Chapter 10
Novel Fermented Meat Products

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10.1   Introduction

Fermented meats are 'traditional/heritage' processed meat products whose origins traverse many ancient human civilisations (c.a. 3500 years old). They are highly diverse, differing as a result of environmental and geographic conditions that ultimately dictated their composition, i.e. from the availability of ingredients and the meat used to differences in their preparation methods (Demeyer, Toldrá, & Leroy, 2014). Meat fermentation is a preservation method that has the following major steps:

1. A low energy biological acidification process that reduces the pH through the formation of lactic acid as a by-product of carbohydrate catabolism
2. A reduction in water activity a_w from the addition of salt and drying process.

This imparts distinctive physico-chemical and sensory characteristics (Ockerman & Basu, 2016). Flavour development is further enhanced in a complex manner by specific enzymatic reactions in the meat and the microorganisms themselves, triggered by the fermentation process, which produces numerous low molecular weight flavour compounds such as peptides, free amino acids, aldehydes, organic acids and amines (Claeys, De Smet, Balcaen, Raes, & Demeyer, 2004). Traditional products would have been fermented by 'wild' microorganisms, ubiquitous in the surrounding environment. However, it wasn't until the mid-nineteenth century that the essential role of yeasts, moulds and bacteria in such products came to be fully understood. This led to the formalising of a controlled and efficient fermentation process that is the forerunner of many contemporary products we consume today (Caplice &

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Fitzgerald, 1999; Ojha, Kerry, Duffy, Beresford, & Tiwari, 2015). The addition of curing salt and limited oxygen in the environment select for specific microbiota, such as lactic acid bacteria (LAB) and coagulase-negative Staphylococci (CNS). These organisms flourish due to their adaptation for the meat substrate and the aforementioned conditions (low a_w and absence of O_2). Nowadays, LAB organisms would be added in the form of a starter culture to improve standardisation of the fermentation process. The LAB initiate fermentation, lowering pH to a final range 4.5–5.5 and induce the denaturation of salt-soluble proteins to a sliceable gel, with the rate of pH decline, addition of curing salt and lowering of the water activity ultimately determining the shelf-life and safety of the products (Demeyer et al., 2014). Considerable amounts of research have been carried out on fermented meats in the past few years. Some of the major areas being explored include:

1. Scientific understanding of the products in order to produce better, more economical and consistent products. These research studies have focused on microbiota identification through genetic means in order to better improve starter culture strains and investigating the increasing importance of the role of enzymes in the development of the physical and sensory characteristics of fermented meats.
2. Improved health and safety—health is being viewed as a major driver of consumer purchasing decisions. As such, interest in not only healthy and nutritious foods has increased but also in products that may offer some additional benefits. Functional foods have been developed to satisfy this need, with functional fermented meats the subject of many recent studies. Furthermore, the safety of fermented products is a key consideration in their development. The emergence of novel non-thermal and thermal technologies could provide improved safety and stability whilst maintaining the inherent characteristics of the products and/ or be used in combination with additive reduction strategies for healthier fermented meats without compromising safety.

10.2   Market and Products Consumed

The global processed meat market was reportedly worth $482 billion in 2013 and is expected to reach >$900 billion by 2020 (ReportBuyer, 2016). Due to the widespread consumption of fermented meat products, the market would seem to be considerable. However, difficulties arise in estimating the true collective value of the fermented meats market. This is due to a number of factors: (1) the diversity of the segment means it is difficult to group under one collective heading of fermented meats, i.e. numbers for production and consumption can often be collected on specific products, e.g. dry sausages; (2) owing to the historical and narrow regional nature of the some of the products, they can often be produced and consumed with no quantities being recorded (Ockerman & Basu, 2016). However, European production of fresh and fermented sausages was estimated between at 2,909,000 tonnes in 1998 (Hui et al., 2004). Table 10.1 is a mixture of traditional and commercial

Table 10.1 Selected fermented meats from different regions around the world

Region	Country/county	Example
North America	Lebanon county, PA	Lebanon bologna
	Various	Pepperoni
South and central America	Mexico, Brazil, Uruguay, etc.	Italian Milano, Cacciaturi
	Andes region	Fermented sausages (with Llama meat and guanaco)
Mediterranean	France	Menage, saucisson d'Alsace, varzi (salamis); Bayonne (dry-cured ham)
	Spain	Salchichón, chorizo (salamis); Serrano, Ibérico (dry-cured ham)
	Italian	Turista, copa, crespone (salamis); mortadella bologna; prosciutto di Parma, San Danielle (dry-cured hams)
Northern Europe	Germany	Greuβner, rügenwalder
	Austria	Katwurst
	Sweden	Metwursk
	Norway	Toppen, trondermorr, stabber
	Finland	Poro meetwurst
	Iceland	Lambaspaeipylsa
Eastern Europe	Poland	Krakowscha, kabanosy, jalowcowa
	Hungary	Hungarian salami
	Romania	Hermannstädler
	Russia	Moscow salami
The middle East	Various	Dry-fermented sausages
Africa	South Africa	Biltong
	North-East Africa	Miriss, mussran
	Sudan	Beirta
East Asia	China	Lap cheong, aap gon cheong, gam ngan cheong
	Thailand	Sai ua, nham, goon chiang
	Philippines	Longamisa
	Korea	Sundae, soonday
Pacific Rim	Australia	Pepperoni

Table summarised from the work of Toldrá and Hui (2015)

produced fermented meats and while the list is not exhaustive, it attempts to give a cross section of the products available in various regions as an example of the strength and diversity of this market cohort.

10.3   Basic Composition

Fermented meats are a highly diverse segment of processed meats that are typically composed of most of the following key ingredients:

10.3.1   Meat

As is the case with all meat products, the raw meat used in the production of fermented meats should be of a high quality (Heinz & Hautzinger, 2007). In particular, it should be free of bacterial contamination as the processing takes place at temperatures ideal for pathogenic bacteria to flourish. For example, pork is susceptible to infection by a genus of parasitic roundworms called *Trichinella spiralis* (Keenan, 2016), which is typically destroyed with adequate thermal processing. However, as fermented products are often not cooked during processing or before consumption, microbial safety of raw meat is essential. Similarly, meats should be free of chemical contamination, and care should be taken where meats with higher contents of unsaturated fats (poultry) are used that may lead to rancidity issues through oxidation. Some of the common meat species used to produce fermented meats are beef, pork, lamb, chicken, duck, water buffalo, horse, donkey, reindeer, gazelle, rabbit and other animal by-products. Initial pH of the raw meat is important (typically 5.5–5.9 for most common meat types) with producers favouring a lower pH (Ockerman & Basu, 2016). Therefore, meat with quality defects such as pale soft exudate (PSE) and dark, firm, dry (DFD) are to be avoided in order to produce optimum quality products.

