# Advances in Meat Processing Technologies:

## Modern Approaches to Meet Consumer Demand

**Daneysa L. Kalschne**
**Marinês P. Corso**
**Cristiane Canan**

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**Authored by**

**Daneysa L. Kalschne**

**Marinês P. Corso**

**&**

**Cristiane Canan**

*Universidade Tecnológica Federal do Paraná*
*Department of Food, Medianeira, Paraná*
*Brazil*

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Authors: Daneysa L. Kalschne, Marinês P. Corso and Cristiane Canan

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# FOREWORD

The aim of this book is to provide an approach to recent improvements in conventional meat products' processing and the development and/or use of new technologies to students, researchers, and lecturers in the meat science and technology field, as well as professionals in the meat industry. Needs and demands by consumers for meat-based products have guided meat processing plants to adapt themselves to this new reality by implementing innovative technologies and ensuring that meat products are stable and microbiologically safe, nutritionally healthy, with good sensory characteristics, practical and of quick preparation, with compatible and affordable costs. Beef, pork, and poultry are the ones most used in meat products preparation. The use of additives and traditional techniques, such as fermentation and drying, salting, smoking, and cooking, contribute to the production of safe meat products. Chapter 1 provides an overview regarding the importance of the meat-based market in the world, as well as overall meat processing aspects. Chapters 2 to 7 describe conventional and emerging technologies presenting relevant and promising data applied in the processing of dry-fermented meat products, emulsified, salted and non-emulsified thick mass, marinated, and restructured products, and advancements in fresh meat tenderness. These chapters discuss the QDS (quick-dry-slice) technology that aims at reducing the processing time of sliced matured and/or fermented meat products; the use of ultrasound or high pressure to reduce salt contents of meat products as well as improve emulsion stability and replace pork fat; and new cooking methods such as microwaving, radio frequency and ohmic heating, the latter two could be used for reducing cooking time and production costs. Also, technologies such as pulsed light, ultraviolet light, irradiation, ultrasound, and high hydrostatic pressure may reduce microbial contamination of meat and meat-based products. Furthermore, the application of ultrasound waves could augment fresh meat tenderness. The use of such new technologies would reduce additives content, posing economic benefits such as reduced preparation time and reduced energy and water consumption. In addition, safety and quality are secured and the processed products have sensory characteristics similar to products obtained using traditional technologies. A specific chapter describes strategies for the development and production of meat analogues with nutritional and sensory properties typical of meat products to meet the demands of vegetarians and vegans alike. New approaches to the use of alternative ingredients in order to obtain meat-based products with technological, microbiological, and sensory quality are discussed in the last chapter. These new ingredients aim at replacing animal fat, reducing sodium chloride, and chemical additives, such as nitrites and synthetic antioxidants. The advancements in processing technologies and/or development of new meat-based products covered in this book were based on relevant literature and experiences of the authors with nearly two decades of experience in lecturing and researching, as well as technical-scientific interaction with meat processing plants. This book on Advances in Meat Processing Technologies ought to provide the readers with further knowledge regarding recent developments in the new technology for the full meat processing chain.

**Elza Iouko Ida**
Centro de Ciências Agrárias, Universidade Estadual de Londrina, Rodovia Celso Garcia Cid, Postal code 86057-970, P.O. Box 10.001, Londrina, Paraná
Brazil

# PREFACE

Meat and meat-based products play an important role as foods in the diets of a large number of people around the world. However, environmental and social issues have posed a challenge on the world's meat production, given the new perspectives of conscious production and consumption of products from animal origin. The authors, meat science and technology researchers, felt the need to present in this book new and key technologies that have been studied in order to reduce production costs, minimize environmental impacts and produce safe and quality meat products. Meat and meat-based products comprise a group of foods that raise the social status when consumed since in ancient times, meat obtention was associated with an efficient and wealthy provider in families. The development of meat science and technology brought solutions that have allowed the consumption of meat in its entirety, in a safer and more diversified way, as in the past, slaughtered animals had to be consumed quickly since household appliances such as refrigerators and freezers were either non-existent or not often found in homes. Faced with the need, traditional processes such as salting, smoking, and fermentation have emerged, and, more recently, processes such as emulsification, marinating, and tenderizing of meats, which in addition to allowing conservation, have further diversified meat products. At present, we find a wide range of industrialized meat products readily available in supermarkets. However, we as consumers do not always come to realize the evolving processes in the meat industry, which aim at meeting consumers' expectations and demands. Besides that, there has been a need for adaptation and modernization of slaughterhouses, as well as the use of more suitable processing technologies, saving water, energy, and reducing waste production. However, these new approaches ought to provide similar or even higher nutritional, sensory, and food-safety levels. Our efforts as researchers and lecturers in the meat science and technology field are not only restricted to our students, this book emerged within this context, aiming at informing students, researchers, lecturers and others who are interested in the subject, about new meat and meat-based products processing technologies. "Advances in Meat Processing Technologies" comprises 9 chapters, the first of which addresses the world panorama of meat production and consumption, highlighting the three most consumed types of meat worldwide - beef, pork, and poultry. Chapters 2 to 7 discuss the use of emerging technologies in traditional meat preservation and diversification processes, including fermentation, emulsification, salting, marinating, and meat tenderization. Emerging technologies studied by several researchers worldwide are addressed in the aforementioned chapters, such as ultrasound, high hydrostatic pressure, pulsed light, ultraviolet light, irradiation, ohmic heating microwaving, radio frequency heating, and quick-dry-slice. Faced with a new trend in the consumption of vegan products, we also have addressed this group of food in a dedicated chapter.

Chapter 8 discusses meat analogues production techniques using alternative protein sources, as well as examples of meat products' preparation using that raw material. Finally, chapter 9 argues on innovations in terms of additives usage since there has been a rise in the use of natural products by consumers without any chemical additives.

The use of phytic acid to replace nitrite is worth mentioning, being one of the greatest innovations developed by our research group, which has already been patented and mentioned in this chapter, as well as proposals for the use of natural antioxidants, and fat, and salt replacers. This book summarizes a part of our incredible experience working with meat and meat-based products, as well as our passion for the meat science and technology field. We hope that the readers will enjoy reading it and wish you a joyful reading!

## ACKNOWLEDGEMENTS

The authors would like to acknowlegde the following Brazilian financial agencies; Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Fundação Araucária, Universidade Tecnológica Federal do Paraná (UTFPR) and the Post-Graduate Program in Food Technology (PPGTA), and Universidade Estadual de Londrina and the Post-Graduate Program in Food Science by their support in our researches and for this book elaboration. The authors would also like to acknowledge the meat processing plants located in Western Paraná State by the collaboration and partnerships in the recent years, the under-graduate and post-graduate students by their motivation, dedication, companionship, and fun, and Dr Paulo Stival Bittencourt for his support elaborating the Figures section. Last but not least, we would like to thank two wonderful Brazilian researchers, Dr Nelcindo Nascimento Terra from the Meat Technology field and Dr Massami Shimokomaki from the Meat Science field (both in memorian), for their great examples that have encouraged and inspired us throughout our careers and in this book elaboration.

## CONSENT FOR PUBLICATION

Not applicable.

## CONFLICT OF INTEREST

The authors confirm that the authors have no conflict of interest to declare for this publication.

**Daneysa L. Kalschne**

**Marinês P. Corso**
&
**Cristiane Canan**
Universidade Tecnológica Federal do Paraná
Department of Food, Medianeira, Paraná
Brazil

CHAPTER 1

# The Meat Industrialization Scenario: Production, Consumption, and Product Changes Driven by Consumers

**Abstract:** Meat is consumed worldwide and from ancient times to the present day, the development of meat products and processes has been driven by meat consumers. Beef, pork and poultry are the most common varieties of meat preferred for human consumption and the emergence of meat processing industrialization has allowed the use of the entire carcass, the development of different products, and microbiological safety due to advances in the technology used. Meat consumers have been driving production trends for meat products that aim at acceptable nutritional, physico-chemical, microbiological and sensory characteristics of the final product. In this context, the development of emerging technologies for meat industrialization aims at improving conventional processes, offering new and suitable solutions to the meat industry to meet consumer demand.

**Keywords:** Additive, Emergent Technologies, Healthier Products, High Hydrostatic Pressure, Irradiation, Microwave, Meat Analogues, Microbiology Safety, Natural Ingredients, Ohmic Heating, Pulsed Light, Radio-Frequency, Ultrasound.

