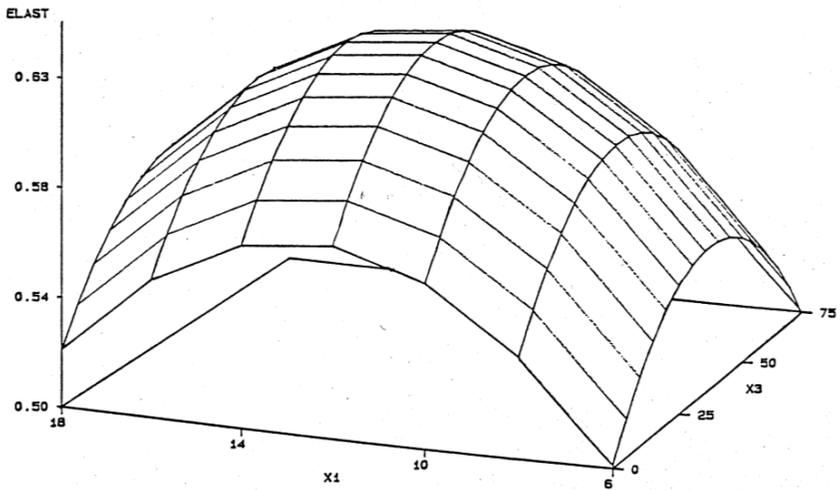


Figure 10.3.3.2 Response surface showing elasticity values for tumbled ham as a function of tumbling time (X_1 in hrs) and NaCl substitution with KCl (X_3 in %) at a tumbling speed of 17rpm. From Lin et al. (1991). With permission.

10.4 Forming, Stuffing, and Netting Equipment

Manual, semi-automated, and fully automated machines are used to form meat into various shapes (e.g., patties, meat balls) and sizes (small sized nuggets, large sized hamburger patties). Stuffing raw meat batter into casings is another way of shaping meat batters (e.g., traditional elongated cylinder type shape, curved sausages at different diameters; see also section on casings in Chapter 13).

10.4.1 Forming Machines

Equipment can be used to produce patties and nuggets that are commonly made from a mixture of ground and/or emulsified meat. The traditional forming machine is basically a press with different templates that can be used to form the desired shape. The meat is fed by a pump from a mixer/blender and is then transferred directly to the forming machine's mold. Alternatively, it can be first fed to a hopper on top of the forming machine (either by gravity or an auger) and later moved to fill the desired mold. The mold is usually made out of metal or hard plastic and can have a single or multiple cavity(ies) (Fig. 10.4.1.1).



Plastic mold to prepare patties

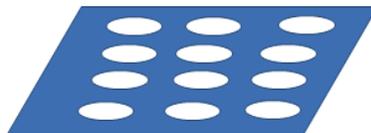


Figure 10.4.1.1 A small patty/nugget forming machine using a wheel based cavities (top; from www.birosaw.com), and a flat type mold used in high speed production lines (bottom).

In traditional forming machines there is a knockout mechanism that discharges the patties onto a conveyor belt. Common equipment on the market operates at 20-60 strokes/min and is capable of forming patties of 30-250 g. New generation forming machines have a gentler discharge performed by compressed air (Fig 10.4.1.2). This can be achieved by using porous metal at the back of the mold. This is also an example of using new technology from the metallurgy field to develop advanced equipment for the food industry. The new generation machines do not have a noisy knock out mechanism and do not exert high pressure on the meat patty.



Figure 10.4.1.2 New generation of low pressure forming machine with compressed air.
Courtesy of Townsend.

The formed products do not usually hold together very well in the raw state, and are therefore “stabilized” by freezing or par frying for 30-90 sec. In some cases, battering and breading equipment is used just after the forming operation to uniformly coat products, such as chicken nuggets, prior to subsequent freezing or cooking. The equipment is usually connected via a series of conveyor belts, which carry the nuggets/patties to a battering and breading machine (see detailed description of equipment in Chapter 14).

10.4.2 Stuffing

Stuffers vary in size and their degree of automation, ranging from manual to fully automated piston/pump driven machines and co-extrusion systems. Traditional stuffers can be divided into two types: piston and direct pump stuffers (Pearson and Gillett, 1996). The piston is driven by manual energy or hydraulic fluid and forces the meat from a cylindrical barrel through a stuffing horn (Fig. 10.4.2.1). The diameter of the horn, the stuffing speed, and the pressure are controlled by the operator and should always match the size and type of casing used (e.g., high speed automated equipment requires strong, uniform casings such as manufactured collagen, plastic or cellulose casings). Different casings (e.g., natural collagen, manufactured collagen, cellulose, plastic; see Chapter 13) are also used for different types of meat products.



Figure 10.4.2.1 Piston type meat stuffer. A knee operating paddle can be seen at the lower part. On the back there is a knob to control the speed of the piston which is moving up and pushing the meat via the stuffing horn; different size horns can be used, depending on the size of the casings. Photo by S. Barbut.