10.3.2   Inoculum and Starter Cultures

10.3.2.1   Inoculum

Historically, fermented meat products depended on wild inocula (natural contamination, natural inocula, back slopping, mother batch, indigenous microorganisms) obtained from the environment and/or equipment and/or previous fermented products (Ockerman & Basu, 2016). While these wild inocula conformed to no specific species of microorganisms, they were usually composed of strains of Lactobacilli and Staphylococci. They were superseded by starter cultures, which were developed to lower the pH in shorter timescales. Although controlled, industrially produced fermented meat products are often considered inferior in sensory quality to traditional artisan products fermented by indigenous microflora, the latter can be affected by poor consistency and additional safety concerns arising out of a more variable fermentation process. Therefore, starter cultures are commonly applied in contemporary fermented meat products to offset these issues.

10.3.2.2   Starter Cultures

Meat starter cultures can be defined as preparations of viable microorganisms that develop desired metabolic activity in meat (Hammes, 1990). Starter cultures are added to most contemporary fermented meat products to improve consistency and

safety. The indigenous microflora of meat usually contain low levels of LAB and CNS (10^{3-4} cfu/g), which increase during the ripening stage (10^{8-9} cfu/g). However, native levels of Enterobacteriaceae can be higher in the raw meat than LAB and CNS sp. (10^5 cfu/g) (Demeyer et al., 2014). Addition of starter cultures can, therefore, promote safety by overwhelming these potentially pathogenic strains through enhanced competition. Research into starter cultures began in the 1940s in the United States by inoculating meat batters with Lactobacilli in order to accelerate fermentation. Subsequent development in Europe in the late fifties using mixed cultures of Micrococci sp. and *Pediococcus cerevisiae* led to the development of the first generation of meat bacterial starter cultures derived mainly from vegetable fermentations. Successive new generations isolated from meat (*L. sakei* and CNS) took place in the 1990s, forming the basis of many industrial starter cultures used today (Cocconcelli & Fontana, 2010). Tailored starter cultures containing a mixture of genera and species can be designed on the basis of specific processing and product requirements. The characteristics of microorganisms considered for starter cultures along with their primary functions are presented in Table 10.2.

Commercial starter cultures are available as freeze-dried powders (most popular until recently) and concentrated hypertonic liquid suspension (Ojha et al., 2015). Starter cultures can decrease the fermentation time compared to natural fermentation by 15–20 %, improve product yield 5–7 %, and subsequently reducing ripening times (Ockerman & Basu, 2016). Starter cultures can be broadly categorised into two major categories: (1) bacterial and (2) fungal [(a) yeasts and (b) mould].

Table 10.2 Important characteristics of microorganisms considered for starter cultures and their primary functions

Characteristics	Primary functions/roles
Non-pathogenic	Acid production
Phage resistant	Catalase activity
Free of microbial/chemical impurities that inhibit safety/manufacturing	Nitrate reduction
Salt tolerant	Flavour formation
Fast growing (brine 6 %)	Bacteriocinogenic and biopreservation
Grows well in the presence of nitrite (80–100 ppm)	Novel/functional (probiotics)
Optimum growth temperatures between 26.7 and 43 °C	
Produces lactic acid	
Positively affects flavour and colour development	
Non-gas forming	
Catalase positive	
Produces little or no acetic acid	
Does not produce off-flavours during fermentation	
Phenotypically and genetically stable	

Bacterial Starter Cultures

In meat fermentation, two main microbial groups are considered important: LAB and CNS (Cocconcelli & Fontana, 2010). LAB are usually present in low amounts (3–4 log cfu/g) initially, becoming dominant during the fermentation step (Demeyer et al., 2014). The primary function of Lactobacilli is to produce lactic acid and acidify the meat. Lowering the pH denatures the proteins which in turn forms a gel, releasing moisture uniformly. *Lactobacillus* includes up to 150 different species all with varying phenotypic, physiological and biochemical traits (Axelsson, 2004), including *L. plantarum*, *L. casei*, *L. sakei* and *L. acidophilus*. Lactobacilli strains are more commonly associated with European fermented meats, while Pediococci are often characteristic of fermented meats originating from North America (Cocconcelli & Fontana, 2010).

Staphylococci sp. are more associated with flavour development with common examples being *S. xylosus* and *S. carnosus*. Some common LAB and CNS species in fermented meats are shown in Table 10.3. However, this does not reflect the true microbial diversity that may exist between species and individual product ecologies. In recent years, molecular methods (e.g. comparative genetics, microarray analysis, transcriptomics, proteomics and metabolomics) have been very helpful in identifying the true interspecies diversity present in fermented meats, and this has been comprehensively reviewed in many studies (i.e. Albano, Henriques, Correia, Hogg, & Teixeira, 2008; Cocolin, Dolci, & Rantsiou, 2011; Giammarinaro, Leroy, Chacornac, Delmas, & Talon, 2005; Leroy, Giammarinaro, Chacornac, Lebert, & Talon, 2010; Paramithiotis, Drosinos, Sofos, & Nychas, 2010). Furthermore, a recent study by Ojha et al. (2015) comprehensively reviews some of the most recent studies on the effects of starter cultures on the technological quality of fermented meats. Combinations of these microorganisms make up the majority of commercial starter cultures currently available on the market. The composition of selected starter cultures used in fermented meats is shown in Table 10.4.

Yeast Starter Cultures

To date, the role of yeast in sausage flavour formation is not fully characterised. However, it is thought that yeast cultures play an important role in lipolytic and proteolytic activities and could positively affect flavour development. The most commonly associated species associated with fermented sausages include *Debaryomyces*, *Rhodotorula*, *Hansenula* and *Candida* (Gardini et al., 2001). Of these, the *Debaryomyces* strain, *hansenii*, has been recommended as suitable for use in a starter culture preparation as it is reported to improve aroma profile (Andrade, Córdoba, Casado, Córdoba, & Rodríguez, 2010; Bolumar et al., 2006; Flores, Durá, Marco, & Toldrá, 2004) and shown to have contributed to proteolytic activity (Patrignani et al., 2007).

Table 10.3 Prevalence of LAB and CNS species in selected tradition dry-fermented products

Product	Country	Species				Reference
LAB		*L. sakei* (%)	*L. curvatus* (%)	*L. plantarum* species (%)	Other (%)	
Sausage	France	95			5 (*Enterococcus*)	Ammor et al. (2005)
	Greece	19	48	20	5 (*L. casei/paracasei*)	Rantsiou et al. (2005)
					<5 (*L. alimentarius*)	
	Hungary	71	7	<5	13 (*Weissella*)	Rantsiou et al. (2005)
	Italy	49	30	12	<5 (*Weissella*)	Urso, Comi, and Cocolin (2006)
	Argentina	55	5	40		Fontana, Sandro Cocconcelli, and Vignolo (2005)
	Spain (salchichon)		59			Aymerich et al. (2006)
Salami	Italy	60	36	<5	<5 (*Leuconstoc*)	Cocolin et al. (2009)
	Spain (chorizo)	89			*Leuconstoc mesenteroids*	Aymerich et al. (2006)
CNS		*S. xylosus* (%)	*S. saprophyticus* (%)	*S. eqorum* (%)	Other (%)	
Sausage	France	11	12	58	8 (*S. succinus*)	Leroy et al. (2010)
	Italy	40	2	11	15 (*S. warneri*)	Iacumin, Comi, Cantoni, and Cocolin (2006)
	Argentina		100			Fontana et al. (2005)
	Spain (salchichon)	73			12 (*S. warneri*)	Martín et al. (2006)
					12 (*S. epidermidis*)	
Salami	Italy	45	17		17 (*S. lentus*)	Mauriello et al. (2004)
					14 (*S. warneri*)	
	Spain (chorizo)	81			8 (*S. warneri*)	Martín et al. (2006)
					6 (*S. epidermidis*)	