## INTRODUCTION

Meat is consumed worldwide. In the past, it was associated with strength and power, a typical illustration of one's social status. Nowadays, this perception is still valid and such a context has persisted over the years [1]. Meat sensory properties, such as color, aroma, texture, flavor, juiciness, and chewability [2] have attracted ever more demanding consumers.

Furthermore, meat is recognized by its nutritional properties, consisting of 70% water, which is affected by the lipid content ranging from 8% to 20%, 18% to 23% protein, 1% carbohydrates, and 1 to 1.2% minerals [3, 4]. The protein content has been highlighted due to amino acids' high biological value especially those essential to the human diet [4 - 6].

The content and composition of meat lipids vary according to aspects such as spe-

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cies, breed, gender, age, feed (especially for pork and chicken), nutritional status, as well as the animal's activity level [7 - 10]. Overall, meat has high saturated fatty acid levels to keep the fat tissue healthy, while phospholipids

possess higher unsaturated fatty acids levels conferring greater fluidity to the muscular cells' plasmatic membrane [3].The small portion (<1%) of carbohydrates is represented mainly by glycogen that is used as a muscle energy source [3, 4].

Meat is considered an excellent source of water-soluble vitamins such as thiamine, riboflavin, niacin, vitamin $B_6$, and vitamin $B_{12}$. For the mineral content, red meat is famous due to its iron content combined with myoglobin content. In addition, potassium, phosphorus and magnesium are also abundant in meat [3, 4, 11]. In addition to the importance of calcium in muscle contraction, considerable amounts of such minerals are only found in mechanically processed meat due to the presence of microscopic bone fragments [3].

In 2018, worldwide meat production increased by 1.0% to 327 Mt, reflecting an increase in bovine (hereafter "beef"), pork and poultry meat production, with rather modest gains for lamb. The world's meat exports (excluding live animals and processed products) are forecasted to increase 18% more by 2028 than in the base period. This represents a decline in the 1.4% average annual meat trading growth rate compared to 3% during the previous decade. However, the total meat output traded share on the global market could increase slightly [12].

According to the data from the United States Department of Agriculture (USDA) [13], worldwide beef production for 2020 could reach 61,861 Mt (carcass weight equivalent), led by the USA and followed by Brazil, the European Union and China. For pork, the forecast for 2020 indicates a 95,223 Mt (carcass weight equivalent) production, led by China and followed by the European Union, USA, and Brazil. For chicken, the production in 2020 could reach 103,498 Mt (ready-to-cook equivalent), led by the USA and followed by China, Brazil and the European Union.

Fig. (**1**) presents the worldwide per capita meat consumption considering beef, pork, and poultry meat per continent. The data were provided by the Organization for Economic Co-operation and Development (OECD) [14]. It was observed that the leading meat producers (including beef, pork and chicken) are also the leading consumers.

The meat marketing success depends on continuous innovation and increased production of high-quality products. It is important to point out that meat consumption patterns are constantly changing. These changes are associated not only with wide-ranging, socio-economic, and cultural trends, but also with specific lifestyles of increasingly diversified consumer groups and the use of natural resources.

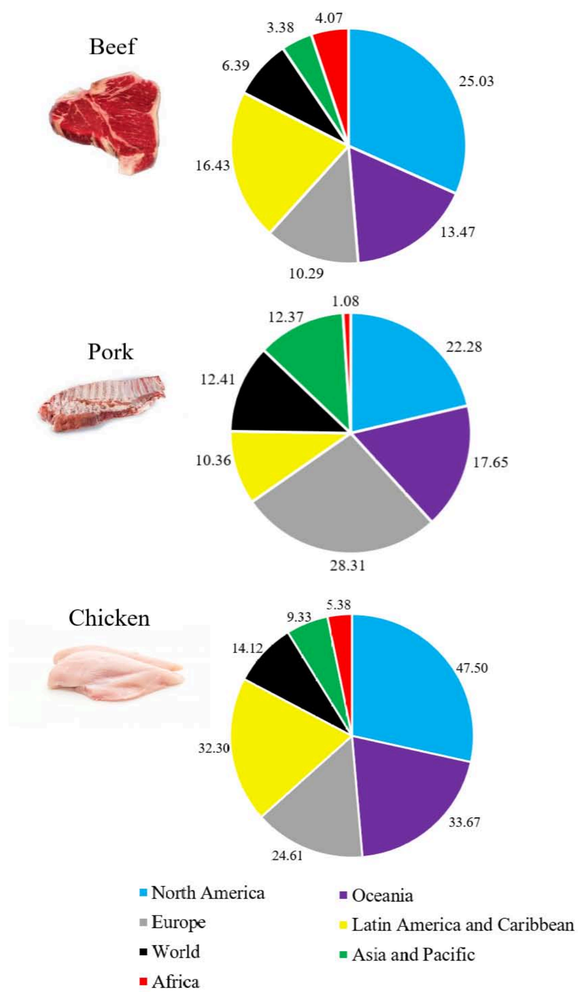


**Fig. (1).** Meat per capita consumption worldwide (%) (data from OECD [14]).

In this context, good taste, convenience orientation, and meat avoidance are some important meat consumption trends that put pressure on policymakers aiming to influence consumer behavior and achieve more sustainable consumption [15]. It should be emphasized that meat products' sales are subdivided into fresh and processed ones and the decision to purchase either one or the other is affected by the consumer profile. Consumer preferences differ according to the type of meat

**CHAPTER 2**

# Dry Fermentation Technology

**Abstract:** The technology of the production of dry-fermented products is old and even in current days these meat products are produced, appreciated and consumed worldwide. The fermentation and drying steps are responsible for chemical and biochemical transformations that ensure the final characteristics of the product were reached. One of the disadvantages in dry-fermented product processing is the time required for all transformations that characterize the product and meets the required standard of safety and quality. Thus, the use of emerging technologies allows the improvement in the production process considering the use of new approaches, always ensuring food safety and quality. In this chapter, the ultrasound, pulsed UV light and QDS process® are discussed. The approach includes the advantages and disadvantages of each technology, the report of researchers describing the use of mentioned technologies and the most probable mechanisms associated with the effects.

**Keywords:** Fermented Sausages, Ham, Pulsed UV Light, Quick-Dry-Slice Process®, Salami, Starter Culture, Ultrasound.

## INTRODUCTION

Dry-fermented meat products are consumed worldwide representing a part of traditional diets and perceived as attractive gastronomic entities contributing to cultural and geographic distinctiveness [1]. This processed meat product group is characterized by a ripening process accompanied by a more or less intense drying and even large of chemical and biochemical transformations [2]. Sausages and some meat cuts are the most popular dry-fermented products, which were named and prepared according to the influence of specific regions and diverse types had the designation of origin recognized. Some examples include Parma ham from Italy, Chorizo, Serrano and Iberian ham from Spain, Milan and Italian salamis, and Sobrassada from Mallorca (Islas Baleares) [2 - 5].

The dry fermented technique was mainly associated with pork meat industrialization [6].

The sausage consisting of seasoned and salted minced meat that is stuffed into intestinal casings, while is based on the art of dry ham production previously developed by the Celts and Gauls, consisting of the salting and drying of hind legs

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of wild boars and pigs [1]. The most popular and famous dry-fermented cut is ham; however, the shoulder and loin are also produced and consumed.

Over the years, fermented meats came to exist in an overwhelming variety, characterized by large differences in ingredients, shape and caliber, and processing conditions. Several types of meat have been applied, including pork, beef, horse, donkey, deer, poultry, and ostrich [1]. In this context, the possibility of the use of emerging technologies on dry-fermented products represents alternatives in order to improve food safety, quality, and manufacturing process time consumption.

## TRADITIONAL DRY-FERMENTED PRODUCTS ELABORATION PROCESS

Salami is prepared by grinding the meat and fat and mixing with all other ingredients including salt, curing salts as nitrite and or nitrate, sugars, spices, antioxidants, and starter culture [6]. Moreover, the processing technologies may differ depending on the drying intensity, ripening length or smoking [2]. Table **1** summarizes some dry-fermented meat product formulations. Note the high salt content used in the formulations, and considering that during the maturation stage the product can lose up to 50% moisture, which causes the salt content in the final product to increase significantly. Thus, the reduction of the salt content of these products is necessary and will be discussed later on as new technologies can contribute.