A pump operated vacuum stuffer (Fig. 10.4.2.2) employs an impeller to move the meat forward. The impeller usually has feedback and pop-off connectors so a vacuum can remove trapped air within the meat batter as well as help draw the meat into the pump impellers. Applying a vacuum is optional and vacuum stuffers are more expensive. However, most if not all, large meat producers use vacuum as it enhances the product's appearance. Air pockets left in the meat batter might later show as empty voids in the cooked product. The voids can also be filled with gelatin (melted collagen), or melted fat during the cooking operation and it is advantageous to minimize their presence because they are unattractive. In addition, evacuating trapped air (specifically the oxygen) will minimize oxidation problems and prolong shelf life. Figure 10.4.2.2 shows equipment where air exclusion starts in the hopper (note: this feature is not found in all vacuum stuffers). Later, a feed screw (see vertical shaft) transfers the meat to a pump where it continues to be subjected to vacuum. The single vane of the pump rotates through 270 degrees before reversing direction and starting another sweep cycle. At the end of each sweep, a combination of inlet-outlet valves rotate, which directs the flow of the meat from the top hopper into the cavity that is formed as the vane discharges the product. In general, finely comminuted/emulsified meat products and fine ground products are commonly processed via pump-operated stuffers. When it comes to coarse ground sausages or products with large particles such as meat/fat/cheese/pimento, some processors prefer a piston-type stuffer because of potential damage to the structure when a rotating pump is used. However new rotary vane pumps and elliptical gear type pumps are now designed to handle delicate products such as dry sausage mixes. In any case, prior mixing and blending can be also done under a vacuum.

Fully automated co-extrusion systems are now becoming popular in medium and large meat processing plants. A conceptual breakthrough has been the idea of coating the meat coming out of the stuffer's horn with a semi-liquid casing that can later be cross linked (i.e., to form a strong casings directly on the product), rather than using pre-made casings (Barbut, 2014). With this new concept, plants can now switch from a batch operation, where the processor needs to stop each time a casing bundle is filled, to a continuous, fully automated operation (see Chapter 1). An example of a co-extrusion process using a collagen gel to form the casings is shown in Fig. 10.4.2.3. The meat is pumped out of the stuffing horn at a constant rate and immediately covered with a thin layer of collagen gel (usually 5% collagen, but can also be a hybrid gel of collagen and alginate, or alginate by itself). The co-extrusion head is divided into inner and outer cones that spin in opposite directions. This design allows the collagen fibers to be aligned on the product and increases the casing strength. The product is then submerged in a salt

brine to remove some of the water from the newly formed film/casings. Later, the long meat rope is portioned/crimped and then moved through an air drying cabinet. This is followed by a spray or a bath of liquid smoke that cross links the collagen fibers with aldehydes (see Chapter 13). The product can then be fully cooked, frozen, or sold raw. When alginate is used, calcium salt is used to cross link the hydrocolloid gum (see Chapter 13).

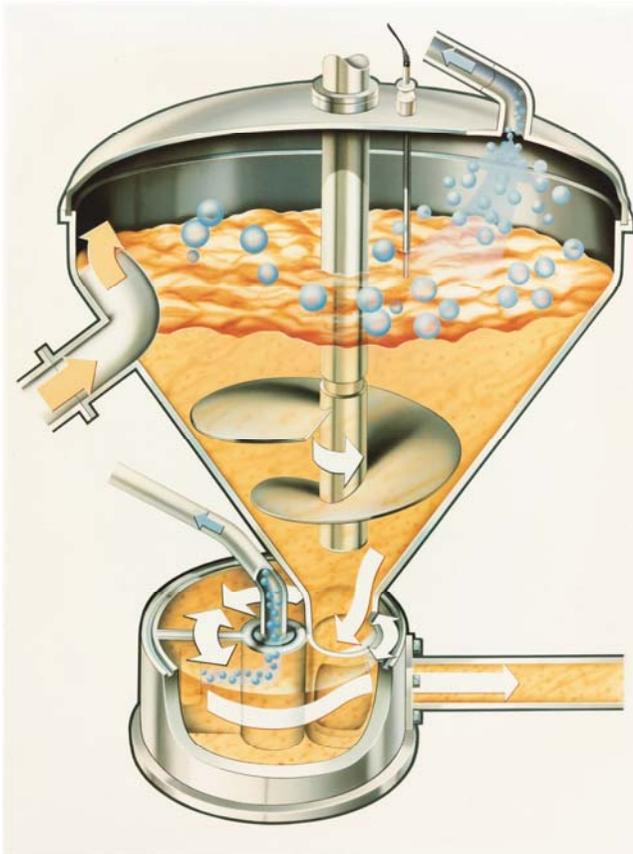




Figure 10.4.2.2 A vacuum meat stuffer (colour illustration), and details of the rotary vane pump mechanism (black and white picture). Courtesy of Handmann.