Where *LAB* lactic acid bacteria, *L. lactobacillus*, *L. plantarum* species includes *L.-plantarum*, *-para-plantarum* and *-pentosus*, *CNS* coagulase-negative Staphylococci, *S. staphylococcus*, % of isolates identified to species. Data adapted from Leroy, Lebert, and Talon (2015)

Table 10.4 Common commercial starter culture species and their primary functions

SC species	Primary functions/roles
Lactobacillus curvatus and *Staphylococcus carnosus*	Fast acidification
	Mild positive aroma development
	Stable colour
Pediococcus acidilactici and *Pediococcus pentosaceus*	Normal acidification
	Positive aroma development
	Stable red colour formation
Staphylococcus xylosus and *Pediococcus pentosaceus*	Initial fast acidification
	Medium pH decline
	Strong colour formation and stability
	Aromatic flavour development
Pediococcus acidilactici, *Lactobacillus curvatus* and *Staphylococcus xylosus*	Fast fermentation
	Distinct, good flavour
	Strong colour formation and stability
	Bacteriocin-producing sp. help control L. monocytogenase
Lactobacillus sakei and *Staphylococcus carnosus*	Mild acidification
	Positive mild flavour development
	Stable colour
Lactobacillus pentosus and *Staphylococcus carnosus*	Intermediate acidification
	Aromatic flavour development
Staphylococcus equorum	Flavour development
	Nitrate reduction

Adapted from Cocconcelli and Fontana (2010)

Mould Starter Cultures

Moulds play an important role in the ripening of many traditional Mediterranean-style-fermented meats. Research has shown that superficial inoculation of sausages with atoxigenic moulds, i.e. *Penicillium* or *Mucor* sp. contributes to sensory quality (Bruna et al., 2001; Bruna, Fernández, Hierro, Ordóntez, & de la Hoz, 2000; Garcia, Casas, Toledo, & Selgas, 2001). These sensory developments have been attributed to a number of actions carried out by the moulds, such as lactate oxidation, proteolysis, degradation of amino acids, lipolysis, lipoxidation, delay of rancidity and reduced water loss due to slower evaporation (Benito, Rodrı´guez, Martı´n, Aranda, & Córdoba, 2004; Sunesen & Stahnke, 2003; Sunesen, Trihaas, & Stahnke, 2004). Furthermore, mould coverage often confers desired visual characteristics that contribute to overall attractiveness of fermented meats which is attributed to improved colour stability (catalase activity), oxygen consumption and protection from light (Leroy, Verluyten, & De Vuyst, 2006).

10.3.3   Fat

Fat is an essential component of fermented sausages that contributes significantly to the characteristic sensory and technological quality, namely ease of chewing, enhanced juiciness, flavour and aroma development and plays a critical role during the dehydration stage of production (Ruiz & Pérez-Palacios, 2015). Pork back-fat is most commonly used in the production of fermented sausages, although the use of more unsaturated added-fat as a substitute for saturated added-fat has grown in popularity over the last number of years in order to produce more fermented meats that are perceived as healthier. Typically, between 20 and 30 % fat is added to fermented sausages although lower levels can be used. However, the sensory acceptance of fermented sausages is intrinsically linked to the level of fat present in the sausages (Mendoza, Garcı́a, Casas, & Selgas, 2001).

10.3.4   Salt

Salt is a major additive in fermented meats, although levels in the final product range widely from approximately 2 % to over 6 % in some traditional dry sausages (Varnam & Sutherland, 1995). It has three major beneficial effects to the meat:

1. Preservative action: Salt inhibits objectionable putrification and dangerous microorganisms and those which it does not inhibit are more or less unobjectionable, i.e. it promotes the growth of LAB. It achieves this by lowering the water activity. Water activity (a_w) describes the relationship between salt and water in the system. Pure water has a water activity (a_w) of 1.0 and raw meat of 0.99. Raw dry-fermented sausages can have water activity (a_w) as low as 0.92 as they are intended for long shelf life without refrigeration.
2. Solublising/extracting proteins: The extraction of myofibrillar proteins is essential for improving moisture retention and in forming the necessary bind and texture in the finished product. Myofibrillar proteins are salt-soluble and the addition of high salt concentration in rubs and brines extracts the proteins, which are essential for water binding and retention. Lowering the salt concentration can have a detrimental effect on the myofibrillar proteins extract and consequently affect the WHC and water binding properties. If the salt content is lowered, closer attention has to be paid to using high quality fresh, raw meat; adequate physical manipulation (tumbling, massaging); and very tightly controlled thermal processing (Claus, Colby, & Flick, 1994).
3. Flavour: Fermented meats are predominantly associated with an acidic and salty character, therefore highlighting the importance of salt in flavour development of fermented meat products. About 3.5–5 % salt in the product is generally considered as the present day upper limit of acceptability, depending on the product.

10.3.5   *Nitrite*

Nitrite salts can be used in the production of fermented meats. They are particularly useful in long shelf life products as they are powerful preservatives against many spoilage and food poisoning organisms. Typically, they act in the form of dissociated nitrous acid (HNO_2), provided the reducing conditions necessary are present. i.e. formation of NO and reduction of nitrosyl metmyoglobin (Ranken, 2000). However, their use can inhibit many starter culture organisms if not handled correctly. Furthermore, excessive consumption can be moderately toxic in humans and, therefore, the quantities permitted in foods have been restricted. Despite this, nitrite is considered very important in the manufacture of cured and fermented meats and is responsible for the following important beneficial effects:

1. Preservative and anti-botulinal effects: Nitrite serves as a vital bacteriostatic control over the outgrowth of spores from *Clostridium botulinum*. These extremely dangerous, toxin-producing bacteria can grow in anaerobic conditions such as those created in canning and vacuum-packing. Without the addition of the nitrite, the spores may produce vegetative cells that are responsible for producing the *Clostridium botulinum* toxin. The disease has a high mortality rate of 20–50 % and those that recover have health problems that take months to resolve. Heating is lethal to most cells and can destroy the toxin which is heat labile. However, the survival of spores in the meat without nitrite could lead to little or no competition from normal meat microflora allowing spores to thrive and produce vegetative cells and thus more toxins (Adams & Moss, 1997).
2. Flavour development: When meat is cured using nitrite, the resultant, desirable flavour is not the same as the flavour of uncured meat (Ramarathnam & Rubin, 1997). Cross and Ziegler (1965) observed that cured meat flavour was comprised of essentially the same constituents, generated by a combination of several reactions in addition to the suppression of lipid oxidation, irrespective of meat type. Nitrite has been shown to retard lipid oxidation and development of warmed-over flavour in cooked meat and meat products. It may inhibit the action of pro-oxidants in the muscle or stabilise the lipid component of membranes (Pearson, Love, & Shorland, 1977).
3. Antioxidant effects: Nitrite contributes to flavour stability by complexing with haem iron which reduces the risk of the iron acting as a potent catalyst in lipid oxidation. This also prevents WOF, which can result from excessive sodium chloride addition (Claus et al., 1994). If the pigment becomes decomposed, the haem portion becomes detached from the protein, the porphyrin ring is disrupted and finally the iron atom is lost from the haem structure.