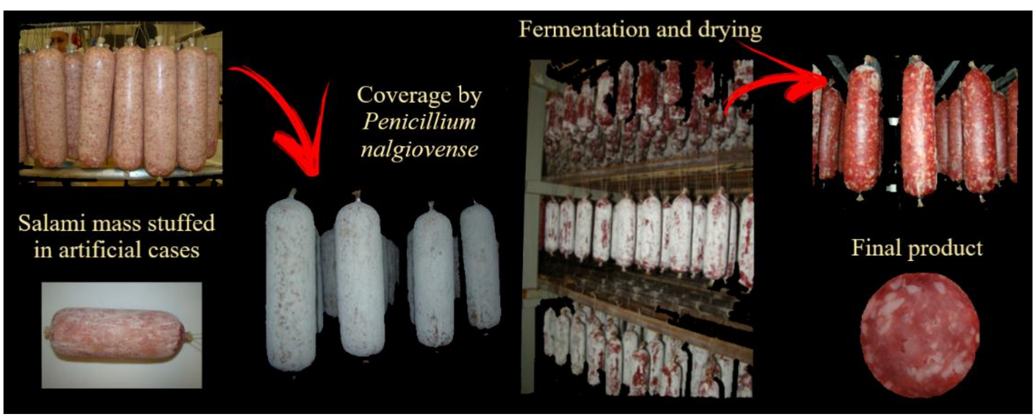


**Fig. (1).** Characteristics of salami during product elaboration.

The mass is stuffing in artificial casings and is submitted to a fermentation/drying for a few days with the external development of mould (*Penicillium nalgiovense*), and ripening for sufficient time up to reaching the desired water activity in the final product (Fig. **1**) [6]. The dry-fermented products were generally packed and stored under a modified atmosphere composed of nitrogen and carbon dioxide (80:20, v/v) or under vacuum to enhance their shelf life stability by minimizing microbial growth and lipid oxidation processes [7, 14].

**Table 1. Dry-fermented meat products formulation.**

| Meat product | Meat base | Ingredients and additives | Starter culture | Reference |
|---|---|---|---|---|
| **Italian salami** | 100% pork meat | 1% salt, 0.3% curing salt, 1% flavoring, 1% sucrose, and 0.25% sodium erythorbate | *S. xylosus, S. carnosus, P. pentosaceus* and *P. acidilactici* | [7] |
| **Italian salami** | 70% pork meat, and 30% pork fat | Salt, spices, aromas, sodium nitrate, sodium nitrite, ascorbic acid, citric acid, milk powder, lactose, and sucrose | *Lactobacillus* | [8] |
| **Italian salami** | 62.09% pork meat, and 19.10% beef | 2.91% salt, 0.28% sodium nitrite and nitrate, 0.23% sodium ascorbate, 0.19% pepper, 0.19% garlic powder, 0.19% nutmeg, 0.28% glucose, and 0.19% sucrose | *P. pentosaceus,* and *S. xylosus* | [9] |
| **Milano salami** | 75% pork meat, and 25% belly | 2.3% NaCl, 0.2% black pepper, 0.1% white pepper, 0.02% garlic, sodium nitrite, sodium ascorbate, dextrose, and saccharose | *L. sakei* | [10] |
| **Milano salami** | 74.95% pork meat, and 30% pork backfat | 2.5% salt, 0.3% curing salt, 0.20% sodium erythorbate, 0.02% white pepper, 0.20% garlic, 1,.0% wine, and 0.8% sugar | *D. hansenii, L. sakei, P. pentosaceus, S. carnosus, and S. xylosus* | [11] |
| **Milano salami** | 69.5% pork meat, and 23% pork fat | 2.3% NaCl, 0.015% sodium nitrite, 0.3% sodium erythorbate, 0.6% flavoring, 1.0% wine, 2.7% milk powder, 0.35% glucone delta lactone, 0.25% sucrose, and 0,25% glucose, | - | [12] |
| **Chorizo** | 100% pork meat | 2% NaCl, 75 to 150 mg/kg of sodium nitrite, and 0.5% dextrose | *L. plantarum,* and *L. delbrueckii* | [4] |
| **Chorizo** | 75% pork meat, 18% pork backfat | 1.5% NaCl, and 0.3% curing salt, and 5.2% sodium ascorbate | *L. plantarum* | [5] |

CHAPTER 3

# Meat Emulsion Technology

**Abstract:** The technology of the production of dry-fermented products is old and even in current days these meat products are produced, appreciated and consumed worldwide. The fermentation and drying steps are responsible for chemical and biochemical transformations that ensure the final characteristics of the product were reached. One of the disadvantages in dry-fermented product processing is the time required for all transformations that characterize the product and meets the required standard of safety and quality. Thus, the use of emerging technologies allows the improvement in the production process considering the use of new approaches, always ensuring food safety and quality. In this chapter, the ultrasound, pulsed UV light and QDS process® are discussed. The approach includes the advantages and disadvantages of each technology, the report of researchers describing the use of mentioned technologies and the most probable mechanisms associated with the effects.

**Keywords:** Fermented Sausages, Ham, Pulsed UV Light, Quick-Dry-Slice Process®, Salami, Starter Culture, Ultrasound.

## INTRODUCTION

Emulsified meat products are widely consumed all over the world and are of great economic importance to the modern meat industry [1, 2]. Although meat batters have been a traditional age-long prepared product, the scientific principles and expertise are significantly important for commercial products [2]. Cooked sausages processed products such as mortadellas (bologna) and frankfurters (wiener, hot dog or franks) are the main meat products obtained using emulsification processes considered the most popular ready-to-eat (RTE) cooked meat products and convenient for modern lifestyles. Nowadays, emulsioned products of several species, especially beef, pork, poultry, turkey, and fish are to be found.

A meat emulsion is a mixture in which finely divided meat constituents disperse analogously to an oil-in-water emulsion. The discontinuous phase is fat, and the continuous phase is an aqueous salt and protein solution, with suspended insoluble proteins, portions of muscle fibers in the sarcolemma, and remnants of connective tissue. The main emulsifying agents are myofibrillar proteins due to

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their higher solubility (saline-solution soluble) [3]. However, the use of stromal proteins, especially collagen and sarcoplasmic proteins, improved the protein concentration and emulsion stability [4, 5].

Meat emulsification is mainly affected by factors such as chopping parameters (temperature, speed, and time) and raw meat materials used (raw meat type, meat pH, type and amount of fat, non-meat ingredients, emulsifiers, and hydrophilic gums) [2, 3, 6]. Therefore, methods allowing accurate meat emulsification process control or improving stability ought to be considered. For this purpose, the ultrasound method will be addressed.

The ultrasound method has been shown to provide fat reduction for emulsified products [7, 8]. This is a quite relevant factor, considering the high-fat content in bologna sausages and frankfurters, which makes it difficult to replace animal fat and the need for the meat industry to meet consumer demand by offering healthier products. The multiple emulsion method (W1/O/W2) has also been shown to improve the technological, physicochemical, and sensory properties of emulsified products made with total or partial replacement of animal fat for non-meat fat [9, 10].

Another point that deserves special attention is that cooked frankfurters and bologna sausages packaging is typically re-exposed to the processing environment processing, leading to potential microorganism contamination. Moreover, to meet consumer demand for ready-to-eat (RTE) products, the meat industry has been providing emulsified meat products, such as bologna sausage in small portions (thin slices) from processed blocks, which could cause microbiological contamination after pasteurization [11 - 13]. Therefore, additional processes are required to ensure the safety of the product. The use of emergent methods such as ohmic heating and pulsed light as well as the use of additives [14] have been studied. The ohmic heating has been identified as a promising cooking process for its use in meat industries due to energy saving and shorter processing time.

Ultrasound, double emulsion, pulsed UV light, and ohmic heating methods are discussed as alternative processes in the preparation of emulsified meat products in this chapter.

## THE TRADITIONAL EMULSIFIED PRODUCTS PREPARATION PROCESS

Frankfurters are generally made of 60% beef and 40% pork. Wieners could be prepared with 100% beef, 100% pork or 100% poultry meat, or a combination of them. Wieners may vary in size and style for different markets. Frankfurters are larger, while Vienna sausages are smaller. The Vienna sausage is also canned and could be stored at room temperature. The formulation and processing of mortadella are similar to franks, but bologna sausage casing is much larger in size than wieners [15].

Mortadella is a large emulsified cooked sausage with different denominations and composition, depending on the geographical location where it is produced. Originally from Bologna in Italy, bologna sausage is made from finely comminuted and cured pork usually added with small pork fat cubes. It has a characteristic garlic flavor and coarse black peppers are added to it in some South American countries.