When using conventional casings, tying the ends or segmenting the product into individual links is performed after stuffing. This can be done by twisting links of small sausages by hand or using special equipment, tying the ends with a thread in the case of medium sized products, or using metal clips for large diameter/heavy products. Large diameter sausages are usually tied or clipped at one end with a hanging loop and then placed on a smoke stick or a hook so the entire surface is free from contact with the equipment or other products. This permits good airflow around the sausages in the smokehouse and prevents touch marks and spotting due to contact with adjacently hung products. In the case of very large, heavy products (e.g., bologna stuffed into 1 – 2 m long cellulose casing), the so called “logs” are placed on metal screens or put into large molds. This horizontal processing helps retain a uniform, cylindrical shape. In general, 25-30% more products can be placed in the smokehouse horizontally as compared to vertically (the degree of smokehouse fill also depends on air flow as well as heating capacity). Processors can choose from various types of fully/semi-automated stuffing machines. Lines that stuff a high volume of sausages (e.g., few hundred frankfurters per min) are now common. Some high-speed stuffing lines are fully automated and the whole line is integrated, synchronized, and computer controlled. In the case of a small

diameter product such as frankfurters, an automated arm can be used to hang the links on a continuous moving line that takes the product directly to the smokehouse. Overall, the high-speed linkers and high volume co-extrusion operations currently set the production economics of the sausage industry.



Figure 10.4.2.3 Co-extrusion head showing meat batter extruded from the stuffing horn and immediately covered with a gel that is de-watered by salt application (blue hose discharging a concentrated salt solution, and then sausage immersed in brine). Later cross linked by smoke. See text for explanation. Courtesy of Townsend.

10.4.3 Netting

Placing large whole muscle products (e.g., turkey breast, ham) or chunked products in nets is advantageous when the product is processed in a smoke house as it allows products to hang next to each other, helps maintain shape, and provides a nice appearance on the products' cooked surface. The product can also be placed in some type of a forming mold to result in a desired shape. The basic equipment consists of a narrowing funnel through which the product is pushed out into a pre-stretched netting sleeve (Fig. 10.4.3.1). There are several options to mechanize the process and often a large diameter pipe (fed via a pump) is used. There are many options for netting including opening size, pattern, strength, coating (protein and/or fat for fast release after cooking), etc.

10.4.4 Cook-in-Bag

Cook-in-bag technology is used to heat different products in a sealed bag. The cooked product can then be removed from the bag and sliced at the plant or by the consumer/retailer (the latter can increase the product's shelf life). The equipment used to fill the bags is similar to that used for netting, but the packaging bag is usually made of a stronger, more durable plastic (see Chapter 11 for more discussion on packaging films). Usually the bag is placed in some type of a forming mold or screen to produce a desired shape.



Figure 10.4.3.1 Raw whole muscle product stuffed into netting. Photo by S. Barbut.

10.5 Smoking

Many meat products are smoked before consumption. Smoking raw meat is done by exposure to traditional smoke, liquid smoke, or by adding smoke extracts. The product can then be sold to the consumer for cooking at home. Smoked raw products can appear cooked on the outside because of colour development during smoking (reactions between carbonyls, reducing sugar, and proteins), so an adequate label is important to alert the consumer. In other cases the processor cooks the products at the plant (e.g., frankfurters, bologna, ham). Quite commonly, processed meat is heated following the smoking process and this is often done in the same chamber. However, it should be realized that these two processes are different. In general, smoking is usually applied prior to heating, however some processors prefer to apply smoke at the end of the cook cycle.

Smoking is one of the oldest methods used to preserve meat. Both the drying and the deposition of numerous antibacterial compounds found in smoke (e.g., aldehydes, acids) help prevent spoilage. Today, smoking is done in dedicated commercial smoke houses (Fig. 10.5.1) and while it is based on the same principles, much less smoke and drying are applied today, mostly to provide unique flavour notes and colour. In such an application, limited amounts of the bacteriostatic compounds found in smoke are deposited on the surface (i.e., penetrating no more than a few millimeters into the product). During the smoking operation the temperature stays low while smoke generated in another area (outside the smoking chamber) is circulated. Alternatively, liquid smoke produced at specialized plants can be used.

Liquid smoke is produced by using small water droplets to capture smoke compounds moving up a long chimney. Traditional and liquid smokes are derived from various hardwoods (e.g., cherry, hickory, oak) that are used to generate the smoke by burning moist sawdust/wood shavings. Softwoods are sometimes used, but special care should be taken to avoid bitter flavour formation. Overall, more than 300 individual compounds have been identified in wood smoke (Maga, 1989; Toledo, 2007).