10.3.6 Sugars

Simple sugars (e.g. dextrose, sucrose) are added (up to 1 %) as a fermentation substrate which can readily be utilised by all fermentation microorganisms. For example, northern European-fermented sausages are typified by their high acid sensorial profile. This is achieved by using a predominantly *lactobacillus*-based starter culture with high quantities of carbohydrate. In contrast, Mediterranean-style sausages use lower concentrations of glucose with Staphylococcus starter cultures and extended ripening period to develop a less intense acidic profile (Cocconcelli & Fontana, 2010). Therefore, the quantity of added sugar will directly influence the rate and extent of acidulation, i.e. final pH. A 1 % addition can result in a drop of one pH unit. If more complex sugars are used, they will be fermented slower, i.e. the production of organic acids is inversely proportional to the molecular weight of the sugars used as a function of the storage time (Ockerman & Basu, 2016). The build-up of organic acids becomes a limiting factor to the process as it inhibits bacterial growth. The residual unfermented sugars can help reduce the harshness of the salt, giving the fermented product a smoother flavour. In addition, Claus et al. (1994) stated that sweeteners have high water attracting properties and develop the surface colour of some products through browning reactions. In more traditional products where nitrate serves as a source of nitrite (e.g. saltpetre—common name for sodium nitrate), sugars/sweeteners provide the energy required for specific microorganisms to reduce NO_3 to NO_2.

10.3.7 Others Additives

10.3.7.1 Spices

Spices are common adjuncts in fermented products, imparting both characteristic flavor, antioxidant properties and as a fermentation aid due to their antimicrobial effects on certain strains of microorganisms (Ockerman & Basu, 2016). The extent of their effects on fermentation depends on the type, source and magnesium content of the spice. For example, pepper, mustard, garlic, allspice, nutmeg, ginger, mace and cinnamon contain magnesium which is a growth promoter for some cultures (Zaika, Zell, Palumbo, & Smith, 1978) and a growth inhibitor in *L. monocytogenes* and *S. areus* (Kang & Gung, 2000).

10.3.7.2 Polyphosphates

Their main function on addition is the improvement of water holding capacity and working synergistically with salt to extract myofibrillar proteins. Alkaline polyphosphates increase the pH moving it further away from the isoelectric point of the protein, thus increasing the water holding capacity. The outcome of this is that

products produced with the aid of polyphosphates retain more of their natural juices and stay moist despite heat processing and subsequent reheating due to increased water retention. Polyphosphates can chelate (bind) specific metal ions such as iron and copper which can act as catalysts in lipid oxidation and have a diminished role in flavour and colour stabilisation (Claus et al., 1994).

10.3.7.3   Sodium Ascorbate (or Sodium Erythorbate)

This is added to promote/improve colour formation, specifically the nitrosyl myochromagen pigment (stable pink colour if the product is cured with nitrite/nitrate) (Varnam & Sutherland, 1995). Sodium ascorbate has antioxidant properties that maintains colour and flavour of the product by chelating metals (copper, iron, zinc) that can promote oxidative rancidity.

10.3.8   Novel Ingredients

Alternative ingredients that perform similarly to their microbial starter culture counterparts are collectively called chemical acidulants (Leroy & De Vuyst, 2009). They have sometimes been used in the manufacture of salami-style products (Sebranek, 2004). These compounds shorten the ripening process by decreasing the pH without the need for microbial lactic acid formation. Rapid acidification has the potential beneficial actions of reduced spoilage and contamination risk, prolonged shelf life, improved colour stability and textural characteristics (Leroy & De Vuyst, 2009). However, some drawbacks have been reported with their use, such as, non-traditional or overly sour flavour profile (Bunčić et al., 1993), higher degree of rancidity and colour defects [due to organic acid inhibition of Gram positive, catalase positive, cocci (GCC)] (Lücke, 1998) and inhibited nitrite reduction (Campbell-Platt & Cook, 1995). In sausage products, the most common chemical acidulants applied are Glucono-delta-Lactone (GdL), citric acid and lactic acid.

10.3.8.1   Glucono-delta-Lactone (GdL)

GdL is very popular in semi- and un-dried sausage products. It's applied as a water soluble crystalline powder that hydrolyses to gluconic acid within a few hours, resulting in a steady decrease in pH (Barbut, 2006). This progressive acidification is partly the reason for its popularity—it results in a milder tasting product compared to other acidulants that instantly acidify the products. Due to its lactone structure (no free acid position) at room temperature, it can be added during sausage emulsification (Leroy & De Vuyst, 2009). The rate of pH decline is also linearly temperature dependant, i.e. under the heat generated in the smoking stage, the rate of ester hydrolysis increases and is partly converted to gluconic acid (Totosaus, Gault, &

Guerrero, 2000). It is commercially synthesised by aerobic fermentation of glucose with *Aspergillus niger* (or its enzymes) to form a mixture of gluconic acid and GdL, the latter of which is separated by crystallisation (Leroy & De Vuyst, 2009). GdL has both GRAS (generally recognised as safe) status according to the US Food and Drug administration and is permitted as a general food additive (E575) in the (CFR, 2015) CFR—Code of Federal Regulations. A study conducted by (Maijala, Eerola, Aho, & Hirn, 1993) showed that GdL addition in meat was effective in reducing biogenic amine-producing Enterococci and Coliforms.

10.3.8.2   Lactic Acid

Organic acids like citric and lactic acids have been used as chemical acidulants. Lactic acid has also been marketed as a sausage-making ingredient that inhibits *L. monocytogenes* (Leroy & De Vuyst, 2009). Its application in the product causes an instant drop in pH. However, liquid lactic acid applications have been shown to result in detrimental effects on texture, microstructure and moisture retention (Barbut, 2006). Encapsulation of liquid acids has been reported to offset some of these deleterious quality issues—by controlled/slow release during thermal processing (encapsulating material melts at 57 °C) rather than during the sausage manufacture itself (Sebranek, 2004). However, encapsulated acids would then only be applicable to products that undergo thermal treatments (such as the majority of products in the USA) (Leroy & De Vuyst, 2009). Product composition will vary depending on the product type, ingredients used, processing and fermentation conditions. However, the nutritional composition of a typical dry pork/beef salami product is given in Table 10.5 as an example of the levels one can expect in the final product.