Other meats such as buffalo, lamb, mutton [16], and fish might also be used in similar products. It is also noteworthy that the use of mechanically separated meat (especially poultry) is law-permitted in some countries and is common in emulsified products [17], also muscle nonskeletal meat (liver, tongue, heart, *etc*.), tendons, and skin are permitted for similar low-cost products. As for the non-meat ingredients, the main one is iced-water for keeping the batter at a low temperature, as well as salt, nitrites, antioxidants, sugars, stabilizers (phosphates and other emulsifiers) and/or water-binders such as soy protein, caseinate, and starch are used in these products. In addition to flavorings, seasonings and spices that are characteristic of each product and are dependent on regional traditions. Table **1** shows some possible emulsified meat product formulations. It is possible to notice the variability of the raw material and ingredients used, which makes it difficult to standardize these products and shelf-life. Therefore, the innovative technologies that will be discussed in this chapter are necessary to contribute to the quality and safety of these meat products.

Frankfurter and bologna sausage production involves the selection of raw material, grinding, seasoning, blending, emulsification, stuffing, cooking, and packaging. Processing up to the stuffing stage is quite similar for both products. According to Abdolghafour *et al*., the process begins by choosing the raw material, which could be either fresh or frozen, but of good microbiological quality. All ingredients must be properly weighted according to the formulation.

The lean meat portion should be trimmed to less than 10% fat and connective tissue, free from tendons, cartilage and bones, for good water-binding capacity [16]. Meats vary in their ability to bind water and hold lean meat and fat together. Lean skeletal muscle tissue proteins contain the best water-retention and fat-emulsifying properties. Adding salt (15–25%) to the formulation for myofibrillar protein solubilization enables it to form a gel when heated [15].

**CHAPTER 4**

# Meat Curing and Preservation Methods

**Abstract:** Salting is one of the oldest food preserving methods. New salting methods for meat products are currently being studied aiming at reducing process time and labour costs, increasing process yield, and producing safe, low-salt content foods with acceptable sensory characteristics. In this context, ultrasound, high hydrostatic pressure and microwave technologies have been highlighted. Several manuscripts have addressed this theme and the results were satisfactory, urging the need for further studies in order to improve and enable the use of such methods. This chapter will cover traditional salting methods and new ones, currently being discussed aiming at improving the quality and yield of products.

**Keywords:** Brine, Dry-Cured Meat, High Pressure, Meat Quality, Microwave, Ultrasound.

## INTRODUCTION

Among the different meat preservation procedures, salting is one of the most ancient methods used. However, due to the development of new food preservation methods, the meat industry currently uses salt as flavouring or flavour enhancer and also as responsible for the desirable textural properties of processed meats [1, 2]. Salt plays an essential role in meat products *e.g.* in protein it activates hydration and water-binding capacity leading to a decrease in fluid loss in thermally-processed vacuum-packaged products; an increase in the binding properties of proteins to improve texture; an increase in meat batter viscosity, facilitating the incorporation of fat to form stable batters; as well as being essential to flavouring and having a bacteriostatic feature at relatively high levels [2].

The terms salting and healing or salty and cured have, for some, the same meaning. Salted meats are also called cured meats when treated with table salt and/or curing and adjuvant salts. Salting and curing are widespread methods for obtaining meat processed products and also, in the original sense of the word, to keep meat fresh for longer.

Sodium nitrite is often included in the brine and is responsible for the cured meat colour, adding flavour, and preventing spores from microorganisms such as *Clos-*

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*tridium botulinum* [3] from developing. A widely used adjuvant is sugar that enhances the taste of meat and counteracts some of the hardening effects caused by salt. Over time, the term meat curing became a synonym to adding salt, sugar, spices, saltpetre (nitrate) or nitrite to meat for preservation and flavour enhancement.

Salt penetration in meat is related to establishing a balance between salt concentrations inside and outside the piece of meat. However, there are a number of factors that influence the speed at which equilibrium is established, as described in Fig. (**1**) [4 - 6].

## TRADITIONAL SALTED PRODUCTS

Salted or cured meat products are widely consumed worldwide. Table **1** presents some of these products and the traditional methods used for their preparation and countries of origin. It is considered that this general knowledge is necessary to arouse the interest in the application of new technologies, since the technical literature has focused mainly on hams.

**Table 1. Salted meat products from different countries.**

| Salted Product | Meat Base | Curing Methods | Origin Country | Reference |
|---|---|---|---|---|
| **Jerked Beef** | Beef | Dry curing | Brazil | [7] |
| **Charque** | Beef, goat | Dry curing | Brazil | [7] |
| **Cecina** | Horsemeat | Dry curing | Spain | [8, 9] |
| **Biltong** | Pieces of pork, beef, goat, venison, and horse | Dry curing | South Africa | [10] |
| **Bresaola** | Pieces of pork, beef, goat, venison, and horse | Dry curing | Italy | [11] |
| **Spanish Serrano ham** | Pork | Dry curing | Spain | [12] |
| **Iberian ham** | Pork | Dry curing | Spain | [12, 13] |
| **Italian Parma ham** | Pork | Dry curing | Italy | [12] |
| **French Bayonne ham** | Pork | Dry curing | France | [12] |
| **Lacón** | Pork | Dry curing | Spain | [12, 14] |
| **Bacon** | Pork | Brine curing and/or dry curing | * Great Britain | [15] |

* It is not known for sure, but records show that Britain's traditional breakfast in 1560 was served with bacon and eggs [15].

## CURING METHODS

Two main forms of applying curing ingredients are dry cure and pickle or brine cure. The dry cure process involves hand rubbing the dry-cure mixture (sugar, salt, nitrate or nitrite) in excess over the external part of the meat. However, most curing procedures use a salt-based brine or pickle for manufacturing the cured meat products [3].

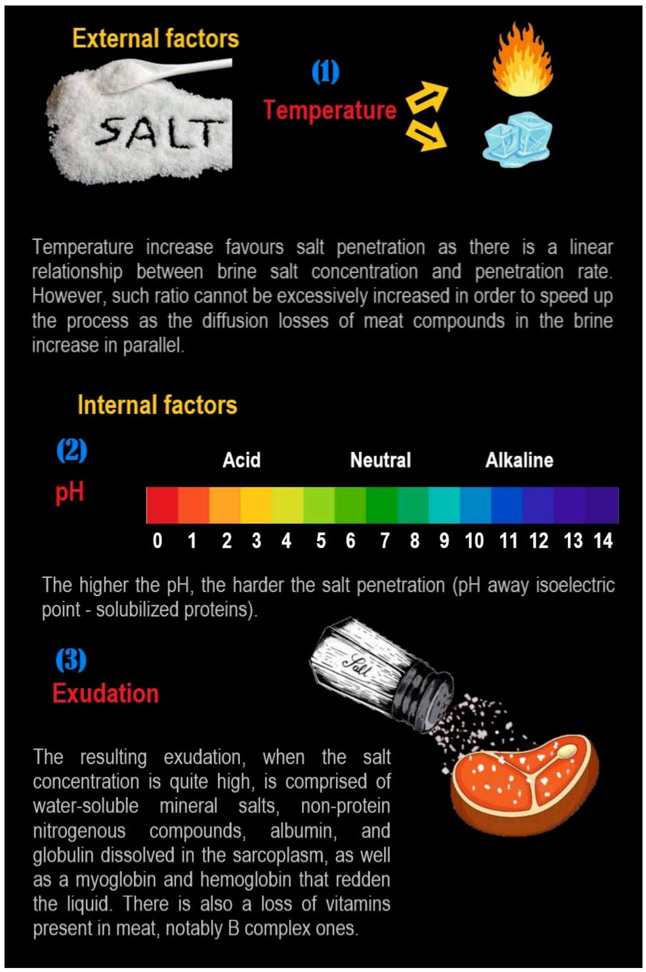


**Fig. (1).** Factors that influence the speed and equilibrium of salted meat products.

Dry-salting might be an extremely time-consuming process and it often requires the constant rotating of meat pieces in order to standardize the product and speed up the process. No water is added, so the curing agents are solubilized in the

**CHAPTER 5**

# Marinating and Meat Restructuring Technology

**Abstract:** Meat products such as marinated meats, hamburgers, and nuggets are well accepted by consumers looking for convenience in preparing their meals. These products possess characteristics such as tenderness, juiciness, diversity of flavors, high yield, and also add value to hard-to-sell meats. This chapter will discuss the traditional and innovative meat-producing methods, also called green technologies, currently aimed at making meat products safer, of higher quality, also reducing production costs. Green technologies use either physical, chemical, or biological methods enabling them to perform the same productive tasks more efficiently due to lower electrical power, chemical, and water consumption as well as wastewater production.