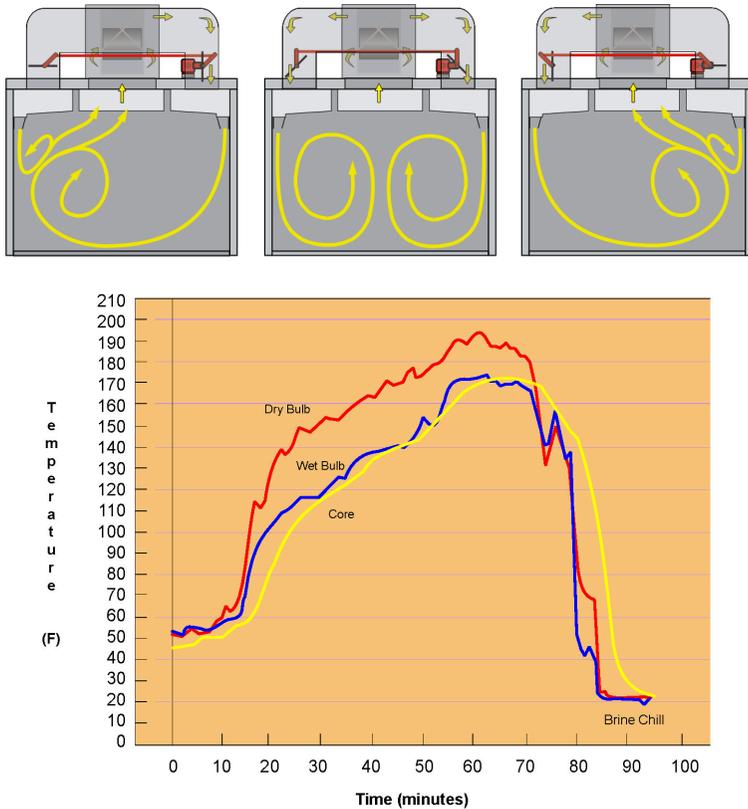


Figure 10.5.1 Illustration of a smokehouse with an air circulating unit, heater and humidifier located on the roof. The smoke unit is placed on the right side (first drawing). Changing air circulation pattern, using dampers, to achieve good heat distribution (second). Example of heating profile of 24 mm diameter wieners (third). Courtesy of Alkar.

Smoking and cooking are considered two separate processes; however, as indicated above, they are usually discussed together because they often occur in immediate succession or even simultaneously in the same location (Rust, 1987). Modern smokehouses are equipped with heat elements and fans so no product movement is required. To achieve the best smoke application the product should be in its raw state because the denatured protein film formed during cooking will reduce smoke migration into the product. Thus, smoking is commonly done at low temperatures, even though some heat is often applied to dry the product's surface. The latter is done to ensure that the smoke will not be washed off the product (e.g., condensation on the cold surface of the product can be a problem).

When liquid smoke is used, the product is dipped or sprayed prior to cooking. In all cases, smoke permeable casings (e.g., collagen, cellulose) should be used. If smoke flavourings are to be added directly into the raw batter, however, a special preparation (e.g., smoke components precipitated on sugar or dextrose carrier, sold as a dried ingredient) is used and the casings need not be permeable.

Modern smokehouses have specialized heating and ventilation systems (usually located on the top) that include fans, dampers, heating elements, and a steam supply. Many systems are computer controlled so the operator can program and save all parameters required for a specific process (e.g., heating, smoking, relative humidity, air flow).

10.6 Cooking/Heating

There are several ways to heat meat products. A brief discussion is provided below and additional information is provided in Chapter 11. Overall, heating can be done in water, oil, by hot air, or by infrared or microwave energy. Cooking produces various flavour/aroma compounds and results in distinct textural changes due to the denaturation of different muscle proteins (see Chapters 16 and 13, respectively).

a. Heating with hot air – using an oven/smoke house is one of the most common ways of cooking sausage-type products. The products are placed in a chamber or moved through a long tunnel while hot air is generated by gas burners, electrical elements, or thermal fluid. An example of a modern spiral oven that employs hot fluid to heat the air that cooks the meat is shown in Fig. 10.6.1. The main determinants of heating rate are the temperature difference between the product and air (also known as “ ΔT ”), air speed, relative humidity, product size, and oven capacity. Relative humidity (expressed as a percent of maximum moisture that can be held by the air at a given temperature) is particularly important as water is a good conductor.

b. Heating with water – is a faster way of transferring heat than hot, dry air. Water baths and steam kettles are used for cooking sausages and whole muscle products stuffed into moisture proof casings, glass jars, or metal tins. In other cases, unpackaged meat cuts are directly immersed in water/soup. The latter is commonly done when prolonged, moist heat is required to tenderize tough connective tissue (e.g., mature poultry/beef meat).

c. Frying – uses hot oil at a temperature of 180-195°C. This is a fast and efficient way of transferring heat because the ΔT is high. Frying also results in a crisp outside

texture and is desirable in products such as chicken/pork nuggets. A detailed description of the frying operation, including an illustration of a continuous deep fat fryer, is provided in the Chapter 14.

d. Microwave heating – uses electromagnetic waves to vibrate water molecules in the product, and is therefore one of the fastest cooking methods. Heating results from friction of water molecule rotation due to rapid fluctuation in the electromagnetic field (915 and 2450 MHz are usually allowed for commercial microwaves, so there is no interference with communication wavelengths). As heating occurs throughout the product, this rapid process often does not allow enough time for surface browning. Therefore, other cooking methods, such as infrared, are also commonly used together to both cook and brown the product. Low microwave energy is also used to defrost meat. However, special care should be taken since there is a large difference between the heating coefficient of water and ice (see Chapter 11).

e. Infrared heating – uses a special lamp that produces a high level of infrared radiation to heat up the surface of the product. The heat is then gradually transferred, by conduction, towards the center of the product. Infrared heating is mainly used to warm up cooked products, keep products on a display counter hot, and brown the surfaces of microwave cooked products.