10.4   Basic Processing

Meats can be fermented as whole meat pieces, e.g. country hams (sometimes fermented, e.g. Wiltshire cure), biltong and jerky, or in smaller comminuted pieces to form sausages, e.g. salami. Some more traditional products include the use of different animal parts in the fermentation, such as intestines, marrow, fat and sun-dried bones (Ockerman & Basu, 2016). A simplified processing flowchart of the main processing steps for a typical dry-fermented sausage is shown in Fig. 10.1. Weighed amounts of ingredients (meat and fat can be pre-minced) are chopped and blended under vacuum in a bowl chopper (or equivalent processing equipment). Batters are created by the chopping action of the blade (1000–3000 rpm) and are slowly mixed in a rotary motion by the moving bowl (10–20 rpm). In most commercial operations, this process is optimised for particle size and minimal damage to fat tissue, i.e. short processing times ≈5 min at 2 °C (Demeyer et al., 2014). Batters are stuffed under vacuum immediately after comminution into natural (cleaned intestines) and artificial (regenerated collagen, cellulose, co-extruded collagen) casings (Ranken,

Table 10.5 Example of nutritive composition of a typical dry salami (pork/beef)

Proximates	Units	Value per 100 g
Water	g	41.2
Energy	kcal	378
Protein	g	21.1
Fat (total lipid)	g	31.1
Saturated		11.4
Monounsaturated		14.7
Polyunsaturated		4.9
Carbohydrate (by difference)	g	0.7
Total dietary fibre (TDF)	g	0.0
Sugars	g	0.3

Source: USDA (2016)—Nutrient database

2000). Sausages are usually hung on racks in air conditioned chambers of high relative humidity (RH) for ripening. This consists of two stages:

1. Fermentation: This stage is associated with bacterial growth. Examples of time/temperature/RH: 62 h/20–28 °C/60–90 % RH for northern European sausage types and 100 h/5–24 °C/60–90 % RH for Mediterranean sausages
2. Drying: This stage is associated with product stability and flavour development. Temperature and humidity conditions would be similar between sausage types (e.g. 14 °C/78 % RH) but applied for different times, i.e. 2 weeks (northern) and several months (Mediterranean) (Demeyer et al., 2014).

Smoking is an optional step that imparts antimicrobial, antioxidant effects and specific flavour and colour components to fermented meats. It is usually applied after the red surface colour becomes fixed during fermentation, and it is more typically associated with northern European-style products than their Mediterranean counterparts. Sausages or whole muscle fermented meats are subjected by controlled combustion (300–600 °C) of wood (oak) to minimise polycyclic hydrocarbons (Demeyer et al., 2014).

10.5   Novel Processing Technologies

As with any meat product, particularly those that are consumed without cooking (e.g. raw fermented sausages), safety is of critical importance to consumers to ensure that they are protected from toxicological and microbiological hazards. Non-thermal processing technologies, such as high hydrostatic pressure (HHP) processing, pulsed-electric field (PEF), X-ray irradiation, pulsed ultra violet (UV) light, power ultrasound amongst others, are being considered across a wide spectrum of meat products for decontamination purposes and process optimisation. With this in mind, these technologies could be of benefit to fermented meat processing.

Fig. 10.1 Simplified processing flowchart of fermented sausages
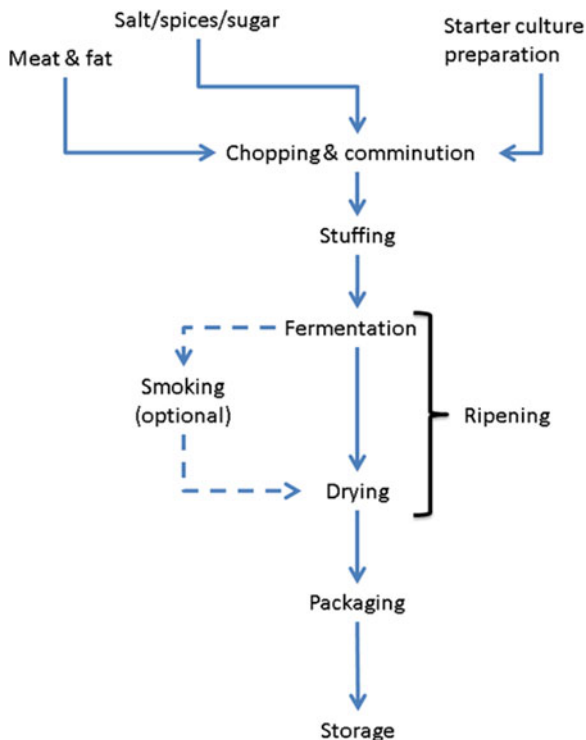
High pressure treatment of foods involve the application of pressures in the range of 100–1000 MPa, and according to the isostatic principle, pressures are applied uniformly and instantaneously through a material independent of its size, shape, composition and packaging (Palou, Lopéz-Malo, Barbosa-Cánova, & Swanson, 2007). While under pressure, molecules obey the Le Chatelier–Braun principle, i.e. promoting reactions that result in a reduction of volume. Such reactions affect the structure of large molecules like proteins causing a partial unfolding of their tertiary structure. Covalent and non-covalent reactions are promoted during and after the release of pressure resulting in denaturation and thus the inactivation of microorganisms and enzymes (Hendrickx, Ludikhuyze, Van den Broeck, & Weemaes, 1998; Knorr, 1993; Oey, Van der Plancken, Van Loey, & Hendrickx, 2008). Furthermore, compounds with little secondary, tertiary and quaternary structures, such as amino acids, vitamins, pigments, flavour, aroma and bioactive compounds contributing to the sensory and nutritive quality of food, may be unaffected (Cheftel, 1992). Advantages of the technique include: It allows food to be processed at ambient or low temperature; it allows instantaneous transmittance of pressure throughout the system, independent of mass and geometry and it causes microbial destruction without resultant heat damage or use of chemical preservatives, thus improving quality (Rastogi, Raghavarao, Balasubramaniam, Niranjan, & Knorr, 2007). The majority of

HHP application in meat research is as a novel pre-/post packaging non-thermal decontamination technique in order to improve the microbiological safety and shelf life (Bajovic, Bolumar, & Heinz, 2012). In fermented sausages, many studies have shown improved product safety with the application of HHP in combination with biopreservation techniques (Garriga et al., 2005; Marcos, Aymerich, Dolors Guardia, & Garriga, 2007; Rubio, Bover-Cid, Martin, Garriga, & Aymerich, 2013). Marcos et al. (2007) reported that the application of high pressure (400 MPa/17 °C/10 min) after the ripening stage reduced *Enterobacteriaceae* without affecting sausage quality, while Rubio et al. (2013) reported that pressures of 600 MPa for 5 min at the end of ripening reduced *Enterobacteriaceae* counts to <1 log cfu/g, 1 log cfu/g reduction for *S. aureus* and *Escherichia faecium* CTC8005 and a 2 log cfu/g reduction for *L. monocytogenese*. These data show that the application of HHP during the production of low-acid-fermented sausages could lead to safer and higher quality products.