**Keywords:** Batter, Breader, Green technologies, Predust.

## INTRODUCTION

Meat is rich in high-quality protein and essential nutrients such as vitamins, minerals, and essential fatty acids [1]. Meat consumption, particularly red meat (beef, pork, and lamb), is dated back to ancient times and remains a dominant lifestyle and nutritionally essential in modern society [2]. Meat quality is influenced by many factors, such as the animal`s breed, genetic aspects, age, gender, pre- and post-slaughter management [3], meat composition just as connective tissue content, streaky or marbled fat, myofibrillar protein components and their myofibrillar contraction level, carcass muscle location, and cooking method [4]. Consumers at the time of purchase choose and evaluate meat cuts based on visual, olfactory, and price perceptions. However, the consumer expects practicality and tenderness during preparation and consumption [5 - 8]. Marinated and restructured processed meat products (breaded or non-breaded) such as seasoned meat cuts, cooked hams, hamburgers and nuggets, meet these consumers' expectations.

Marinated meat is a spicy product produced generally with a whole meat piece with a specific flavor, tenderness, and juiciness [9]. Marinated meat preparation consists of adding brine containing a mixture of additives, spices, and flavorings to the meat. It might occur by immersion, diffusion penetration, injection, or vacuum tumbling [9, 10]. On the other hand, restructured products such as nug-

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gets are prepared by mechanical disintegration of meat, followed by ingredients mixing and homogenization. The prepared meat batter is placed in containers and inserted in a freezing tunnel [11]. Subsequently, they are nugget-shaped cut, breaded, pre-fried and frozen-stored. For products such as cooked ham - a marinated and restructured meat product - brine is applied to the pork leg either by immersion, injection and/or vacuum tumbling, then the leg cuts are shaped and cooked, resulting in one-piece [12]. It is important to point out that less tender meat remnants from the boning process and difficult-to-market meats could be used for developing marinated and restructured meat products [10]. The subsequent paragraphs describe in more detail the marinated and restructured meat product preparation.

## MARINATED MEAT PRODUCTS

Marinating is a process that has been long used that consists of soaking the meat in brine added with simple ingredients, improving the taste and masking some undesirable odors. The brine used in processing is usually a mixture of water, additives, spices, and flavorings and is applied to the meat by dipping, massaging, or tapping, injection for a set period of time. The most demanded functions with marinating are shelf life extension and microbiological, culinary, and technological quality enhancement (jutosity, taste, tenderness, water retention, and mass yield) [13, 14].

Salt is the most important ingredient in marinating as it increases myofibrillar protein solubility and in conjunction with sodium pyrophosphate, sodium hexametaphosphate, and sodium tripolyphosphate enhances the sensory properties of processed meats, increases water retention capacity, assists on the emulsion, color, and flavor stabilization [12], and reduces water loss during the cooking process [15]. The use of acid and alkaline phosphate mixtures provides greater product functionality, contributing to a greater meat water retention capacity, which is of great technological interest, as well as greater juiciness and product slicing easiness. Ingredients such as non-meat proteins, vegetable proteins, hydrocolloids, carrageenan, xanthan, and organic acids mix contribute to the preparation of standardized quality meat products with high water retention capacity, attractive flavor, and low-cost [16].

The marinating methods are primarily responsible for the quality of the final product. The application is essentially static (by meat immersion in brine) or dynamic (using force and friction). Meat immersion in brine is possibly the oldest marinating method, where the migration of ingredients into the myofibrils depends on brine solids concentration and the length of time the meat is dipped [8]. Upon immersion, the salt and acid present in the solution impregnate the tissues, causing a fall in pH, which results in significant hydration of the proteins if the salt content of the solution is less than 0.3 M [13]. For tumbling, the cuts must be carefully chosen due to a high risk of bone breakage or skin separation from certain parts, especially of the chicken, so the tumbler is recommended for small, boneless, skinless pieces of meat, and for other cuts [17]. Injecting equipment that uses pumps to propel the brine through needles into the myofibrillar proteins has been the most used method in the meat industry (Fig. **1**). This equipment provides a spray effect, avoiding brine pockets forming in specific parts of the meat since it maintains brine dispersion in millions of micro-drops with a homogeneous distribution of the marinade in the meat [8]. There is also partial hydration of gel-forming myofibrillar proteins that denature upon heating, leading to meat cuts aggregation [12].

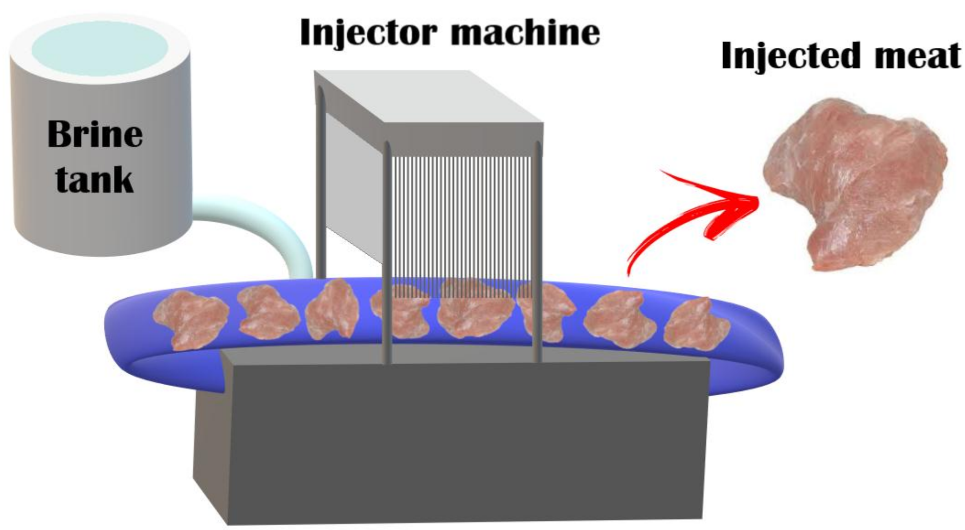


**Fig. (1).** Injector machine used for meat injection.

The thermal processing (cooking) of ham is carried out in baking ovens until the product reaches an internal temperature of approximately 68 ± 1 °C. At this stage, the killing of most vegetative cells of microorganisms occurs. The survival and/or proliferation of pathogenic microorganisms might occur if the heating treatment is insufficient, which could be dangerous [15].

## RESTRUCTURED MEAT PRODUCTS

Consumers nowadays, due to an increasingly busy lifestyle, are seeking products that are quick and easy to prepare, which would make their daily lives easier.

CHAPTER 6

# Non-emulsified Sausage Processing Technology

**Abstract:** Non-emulsified sausages represent a wide group of processed meat products with peculiar characteristics depending on the region of production. In general, they are recognized as thick dough sausage products, stuffing and commercialized in a fresh way, or submitted to smoking or cooking. The fresh non-emulsified sausages are a highly perishable food that cannot be submitted a previous heat treatment before the sale, once the consumer will bake it in the consumption moment. In this context, the high hydrostatic pressure and irradiation are of great interest because only a slight increase in the temperature was observed during the processing step, and can be applied in the finally sealed packages, avoiding re-contamination. Furthermore, for cooked non-emulsified products, the number of possibilities for alternative technologies employment is greater. The high hydrostatic pressure and irradiation can be applied for microbial reduction after cooking step already in the package, and the alternative heating technologies such as ohmic heating, microwave, and radio-frequency can be tested in order to replace the conventional cooking procedures improving the microbiological safety. Thus, the use of emerging technologies represents an interesting point of view in the processing of non-emulsified products, justifying the proper attention of further studies.

**Keywords:** Electron-beam Irradiation, High hydrostatic pressure, Irradiation, Microwave, Ohmic Heating, Radio-Frequency.

## INTRODUCTION

The sausages were recognized as a processed meat product placed inside a wrap. However, there are different groups of sausages, such as the emulsified (thin dough), the dry fermented (thick dough), and the non-emulsified, but proceeded by coarse grinding (thick dough). Fig. (**1**) presents some examples of the three mentioned types of sausages. The non-emulsified sausages may be commercialized as cooked, smoked, or fresh products. The thick dough sausage production includes grinding, seasoning, blending, stuffing, fermentation (applicable only for fermented sausage), smoking (optional), cooking (applicable only for cooked sausage), and packaging. The fresh sausages are highly perishable products if compared with fermented and cooked ones since they are manufactured from fresh ground meat, which is friendly for microbial growth of spoilage and pathogenic microorganisms; moreover, the fresh sausages generally

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present a high-fat content, favorable for lipid oxidation [1]. In this context, the use of innovative technologies applied for meat and meat products highlights as an alternative, and for sausages, they are primarily used in order to reduce microbial contamination. This chapter gathers information about non-emulsified sausages, less researched in comparison with other sausages types, and some prepositions of alternative technologies that can be applied based on studies already done in other sausages.