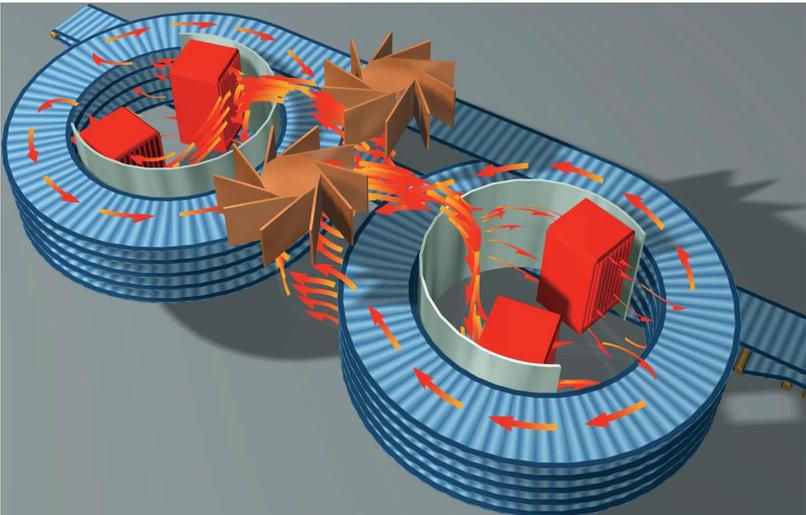


Figure 10.6.1 A spiral oven utilizing hot air for cooking meat and other food products. This oven has two separate towers/zones and each can operate under different conditions (e.g., temperature, humidity, air speed). Courtesy of Marel.

10.7 Cooling

Cooling of the heated meat products is required if the product is not consumed right away. The time to cool the product to a safe, refrigerated storage temperature is usually government mandated (see example in Chapter 12, dealing with HACCP) and can affect food safety (see example of *C. prefringens* in Chapter 15).

Cooling can be done using different mediums and methods. The most common include:

- a. Water chilling by applying a cold shower to sausages in a smoke house or by immersing products packaged in moisture proof casings in cold water. When immersion is used, a counter current should be applied such that the product and water flow in opposite directions.
- b. Air chilling by using cold air (e.g. -5 to 5°C) in specially designated refrigerated areas. Air speed, temperature, and humidity are major factors in establishing cooling rates.
- c. Contact plate chilling for uniformly packaged products where they come in contact with very cold plates that serve as a large “heat sink” that quickly remove the heat from the product. Some of the plates are hollow and a cold fluid can be circulated inside.
- d. Cryogenic chilling is used when very fast cooling is required. In this case carbon dioxide snow or liquid nitrogen are used. The boiling point of these materials is very low and therefore heat removal is fast. Figure 10.7.1 shows a cryogenic chilling/freezing operation.



Figure 10.7.1 Cryogenic chilling/freezing operation.
Courtesy of Praxair.

10.8 Peeling

The casing can be peeled at the plant or by the consumer. In the case of small diameter products such as hot dogs/frankfurters, peeling is often done at the plant by automated equipment. The products are passed through a short steam tunnel to help loosen the casing and then a small blade is used to cut open the casings along the moving product. The machine can strip off hundreds of casing links per minute. In such products, so called “easy to peel” cellulose casings are used (see micrographs of such casings in Chapter 13) to prevent excessive adherence. When large diameter products are prepared for slicing (e.g., bologna), the thick cellulose/plastic casing is removed by hand or semi-automated equipment.

10.9 Slicing

Cooked sausages and products such as whole muscle roasts/hams are often sliced and packaged in the processing plants. This provides the consumer with a convenient, easy to use product. The industry has developed high speed, automated slicing equipment with precise portion control. The introduction of computerized weighing equipment has had a significant contribution on the development of modern slicing equipment. Figure 10.9.1 shows an example of a high speed slicing line that also has a packaging module. The slicer has a large circular blade that slices the product at a predetermined thickness. The products sliced by this machine are usually long rolls (e.g., 1 – 2 meters) and the machine can later stack the slices at a predetermined number and orientation (e.g., shingle arrangement). Stacks are then placed on a conveyor belt and moved to an automatic packaging machine. The equipment can also be programmed to stack products with or without the insertion of paper/film in between individual slices or stacks. A number of new machines on the market today can self-correct weight variations using a fast feedback control mechanism that increases/decreases slice thickness. This is done by continuous computer monitoring of the weight of each stack of products.