HHP application in meat products is also seen as a potential added hurdle for products in salt reduction strategies (Verma & Banerjee, 2012). Omer et al. (2010) studied the effects of HHP with reduced additives, i.e. sodium chloride and sodium nitrite on the survival of verotoxigenic *Escherichia coli* (VTEC) in Norwegian-style dry-fermented sausages. These authors concluded that HHP had the potential to make the sausages safer. Other studies have also reported on a reduction in bioactive amine generation (Garriga et al., 2005; Ruiz-Capillas & Jiménez-Colmenero, 2004; Simon-Sarkadi, Pásztor-Huszár, Dalmadi, & Kiskó, 2012). For example, Latorre-Moratalla et al. (2007) reported strong inhibition of diamine (putrescine and cadaverine) accumulation in pressurised sausage batter (200 MPa/17 °C/10 min) prior to fermentation, while Ruiz-Capillas, Jiménez Colmenero, Carrascosa, and Muñoz (2007) found significant decreases in tyramine, putrescine and cadaverine in pressurised (400 MPa/30 °C/10 min) Spanish 'chorizo' sausages.

Food irradiation as a preservation technique dates back to the 1950s, and numerous studies have been carried out in relation to its impact on meat safety and quality (Brewer, 2009). In fermented meats, Johnson, Sebranek, Olson, and Wiegand (2000) reported irradiating (1.5 and 3.0 kGy) raw materials prior to the production of pepperoni that provided a 5 log reduction of *E. coli* O157:H7 and produced a product comparable to a traditional dry sausage, while Samelis, Kakouri, Savvaidis, Riganakos, and Kontominas (2005) reported similar findings for gamma irradiated (2–4 kGy) frozen meat/fat trimmings prior to fermented sausage production. However, the latter authors also found that gamma irradiation was less promising in its control of *Listeria* spp., including *L. monocytogenes* in that study. Further work by Kim et al. (2012) reported that significant detrimental dose-dependent effects on quality (colour, lipid oxidation, sensory parameters) characteristics were observed in gamma irradiated (0.5–4 kGy) vacuum-packed dry-fermented sausages. With this in mind, and due to some other drawbacks (rise in temperature, requirement for a radiation source), electron beam irradiation techniques have shown some promise as an alternative irradiation technique. Studies by Lim, Seol, Jeon, Jo, and Lee (2008) and Cabeza, de la Hoz, Velasco, Cambero, and Ordóñez (2009) found that electron beam irradiation treatments (2 kGy) were an effective biocide in the production of food-borne pathogens, specific to dry-fermented sausage products.

Like HHP, PUVL/pulsed light (PL) have been used as a decontamination technique in food applications. PL consists of short length flashes (10^{-3}–10^2 ms) of intense, broad spectrum light, rich in UV (Ojha et al., 2015). Decontamination occurs by way of photochemical changes to DNA caused by UV-C, photothermal and photophysical damage to cells, i.e. water vaporisation and cell membrane disruption. This makes it a very simple and cost-effective technique to increase the safety of ready-to-eat meats, like dry cured products. Ganan, Hierro, Hospital, Barroso, and Fernández (2013) evaluated the efficacy of PL in salchichón (pork dry-fermented sausage) on the inactivation of *L. monocytogenes* and *Salmonella enterica serovar Typhimurium*. Log reductions between 1.5 and 1.8 cfu/cm^2 were obtained for both organisms when an application of PL (11.9 J/cm^2) was applied.

10.6 Basic Fermentation Biochemistry

During the ripening stage, the fermented meat is a dynamic system and is affected by both microbial and endogenous enzymes (Demeyer et al., 2014). The microbial decomposition of carbohydrates, lipids and proteins are the primary factors influencing the development of characteristic appearance, flavour and texture attributes of fermented meats (Paramithiotis et al., 2010), which are shown in Fig. 10.2. During fermentation process, breakdown of macronutrients, namely carbohydrates, proteins and lipids, occurs as discussed below.

10.6.1 Carbohydrate Breakdown

Carbohydrates serve as the energy and carbon sources for the endogenous microbiota and the added starter culture. The most obvious aspect is the production of lactic and other organic acids by microbial breakdown of these carbohydrates. The formation of lactic acid isomers (D- and L-) is a function of the most dominant species of microbiota present. The result of increasing build-up of organic acids is a concomitant decrease in pH. Decreasing pH in the product promotes or initiates other fundamental changes such as an increase in product stability (inhibiting spoilage and pathogenic organism), salt solubilisation, water release as the proteins coagulate and protein hydrolysis (Demeyer et al., 2014; Paramithiotis et al., 2010).

10.6.2 Proteolysis

Initial proteolytic activity is carried out by endogenous muscle proteinases (Lücke, 2000), for example, actin and myosin are mainly hydrolysed by cathepsin D which is activated at acidic pH. The resultant polypeptides formed are further hydrolysed
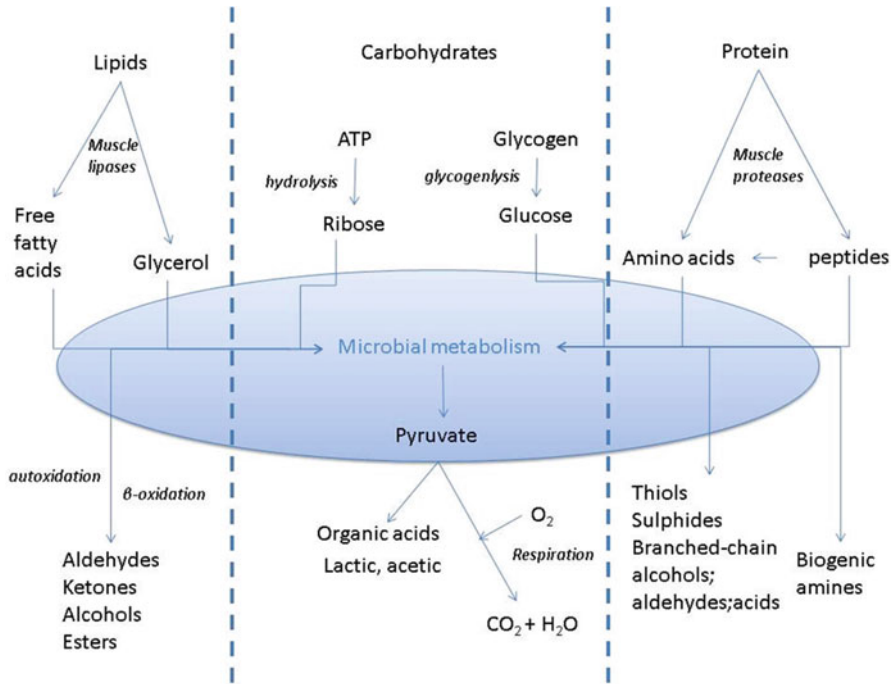
Fig. 10.2 Simplified biochemical changes during meat fermentation [based on Demeyer et al. (2014) and Paramithiotis et al. (2010)]