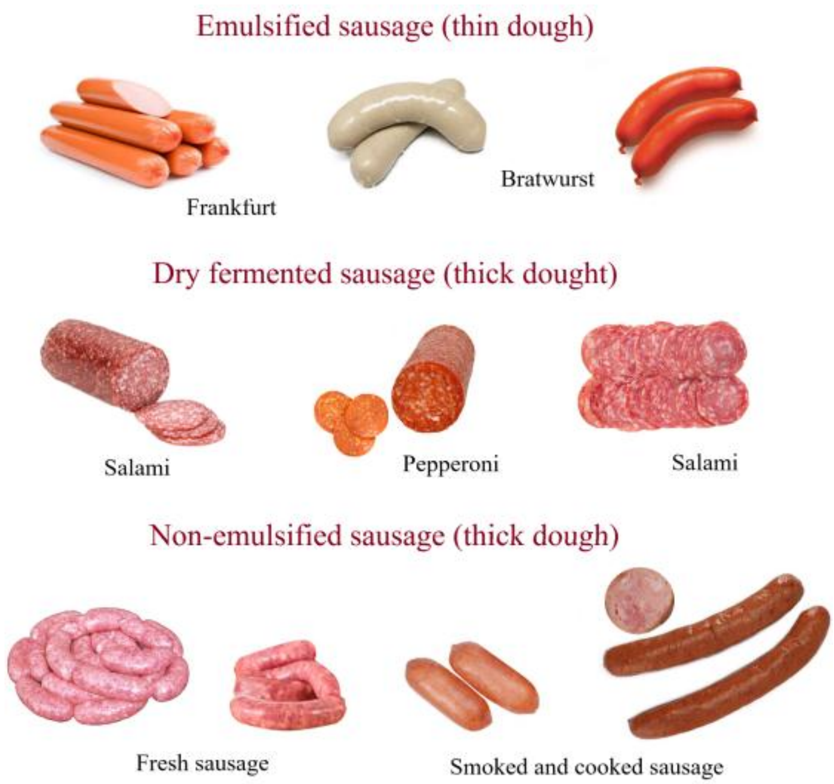


**Fig. (1).** Examples of different types of sausages.

## USE OF NEW TECHNOLOGIES IN SAUSAGE PRODUCTS

Novel and emerging food processing technologies applied to meat and meat product elaboration have increasingly gained interest. More recently, there has been growing consumer demand for the minimally processed, free from chemical additives and healthier meat, highlighting the development of alternative technologies to improve or replace the conventional heat treatments [2].

The use of steam and hot water in conventional hot treatments for meat or meat products has the disadvantage of slow heat conduction flowing from the heating medium to the thermal center of the product [3]. As the heating is slow, the use of slightly higher temperatures may cause an overheating on the outer surface of the food, effecting the quality of the product, which includes the formation of a free fat layer between the gut and the sausage. In this context, the use of alternative heat treatments represents an interesting solution for the meat industry, especially for uniform sausages that can be heat processed from the inside out, in a standardized way.

## HIGH HYDROSTATIC PRESSURE

The high hydrostatic pressure (HHP) is defined by the application of pressure in the range from 100 to 1000 MPa. The emergent technology of HHP has been employed mainly for microorganism reduction in meat and meat products at low or moderate temperature. The highest potential application for meat products might be to pressurize finally sealed packages of contaminated generally sliced products as the color of those products can resist high pressure [4].

According to Balamurugan [5], the effect of HHP (600 MPa for 3 min) was comparable with hot water pasteurization (75 °C internally kept for 15 min) in cooked pork sausage; both pasteurization processes were efficient for preventing the development of both, *Listeria monocytogenes* and lactic acid bacteria, for 35 and 21 days at 4 °C and 10 °C, respectively. Furthermore, both the pasteurization processes were efficient, enabling negative test for *Pseudomonas* spp. and coliforms throughout the 35-day storage at 4 °C and 10 °C.

Similarly, Rubio *et al*. [6] employed the HHP (from 349 to 600 MPa, at 18 °C from 0 to 12.53 min) for *Listeria monocytogenes* inactivation in Spanish chorizo sausage. The authors observed that microorganism reductions increased as the pressure and duration of HHP treatments rose. Moreover, as chorizo presents a low value of water activity, the authors concluded that this parameter seemed to exert a protective effect on the *L. monocytogenes* cells, and pressures below 400 MPa did not lead to significant pathogen reduction.

In the same context, a Spanish blood sausage produced with thick dough and cooked, named Morcilla de Burgos, has been submitted to HHP in order to reduce microbial contamination. The sausage was added to potassium and sodium lactate, and the application of HHP (600 MPa for 10 min) increased the shelf-life of the Morcilla de Burgos by 15 days. Enterobacteria and *Pseudomonas* populations were effectively reduced at all pressures tested (300, 500 and 600 MPa for 10 min). However, for lactic acid bacteria, only the 600 MPa allowed lower counts up to 21 days of storage [7].

The main purpose of using HHP to treat meat products is to improve microbial

**CHAPTER 7**

# Effect of Ultrasound on Fresh Meat Tenderness

**Abstract:** Ultrasound is considered a "green technology" based on acoustic energy. It is a mechanical, nonionizing, and nonpolluting technology that contributes to the improvement of numerous food industry processes. Several articles published in recent years have reported the effects of ultrasound on beef tenderness. Therefore, we have chosen to write this chapter as we believe that the use of ultrasound could assist the industry to establish effective and efficient processing conditions to improve meat quality and meet consumer demands. In this context, the effect of ultrasound on beef tenderness should be addressed, especially as beef is less tender than poultry, pork and lamb meat.

**Keywords:** Cavitation, Emerging Technology, Proteins, Proteolytic Enzymes, Ultrasound Waves.

## INTRODUCTION

Red meat is considered a prime food for humans due to the quality of its protein and essential nutrients such as vitamins, minerals, and especially essential fatty acids [1]. According to consumers, tenderness is one of the key attributes they look for when buying fresh meat [2 - 5]. However, expectations are often not met as tenderness is influenced by many factors, such as breed, genetic aspects, age, gender and pre and post-slaughter management [6].

In China, Japan, and the USA, beef acceptability is increased with increased marbling [7], which is related to tender meat [8]. In some countries like Brazil, the genetic basis used for beef production comes from animals with a great Zebu genotype contribution, which negatively affects tenderness since these animals have a low marbling score. Thus, alternatives that could contribute to the improvement of meat tenderness are quite relevant. High-power ultrasound is a green emerging technology offering great potential for application in a large number of food industry processes [4, 9 - 12].

In recent years ultrasound has been gaining space in food technology, and various studies have focused on its application to both fresh meat and processed products. The use of ultrasound aims at increasing water retention capacity, accelerating

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maturation, improving the palatability of non-prime food cuts [13, 14], lowering energy usage during cooking [15], emulsion elaboration [16], increasing marinated products brine absorption (improving tenderness and yield of different meats) [17 - 19], and contributing to small ice crystal formation during freezing (reducing exudate loss during thawing) [20].

Satisfactory results have been obtained from ultrasound application on meat tenderness [12, 21, 22]. Variables such as cut type, size, weight, and physicochemical and functional properties should be considered when developing ultrasound systems to obtain quality products under optimal conditions [10]. This chapter presents the results of the use of ultrasound in fresh beef tenderness contributing to its improvement and its industrial application.

## ULTRASOUND PRINCIPLES

Ultrasound technology is based on the use of high-intensity elastic waves to alter the treated media by the adequate nonlinear phenomena exploitation associated with high amplitudes such as radiation pressure, wave distortion, streaming, and cavitation in liquids and dislocation in solids [12]. Its use in the food industry is related to physical, chemical, functional or microbiological changes that may occur in food due to its use, along with increased productivity, yield and/or quality improvement, as well as food safety assurance. It is also noteworthy that it is a clean, fast, non-invasive, non-destructive, and accurate technology [23], with less processing time, lower water consumption, lower energy expenditure, less wastewater and toxic substances production, and safe food production [24, 25].