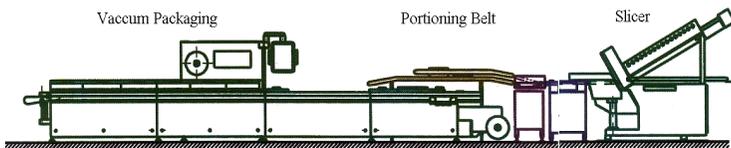
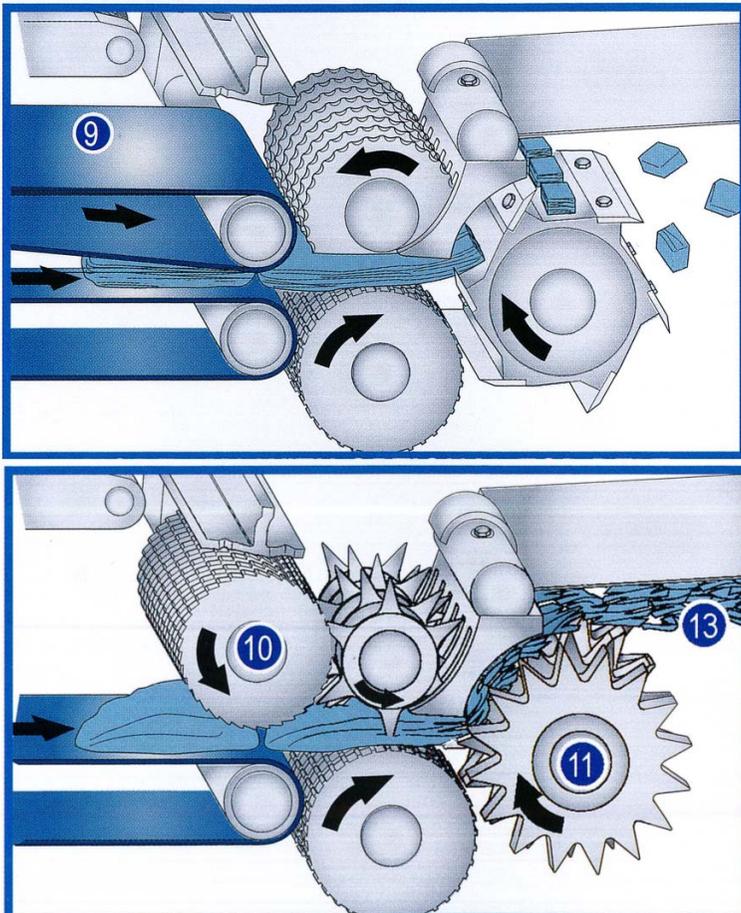


Figure 10.9.1 Illustration of a high speed slicing line. Courtesy of Dixie Inc.

Producing cubes, strips, or diced product is done for a variety of reasons. Whole muscle strips can be used in tacos by the fast food industry or consumers at home. The machine shown in Figure 10.9.2 can also be used to cut frozen or tempered fresh meat. Feed rollers hold the product flat while a moving belt advances it towards the cross-cut knives, which slice the product into strips (thickness can be changed by inserting more/less knives). The process can be terminated at this point or continued to dice the strips by a second set of circular knives. Overall, different cube sizes and shapes can be produced by spacing the knives at different distances from each other.



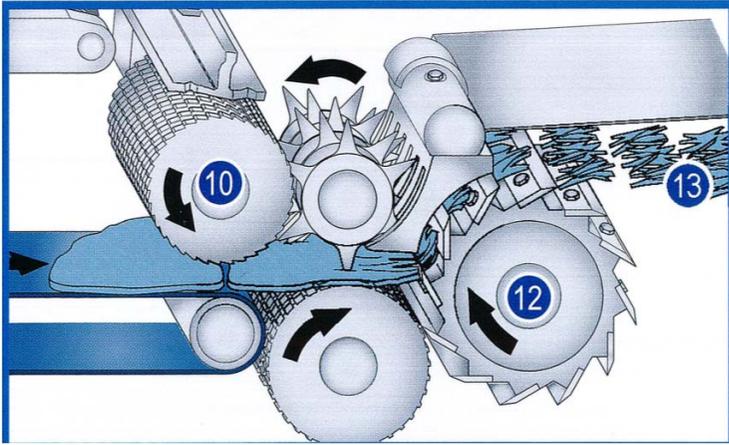


Figure 10.9.2 Principle operation of different dicing devices to produce cubes and strips.
Courtesy of Urschel Inc.

10.10 Packaging

Most meat products are packaged prior to being shipped from the plant. The packaging material protects the product from physical damage, recontamination, and can also serve as a marketing tool (e.g., company logo, advertising, cooking/serving suggestions). The diversity of packaging materials and equipment used by the meat industry is beyond the scope of this book and the reader is referred to textbooks such as Robertson (2013). However, an illustration of two basic meat packaging concepts (vacuum packaging and skin packaging) are provided here and the properties of common packaging films used for food/meat are provided in Chapter 11. Figure 10.10.1 illustrates the use of a vacuum chamber to package a meat product. After the lid is closed, a vacuum is applied and air is evacuated from the chamber. The plastic bag is then sealed by applying heat to a special polymer that melts in the seam area. The process can be done manually or automatically on a high speed line. The manual operation is a batch process (i.e., each package is placed and removed manually from the chamber) while the automated process is continuous line where the product is placed on a special platform, covered with the lid, the air is pulled out, and the bag is sealed. This is commonly done in a round table configuration (to gain space), where enough time is allowed for air removal from this specially designed platform. Packaging films are usually composed of different layers, each contributing a specific function (e.g., oxygen barrier, heat sealant, strength; see Chapter 11).