to smaller peptides (1–10 kDa) and amino acids by endogenous and microbial peptidylpeptidases and aminopeptidases (Demeyer et al., 2014). Amine production is generally a function of the initial contamination of the raw materials/sources within the production cycle rather than the starter cultures themselves. Interest in the formation of biogenic amines (BA) in foods like fermented meats has grown over the last few decades due to the increasing number of sensitive consumers within the general population (Cocconcelli & Fontana, 2010). They represent a health concern due to the toxicological symptoms they can exert i.e. histaminic, intoxicative and interactive behaviour with drugs (Shalaby, 1996), with excessive consumption leading to nervous, gastric, intestinal and blood pressure problems (Suzzi & Gardini, 2003). BA require the presence of amino acid precursors, microorganisms with amino acid decarboxylase activity and favourable pH and temperatures in order to accumulate (Cocconcelli & Fontana, 2010). During the ripening phase of fermentation, many of these amino acid precursors can be formed in the presence of large quantities of protein (raw material) and the proteolytic activity (Komprda et al., 2004). High levels of BA, e.g. tyramine, histamine, putrescine and cadaverine have been reported in fermented sausages (Bover-Cid, Hugas, Izquierdo-Pulido, & Vidal-Carou, 2000; Bover-Cid, Izquierdo-Pulido, & Vidal-Carou, 2000; Hernández-Jover, Izquierdo-Pulido, Veciana-Nogués, Mariné-Font, & Vidal-Carou, 1997a, 1997b).

More comprehensive reviews on the proteolytic capacity of several LAB and Staphylococci strains in fermented meats have been investigated (Drosinos, Paramithiotis, Kolovos, Tsikouras, & Metaxopoulos, 2007; Mauriello, Casaburi, & Villani, 2002; Sanz et al., 1999), which will not be discussed in detail as it exceeds the scope of this chapter.

10.6.3   Lipolysis

Lipolysis is extensively carried out by endogenous tissue lipases (between 60 and 80 %), with the rest being the result of microbial lipases (Molly et al., 1997; Molly, Demeyer, Civera, & Verplaetse, 1996). Polyunsaturated fatty acids are preferentially released due to the phospholipase activity on the muscle membrane and the specificity of fat cell lipases. Of the starter culture strains, LAB hydrolyse mono-, di- and tri-glycerides at a lower rate (Sanz, Selgas, Parejo, & Ordóñez, 1988) than their Staphylococci counterparts (Casaburi et al., 2007; Coppola, Iorizzo, Saotta, Sorrentino, & Grazia, 1997; Kenneally, Leuschner, & Arendt, 1998; Mauriello, Casaburi, Blaiotta, & Villani, 2004; Miralles, Flores, & Perez-Martinez, 1996). Once the free fatty acids are liberated, they become part of oxidative reactions forming flavour volatiles such as aliphatic hydrocarbons, aldehydes, alcohols, ketones and esters. Excessive oxidation can result in the generation of off-flavours through rancidity, which can be offset by the microbiota themselves through their consumption of oxygen (Paramithiotis et al., 2010).

10.6.4   Novel Approaches to Better Understand and Control Basic Underlying Biochemistry

The safety, shelf life and sensory characteristics of fermented meats are the result of a complex set of interacting microbiological, physical and biochemical changes that occur during ripening (Demeyer et al., 2014). Therefore, standardisation of the fermented meat process requires comprehensive knowledge of many of the interactions involved i.e. the effect of ingredients—spices (Verluyten, Leroy, & De Vuyst, 2004); non-meat proteins (Papavergou, Bloukas, & Doxastakis, 1999); the effect of processing conditions—changing temperature/RH combinations (Papadima & Bloukas, 1999); product characteristics—sausage diameter (Ruiz-Capillas & Jiménez-Colmenero, 2004). The distinctive flavour of, e.g. Mediterranean-style sausages is associated with a very specific pattern of proteolysis which is characterised by a lower peptide/free amino acid ratio as well as higher ammonia levels and dictated by specific changes in pH, dry matter, a_w, fermentation type, fermentation temperature, length of ripening, SC used, meat type and sausage diameter (Demeyer

et al., 2014). Simple models (although often over-simplified) can be used to predict and better understand these interacting relationships:

1. Analytical models: Linear or exponential kinetics of time-related changes in metabolite concentrations, microbial characteristics or sensory quality.
2. Mechanistic models: Relate weight losses to changes in: dry matter, pH, a_w, texture; relate the kinetics of pH change to lactic acid and ammonia production, amounts of end products and substrates metabolised within the biochemical and microbial stoichiometry framework (Demeyer et al., 2014).

Other, more complicated multivariate models, such as principal component analysis (PCA) and partial least squared (PLS) regression have been found to be useful in evaluating the technological effects on the sensory and aroma characteristics of fermented meats (Casaburi et al., 2008; Henriksen & Stahnke, 1997).

10.7 Emerging and Future Novel-Fermented Products

Fermented meats are products of historical, regional and cultural significance. They are a marriage of artisan craft and industrial process that are numerous in variety, sensory characteristics and unique ecosystems for microorganisms. Standardisation of the fermentation process is reinforcing their market, and their continued development will open up new avenues to how they are viewed and consumed. Some of the future trends are listed below:

10.7.1 Functional Starter Cultures: Safety

The antimicrobial effect for ensuring the safety of fermented meats is primarily the rate acidification of the raw meat (Lücke, 2000). Despite this, other antimicrobial characteristics can be effective in reducing or eliminating pathogenic microorganisms present in fermented meat products that display acid tolerance, e.g. *L. monocytogenes* (Leroy et al., 2006).

10.7.1.1 Bacteriocin Producers

Strains that produce bacteriocins (bacteriocinogenic) are also considered desirable as they can be helpful in inhibiting several food-borne pathogens and, therefore, improve product safety. Bacteriocins are antibacterial peptides that inhibit the growth of other gram positive bacteria (Cintas, Casaus, Herranz, Nes, & Hernández, 2001; Cleveland, Montville, Nes, & Chikindas, 2001; De Vuyst & Vandamme, 1994). They are often characterised by a narrow inhibitory range that are most active against

closely related species (Eijsink et al., 2002). For example, LAB produce many bacteriocins that actively disrupt other LAB, thereby eliminating a competitor strain, but they are also known to be affective against food-borne pathogens such as *L. monocytogenes* (Leroy et al., 2006). Many bacterial strains have been screened for bacteriocinogenic properties against several food-borne pathogens, including *Lactococcus lactis* (Rodríguez et al., 1995), *L. sakei* (Aymerich, Garriga, Monfort, Nes, & Hugas, 2000) and Enterococci (De Vuyst, Foulquié Moreno, & Revets, 2003). New bacteriocin-producing strains have been isolated and used as new functional starter cultures (Coffey et al., 1998; Scannell, Schwarz, Hill, Ross, & Arendt, 2001). In situ bacteriocin production does not appear to have the disadvantages of flavour modification, which may be the case with utilising other bacterial strains. However, it is recommended that the strains are selected on their suitability for a fermented meat environment to ensure optimal performance and bacteriocin production (Leroy, Verluyten, Messens, & De Vuyst, 2002). Therefore, while bacteriocins do not represent the primary means of preservation, their appropriate integration in a multihurdle preservation protocol can help improve product safety and stability (Leroy et al., 2006).