Ultrasonic waves could be classified into (a) high frequency (2-20 MHz), low intensity ($<1$ W cm$^{-2}$) and non-destructive waves applied in non-invasive imaging techniques, sensors and composition and dispersion or concentration analysis of particles in fluids [26]; (b) low frequency (20-100 kHz) and high intensity (10-1000 W cm$^{-2}$) waves, which break the intermolecular binding due to higher power levels, causing a cavitation effect that alters physical properties and fosters chemical reactions [27]. Cavitation takes place when areas of pressure change occur in the environment with gas bubbles formation, which might or might not implode. The bubbles increase the expanding gases diffusion in the medium, causing alternation between compression waves (positive pressure) and rarefaction one (negative pressure) [27, 28]. Cavitation could be classified according to the mode in which it is generated, namely acoustic, hydrodynamic, optical and particle [29]. However, acoustic and hydrodynamic cavitations are the only ones with suitable intensities to cause physical and chemical changes in food [30]. The acoustic parameters (frequency, intensity, treatment duration, and temperature) determine the extent of the desired sonication result, as well as the characteristics of the sample [14, 31].

The improvement of both food processing and final product by ultrasound is due to the reactions using cavitation presenting shorter reaction times, increased yield, less severe processing conditions use, higher reaction products selectivity, as well as a lower temperature and pressure use, which contribute to the maintenance and integrity of components of interest in food [30].

Ultrasound is applied by ultrasonic wave generating equipment such as ultrasound baths (indirect application) and immersion probes (direct application), which may vary in size, diameter and tip geometry, depending on the need. The differences between the ultrasound bath and the ultrasound probe are depicted in Fig. (**1**).

## ULTRASOUND ON BEEF TENDERNESS

Meat palatability depends on quality parameters such as aroma, taste, appearance, juiciness and tenderness, which are all difficult to control as they are associated with cattle breed, genetic crossbreeding, rearing system (pasture or confinement), age, and gender [6]. The importance of quality parameters, such as tenderness, depends on the product and its final destination. However, at the time of purchase, meat tenderness is the most sought-after attribute by consumers [2, 3].

Muscle meat must undergo some biochemical changes to become the final product, and after that, it needs to develop the proper organoleptic peculiarities, including tenderness [32]. The maturation or resolution of *rigor mortis* comprises of changes after cadaveric stiffness development. At that stage a slow muscle relaxation occurs, causing tenderness to meat after 3-4 days of refrigerated storage [8]. Maturation is also a conservation method. It involves storing meat cuts for 15 to 21 days, at above meat freezing point temperature (around 0 ºC) [8].

However, if maturation exceeds long periods, undesirable changes such as non-characteristic color pigment and flavor formation might occur. During maturation, the myoglobin iron atom oxidizes losing its oxygen-binding ability (the myoglobin molecule is now called metmyoglobin). In this oxidized condition, the meat turns brown. Although this color is not harmful, it indicates that the meat is no longer fresh, which is a problem for beef marketing. In contrast, the most compromising issue, beyond meat discoloration, is the microorganism development that can lead to green pigments formation, such as sulfomoglobin produced by $H_2S$-producing bacteria ending in actual putrefaction.

The effect on meat tenderness during maturation is not due to the dissociation of actomyosin formed during *rigor mortis*, but to the action of several meat-endogenous enzymes, especially cathepsins, calpains, and calcium-activated

**CHAPTER 8**

# Botton-up and Top-down Strategies for Processing Meat Analogs

**Abstract:** There is a worldwide concern regarding the supply of protein source for both human food and animal feed. In this context, meat has a major impact on the environment and consumers and health professionals have been expressing growing concern over high meat consumption. In this respect, meat analogue products - defined as compounds structurally similar to meat, however, differing in composition - have been attracting ever-increasing attention and interest of the environment and health concerned consumers. Furthermore, the number of people identifying as vegetarian and vegan have been increasing as they look for more sustainable options due to a unique lifestyle. In this chapter, the main aspects of bottom-up and top-down strategies are presented and discussed. The literature describes different approaches to simulate animal meat, such as cell culturing, mycoprotein and spinning techniques (bottom-up strategies) extrusion, proteins and metal-cation-precipitated polysaccharides, freeze structuring and shear cells technology (top-down strategies). Meat analogues have to present typical sensory and nutritional properties of animal meat for both vegetarian and non-vegetarian consumers. Thus, food scientists ought to test texturization techniques, develop more industrialized meat analogue products, evaluate the scalability of production process and quality control of meat analogues, improving the existing technologies and developing new ones that meet consumer demands.

**Keywords:** Bottom-Up Strategy, Cell Culturing, Extrusion, Polysaccharides, Protein, Shear Cells Technology, Top-Down Strategy.

## INTRODUCTION

Since ancient times and up to this day, meat-consuming individuals are referred to as strong and powerful, making meat consumption a sign of social status [1]. Moreover, meat possesses a high biological protein value, due to its amino acid composition, vitamins and minerals [2]. However, its production requires a large number of natural resources, such as water, causing a large environmental impact [3, 4]. This fact contributes to the increased advocacy of plant proteins and their health benefits, justifying the importance of research and development of meat analogues [5].

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In this scenario, meat analogues have been emerging as replacers [6], especially based on consumers' interest in plant-based products that could replicate meat in terms of mouthfeel, texture, taste, color and smell [4].

Moreover, animal cells and mycoproteins have also been studied as meat analogues for human consumption. Although meat analogues might replace meat in terms of its functionality since they achieve similar product properties and sensory attributes to meat [3], amino acids' biological value is also required. Meat analogues could be categorized as ground, comminuted and whole muscle. Fig. (**1**) shows some examples of meat analogue products, visually similar to animal meat.

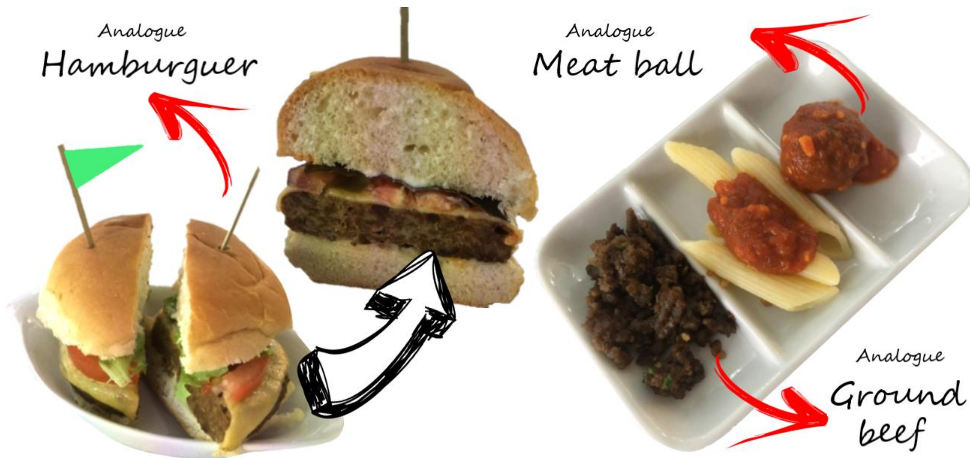


**Fig. (1).** Meat analogue products.

Different structuring techniques aimed at creating fibrous plant protein materials could be used to develop meat analogues. Dekker at al. classified these techniques as bottom-up and top-down strategies based on their key approach to create animal-meat-muscle-like fibrous structure [3]. According to the authors, the bottom-up strategy consists of creating anisotropic structural elements that are later assembled into larger products, whereas, the top-down strategy creates fibrous products by structuring biopolymer blends, in which the fibrousness of the product becomes apparent when stretching the material, mimicking the structure on larger length scales only. This nomenclature is used in the current chapter.

Plant protein sources, such as wheat, soy, pea, and peanut are the most widely used raw materials for the development of meat analogues [4 - 9]; however, some animal proteins, especially egg and milk-based [10, 11], and fungi protein [12] have also been studied. The literature describes several animal meat simulating techniques, such as cell culturing, mycoprotein and spinning (bottom-up strategy); extrusion, proteins and polysaccharides precipitated by metal cations, freeze structuring and shear cells technology (top-down strategy) [3]. However, high-moisture extrusion has emerged as a food processing technology applied for meat analogues production that has gained the interest of food scientists and is recognized as the most studied technique [5 - 9]. This chapter discusses some innovations concerning food structuring processes for protein texturization, allowing meat analogues production.