Figure 10.10.1 Illustration of a vacuum packaging machine. Bags are placed with their opening facing the vacuum nozzles side and on top of the heat sealer strip (gray strip). When the cover is lowered vacuum is pulled (degree adjusted on the front panel). When the required level is reached, the upper heating sealer is lowered and forms a permanent seal. Note: the bag must have an inner layer of heat sealing polymer which allows this to take place.

Photo by S. Barbut.

Skin packaging of sliced or unsliced meat products is also common. The process involves placing the product on a piece of soft or rigid cardboard or plastic film, which is then covered by a flexible film (Fig. 10.10.2). In the sealing station, heat is applied at the seams and the special polymer sealant is fused together (from both sides) to provide a complete integral seal. The packages are then separated automatically by cutting around the seal's perimeter, labelled, and moved to the boxing area.

Special ridged plastic packages filled with inert gas are also used for fragile products that might stick together and deform, such as pre sliced luncheon meats.

Meat processors can select from an assortment of different packaging materials that include single and multilayer films. As indicated before, most packaging films are composed of several layers in order to achieve desired characteristics in a cost effective manner, while still obtaining a relatively light, workable film. Saran, which has low gas and water permeability, is a popular film used in multilayer film production, together with other materials such as polypropylene, which

provides high stretchability. Modern packaging films can have up to a dozen layers that include printed material, coating to protect the print from smearing, and layers to minimize dust collection, oxygen transmission, and provide a UV barrier.

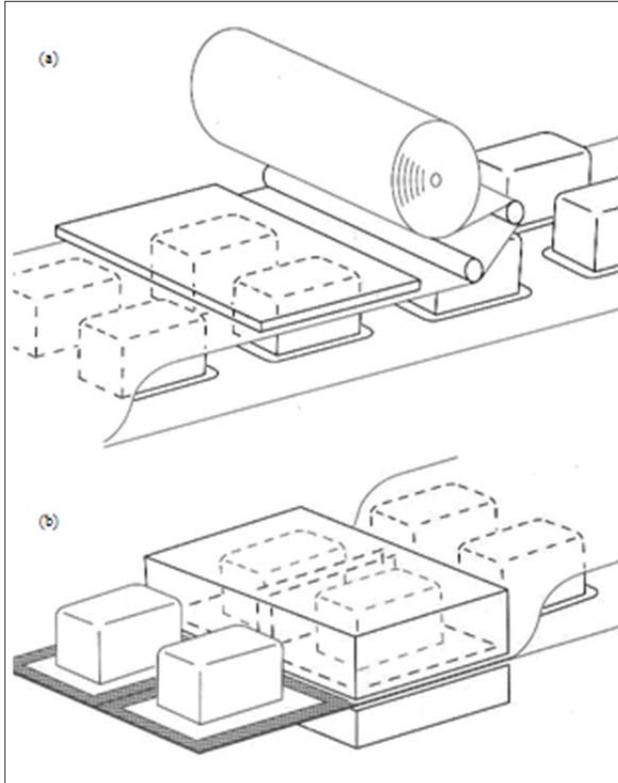


Figure 10.10.2 Illustration of the skin packaging concept showing entry to the sealing station (a) and the sealing section (b). Courtesy of Dixie Inc.

10.11 Safety Checks (foreign objects, seal integrity)

Various checks are performed by quality control personnel on random samples. In addition, all products go through metal detectors, which are mandatory in many countries and are now installed in most processing plants. Regulatory bodies such as the USDA have indicated:

“The extensive exposure of some products to metal equipment such as grinders, choppers, mixers, shovels, etc., causes the possibility of metal contamination ... therefore the use of electronic metal detectors is highly recommended ...”

In addition to meeting regulatory requirements, the detectors can also help the processor:

- a. Prevent damage to processing equipment
- b. Comply with quality standards of various retailers
- c. Avoid the cost of consumer complaints and recalls

The most common types of metallic contamination in the food industry include ferrous (iron), copper, aluminum, and various types of stainless steel. Of these, ferrous metal is the easiest to detect, and relatively simple detectors, or even magnetic separators, can perform this task well (Anonymous, 1996). Stainless steel alloys are extensively used in the food industry and are the most difficult to detect, especially the common, non-magnetic grades such as 316 (EN58J) and 304L (EN58E). Non-ferrous metals such as copper fall between these two extremes. To detect other materials, such as hard plastic or glass, x-ray machines can be used.

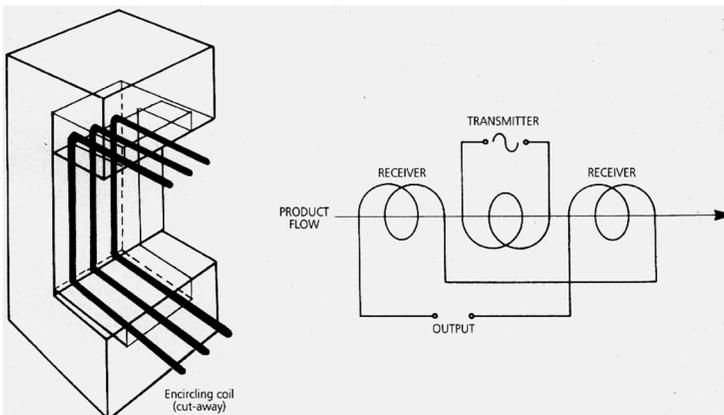


Figure 10.11.1 Illustration of the principles used in constructing a metal detector.
Courtesy of Safeline Inc.

Metal detectors that employ a balanced, three-coil system are common since they have the capabilities to detect small particles of non-ferrous and stainless steel. The three coils are wound on a non-metallic frame or former, each exactly parallel

with the other (Fig. 10.11.1). The center coil is connected to a high frequency radio transmitter and the coils on either side of the center coil act as radio receivers or aerials. As these two coils are identical and the same distance from the transmitter, they pick up the same signal and an identical voltage is induced in each. When the coils are connected in opposition, they cancel out and result in zero output but when a metal particle passes through the coil arrangement the high frequency field is disturbed and the state of perfect balance is lost and the output is no longer zero. The resulting signal is processed, amplified, and used to detect unwanted metal (Anonymous, 2014). To prevent airborne electrical signals or nearby metal items and machinery from disturbing the detector, the complete coil arrangement is mounted inside a metal case with a hole in the center to allow for product passage. For suggested installation points, such as after packaging fresh meat or after freezing fried products, see the HACCP generic models in Chapters 6 and 14, respectively.

An x-ray detector, shown in Figure 10.11.2, can also be used at the end of a line. The x-rays that go through the product reveal items with different densities within the food matrix (i.e., same as used for medical imaging or security checks at airports). The equipment scans each package and materials reflecting x-rays are seen on a computer screen. A computerized image analysis system can be used to sound an alarm, take a picture, and/or kick the product out of the line. Many fast food and supermarket chains require that their suppliers use such equipment.



Figure 10.11.2 An in-line x-ray detector system. The system can be programmed to detect and automatically eject products with foreign objects (e.g., bone fragments with a minimum size of 2 mm). Images and data are saved to assist employees to determine the location and quickly deal with rejected samples. Courtesy of Marel.

10.12 Labeling

Package labeling is usually done at the plant, as it is not difficult to customize labels for each supermarket/grocery store. High speed weighing equipment and printers place exact information (e.g., weight, price, best before date) on each package. This is usually done on top of pre-made colourful labels/stickers that are placed on the product. Figure 10.12.1 shows the concept of high speed automated labeling at the end of the line.

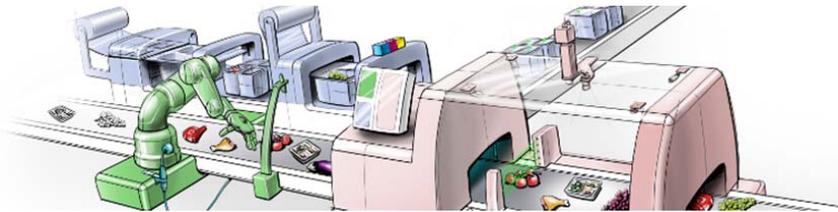


Figure 10.12.1 Concept of high speed labeling using image analysis and automatic robotic system. From www.picknpack.com.

10.13 Storage and Distribution

After the product has been packaged it can go directly to the store (i.e., put on a truck) or be stored at the plant/warehouse for a certain period of time. Freezing can be used as another option to extend the product's shelf life. As both raw and cooked meat products are susceptible to spoilage (unless canned or fully dried), they should be stored at a low temperature. Today, meat companies and supermarkets invest a lot of money to maintain and improve their cold chain distribution channels. In addition, government agencies monitor and inspect the distribution system and ensure consumer safety.

References

- Anonymous. 2014. The Guide to Reducing Metal Contamination in the Food Processing Industry. Safeline Ltd., Salford, UK. Available on Web.
- Barbut, S. 2014. Review – Automation and meat quality – global challenges. *Meat Sci.* 96(1):335.
- Barbut, S. 1999. Advances in determining meat emulsion stability. In: *Quality Attributes of Muscle Foods*. Xiong, Y.L., C.-T. Ho and F. Shahidi (Eds). Kluwer/Plenum Publishers, New York, NY, USA.
- Hanlon, J.F. 1992. *Handbook of Package Engineering*. Technomic Publ., Lancaster, PA, USA.
- Lin, G.C., G. Mittal and S. Barbut. 1991. Optimization of tumbling and KCl substitution in low sodium restructured hams. *J. Muscle Food.* 2:71.
- Maga, L.A. 1989. *Smoke in Food Processing*. CRC Press, Boca Raton, FL, USA.
- Pearson, A.M. and T.A. Gillett. 1996. *Processed Meats*. Chapman & Hall Publishing, New York, NY, USA.
- Robertson, G.L. 2013. *Food Packaging: Principles and Practice*, 3rd Edition. CRC Press, New York, NY, USA.
- Rust, R.E. 1987. Sausage products. In: *The Science of Meat and Meat Products*, 3rd Edition. Price, J.F. and B.S. Schweigert (Eds). Food & Nutrition Press, Westport, CT, USA.
- Toledo, R.T. 2007. Wood smoke compounds and functional properties. In: *International Smoked Seafood Conference Proceedings*. Kramer, D.E. and L. Brown (Eds). Alaska, USA.