## BOTTOM-UP STRATEGY

The bottom-up approach refers to a combination of individual structural elements to create subsequently assembled larger products [3]. It should be noted that meat is formed by the muscle (*in vivo*) composed of elongated cells arranged in parallel to form muscle fibers ranging from 10 to 100 µm in width and of a few mm in length [13]. Thus, the bottom-up strategy is associated with the combination of protein structures that could be grown by satellite-cell-culturing, filamentous fungi biomass production, or by creating protein fibrils or fibers from either a vegetal or animal protein source, depending on the adopted strategy.

## CULTURED MEAT

Skeletal muscle-tissue engineering could be applied to cell-based meat production for human consumption [14]. To culture muscle fibers, initially, myoblast-form satellite cells should be harvested from the skeletal muscle of an animal; afterwards, the cells are replicated using a serum-supplemented medium with the nutrients needed for cell growth, such as amino acids, lipids, vitamins, and salts [3]. Cells culture media could be completely synthetic and devoid of serum products, however, serum-based media are still superior to synthetic ones [15].

After obtaining enough cells, they are placed onto a scaffold with anchor points to connect and align the cells, yielding a multicellular tissue. Cells alignment and muscle fibers development are ensured by either electric fields or other means, and after approximately three weeks, the muscle fibers would mature and could be harvested [3].

Satellite cells are undifferentiated and mononucleated [16], and according to Post [15], muscle cells culturing from satellite cells could be separated into two phases. The proliferation phase aims to obtain the highest number of cells from the cells of the starting batch, to maximize the number of doublings. Subsequently, the differentiation into skeletal muscle cells and maximum protein production (hypertrophy) occur. The author reinforces that differentiation in satellite cells occurs almost naturally with a very little adjustment to culture conditions. The

CHAPTER 9

# Alternative Additives and Ingredients

**Abstract:** Meat products conventionally contain fat, saturated fatty acids, and high salt contents, as well as health-harming chemical additives, such as nitrites and synthetic anti-oxidants. The meat industry has been striving to find alternatives in order to meet consumer demands for healthier products, either reduced or free of such components. For this purpose, various studies have been carried out for alternative ingredients. Vegetable oils have achieved positive results as fat replacers. Methods such as pre-emulsion, emulsion-templated, microencapsulation, and oleogel formation (hydrogel or organogel) have been excellent on partial pork fat reduction, and consequently saturated fatty acids or n-3 PUFA-rich oils incorporation. Plant materials are seen as a good alternative for synthetic anti-oxidants. Various plant derivatives have been tested and presented anti-oxidant potential due to their bioactive contents, such as phenolic acids, phenolic diterpenes, flavonoids, and volatile oils. Other salts, especially potassium chloride, have stood out on replacing sodium chloride. The use of natural sources of either nitrites or nitrates, such as celery and powdered vegetable juice, has been suggested as their replacers, as well as the use of different compounds with potential natural food preservative characteristics. Overall, considerable progress has been made over the past few years in the field of non-meat ingredients as alternative to conventional ones, conferring a healthier approach to meat products. However, overall strategic approaches to meet one or more simultaneous demands, such as fat and salt reduction, among others, in terms of sensory, technological and microbiological efficiency ought to be encouraged.

**Keywords:** Animal Fat Replacer, Natural Anti-Oxidants, Nitrite-Free Product, n-3 PUFA, Potassium Chloride, Salt Replacer.

## INTRODUCTION

Consumer demand for healthier meat products has increased in recent years following overall diet changes. To meet this demand, the meat industry has been striving to innovate on the processing of healthier products, either by reducing the number of compounds with negative health impacts or by incorporating ingredients that could offer benefits to consumer health when included in the diet.

Consumer evaluations for reformulated and healthier processed meat products showed that healthy ingredients, salt, and/or fat contents are the most important factors on consumers' purchase intention, second only to price and meat-based

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products. For reformulation, consumers preferred salt and/or fat-reduced products over non-reduced ones. For healthy ingredients, Omega 3 was the preferred one and healthier reformulations improved the health perception of processed meats [1].

Typically, meat products belong to a caloric food category due to their high-fat content, mainly saturated fat, high sodium content and chemical additives such as nitrates and nitrites, synthetic anti-oxidants, polyphosphates, or even allergenic compounds, such as soy proteins, milk proteins and others that are associated with health problems. Such ingredients have been widely used by the meat industry due to their technological functions, sensory properties, microbiological safety, and the economic viability that they confer to meat products.

Therefore, this chapter aims at addressing alternative replacements to the negative connotations of more conventional ingredients and additives (fat and/or saturated fatty acid, synthetic anti-oxidants, salt, nitrates, and nitrites), aiming at a healthier approach to meat products.

## ANIMAL FAT REPLACERS

The high animal fat contents found in meat products are comprised of high saturated fatty acid content. Pork fatback is the most commonly used fat, providing the product with the taste and texture characteristics that ensure its sensory acceptance by consumers. However, consumers aim for healthy products as well as sensory quality and the meat industry has been looking for pork fat replacers, given the difficulty of bridging sensory quality, low saturated fatty acids concentration, n−3 PUFA-rich oils, and oxidative stability of products.

Given the inefficiency of applying vegetable oils directly to the products, more satisfactory results have been verified from the application of pre-emulsified vegetable oil, as previously covered in chapter 3. Oil pre-emulsification increases protein-covered fat globules with consequently greater batter stability. Kang *et al.*, using pre-emulsified soy oils to replace pork fatback changed the protein structure (higher ß-sheet and lower α-helix content, tyrosine residues were exposed, and more hydrophobic interactions were formed) allowing for lower fat and energy content, enhancing the quality of frankfurters [2]. Utama *et al.*, when using oil-i--water (o/w) emulsion, consisting of perilla and canola oil, polyglycerol polyricinoleate, soy protein isolate, and inulin as an animal fat replacer in chicken sausage found that the emulsion could effectively improve the fatty acid profile and oxidative stability without deteriorating the sensory characteristics of the emulsified sausage [3]. Hu *et al.*, using pre-emulsified soybean oil with regenerated cellulose and sodium caseinate in emulsified sausages [4], and Pintado *et al.*, using water and chia flour with pre-emulsified olive oil in frankfurters have also achieved satisfactory outcomes [5].

Another approach for pork fat replacement is the incorporation of vegetable oils in oleogel-form (gel in that the liquid phase if oil). The vegetable oil is structured by a gelling compound that, by heating and cooling, is stacked in organized three-dimensional networks, thus providing the vegetable oil nutritional benefit and the positive sensory and technological properties of a more saturated and harder animal fat [6]. Several gelling compounds have been suggested, including kappa-carrageenan [7, 8], hydroxypropyl methylcellulose [9], monoglycerides and phytosterols [10], rice bran wax [6], ethylcellulose [8, 11], alginate [12], and others. According to Taverniers *et al*., polymers appear to be the most promising candidates since a considerable number have been approved for use in food products, capable of providing structure, as well as being widely available and cost-effective [13]. The most recent oleogel application in meat products and the main results are presented in Table **1**.

**Table 1. Examples of oleogel applied in meat products as pork fat replacers**

| Meat product | Oleogel composition | Mainly results | Reference |
|---|---|---|---|
| **Meat batters** | Hydrogel: Canola oil (40%), polysorbate 80 (oil: surfactant ratio was 0.05%, 0.003), BHT (0.01%), kappa carrageenan (1.5% or 3%), and deionized water (up to 100%) Organogel: Canola oil (88%, 86.5% or 85%), ethylcellulose (12%), glycerol monostearate (0%, 1.5% or 3%), BHT (0.01%). | Replacement by regular canola oil increased hardness and lightness when compared to those with beef fat Batters formulated with organogel showed enhanced matrix stability compared to those with hydrogelled emulsions. | [8] |
| **Meat patties** | Hydrogel: Hydroxypropyl methylcellulose dissolved in distilled water (1%, w/w) overnight and added with canola oil (2, 4, and 6%, w/w). | The 50% replacement of beef tallow by HPMC oleogels reduced cooking loss, improved saturated to unsaturated fat ratio from 0.73 to 0.18 and produced meat patties with good sensory properties. | [9] |
| **Frankfurter-type sausages** | Rice bran wax (2.5% and 10% wt/wt) and correct amounts of soybean oil. | Oleogel treatments were less dark and less red with reduced flavor. It was similar to pork fat treatment for firmness, chewiness, springiness and aroma. | [6] |
| **Frankfurter sausages** | Sunflower oil (80%), gelators' (20%) (monoglycerides/phytosterols weight ratios were 10:10 (1:1) and 15:5 (3:1) w/w). | For the control, no differences were detected in the oxidation levels and sensory evaluation. | [10] |

## SUBJECT INDEX



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