10.7.1.2   Negative Decarboxylase Activity (Biogenic Amines)

Starter cultures with negative decarboxylase activity could prevent the growth of BA producers and lead to end products almost free of BA, provided the raw material is of good quality (Cocconcelli & Fontana, 2010). Bover-Cid, Izquierdo-Pulido, and Vidal-Carou (2001) and González-Fernández, Santos, Jaime, and Rovira (2003) reported that a selected starter culture, i.e. *L. sakei* CTC494, greatly reduced BA accumulation in fermented sausages. Furthermore, several authors have suggested that starter strains that have amine oxidase activity could further decrease the amount of BA during the fermentation process (Fadda, Vignolo, & Oliver, 2001; Gardini, Tofalo, & Suzzi, 2003; Martuscelli, Crudele, Gardini, & Suzzi, 2000; Suzzi & Gardini, 2003).

10.7.1.3   Other Antimicrobials

Antimicrobial actions, other than that of bacteriocin production, in starter cultures have also been considered. For example, the introduction of the lysostatin gene—an endopeptidase—(from *Staph. simulans* biovar *staphylolyticus*) into a Lactobacilli meat starter (Cavadini, Hertel, & Hammes, 1996, 1998; Gaier, Vogel, & Hammes, 1992) can be used to prevent the growth of *Staph. Areus* by cleaving the specific glycine–glycine interpeptide cross-bridge in its cell wall (Leroy et al., 2006). *Lactobacillus reuteri*, which produces reuterin (a broad spectrum of activity against fungi, protozoa and wide range of gram positive/negative bacteria) or reutericyclin (tetramic acid antibiotic active against gram positive bacteria), have been recommended for inclusion in starter cultures (Ganzle & Vogel, 2003; Paul Ross, Morgan,

& Hill, 2002). Antimicrobials with interesting application possibilities are continuing to be discovered and can be read in greater detail (Niku-Paavola, Laitila, Mattila-Sandholm, & Haikara, 1999; Papamanoli, Kotzekidou, Tzanetakis, & Litopoulou-Tzanetaki, 2002; Pidcock, Heard, & Henriksson, 2002; Sjogren, Magnusson, Broberg, Schnurer, & Kenne, 2003; Strom, Sjogren, Broberg, & Schnurer, 2002; Työppönen, Petäjä, & Mattila-Sandholm, 2003; Valerio, Lavermicocca, Pascale, & Visconti, 2004).

10.7.2 Functional Starter Cultures: Production and Technological Advantages

As previously discussed, bacteriocin-producing strains have the potential to improve safety-fermented meat products. Consequently, they could be effective in the control of some of the deleterious effects of food spoilage. For example, their action could be inhibitive to certain strains of LAB that produce unwanted hydrogen peroxide, product sliminess and off-odours and –flavours (Ennahar, Sonomoto, & Ishizaki, 1999). Furthermore, bacteriocin-producing strains are more competitive than their non-producing counterparts implying that their application within starter cultures may improve the overall competitiveness of the starter culture and lead to a more controlled and standardised fermentation (Vogel, Pohle, Tichaczek, & Hammes, 1993). Other functional starter cultures may be of use in reducing the levels of ingredients used in the fermentation process, e.g. nitrate and nitrite, that may have negative implications for health, i.e. nitrosamines. As nitrates/nitrites are important quality (colour) and safety hurdles (especially for the control of *C. botullinum*), it is hoped that the production of bacteriocins could compensate for this effect, while the use of strains to convert brown metmyoglobin to red myoglobin derivatives could substitute for the distinctive colour of these products (if these ingredients are reduced or removed) (Leroy et al., 2006). The latter possibility was demonstrated by Møller, Jensen, Skibsted, and Knöchel (2003) in smoked sausages using *Lactobacillus fermentum*.

10.7.3 Functional Starter Cultures: Health

Foods that have health benefits beyond those of just basic nutrition (functional foods) are increasingly being sought by more health conscious consumers. With this in mind, the meat industry is examining the possibilities of meat-based functional foods as an opportunity to improve its public image and update dietary goals (Jiménez-Colmenero, 2007). Some of these health strategies are outlined below:

10.7.3.1   Probiotics

Probiotics are live microorganisms that can confer health benefits when consumed in adequate amounts. They can be taken as a dietary supplement or consumed as part of foods, with the food acting as a carrier for the probiotic (Leroy et al., 2006). To date, the most common vehicles for probiotics have been dairy products, e.g. yogurts, but meat products, specifically fermented meats, have been considered promising candidates for their inclusion (Incze, 1998). However, meat products do not typically conform to the reputation of health foods and, therefore, this may compromise their marketing potential (Lücke, 2000). Työppönen et al. (2003) gave the most comprehensive review to date on fermented meats containing probiotics. This review focussed primarily on organisms that had the specific capabilities for meat carbohydrate fermentation. In determining the suitability of other organisms, the first step would be to determine the probiotic activity of: (1) commercially available strains (Erkkilä & Petäjä, 2000), (2) sausage isolates (Papamanoli, Tzanetakis, Litopoulou-Tzanetaki, & Kotzekidou, 2003; Pennacchia et al., 2004) and (3) intestinal isolates that perform well in the fermented meat environment (Arihara et al., 1998; Pidcock et al., 2002; Sameshima et al., 1998). Determining the effects of such microorganisms on the quality indices, particularly the sensory performance, would be an important step in determining their suitability, especially if the strains are derived from non-meat sources. Finally, clinical human intervention studies are the key to confirming efficacy, e.g. (Jahreis et al., 2002).

10.7.3.2   Nutraceutical and Micronutrient Producers

A nutraceutical is defined as substance that is considered a food or part thereof that confers medicinal or health benefits on those who consume it (Andlauer & Fürst, 2002). Most LAB have limited biosynthetic properties for the production of vitamins (Leroy et al., 2006). However, more significant amounts of vitamin production could be possible from more careful selection of strains (Lin & Young, 2000; Morishita, Tamura, Makino, & Kudo, 1999; Sybesma, Starrenburg, Tijsseling, Hoefnagel, & Hugenholtz, 2003), while metabolic engineering shows further promise to further develop cultures with in situ vitamin production capabilities (Hugenholtz et al., 2002). Conjugated linoleic acid (CLA) is a compound found mainly in the meat of ruminants that has been the focus of much food research due to its purported health promoting properties i.e. anti-atherogenic, cancer inhibition, anti-diabetic, obesity lowering and improved immunity (Belury, 2002). Certain bacterial species such as Lactobacilli, Bifidobacteria and Propionibacteria can produce CLA (Alonso, Cuesta, & Gilliland, 2003; Coakley et al., 2003; Jiang, Björck, & Fondén, 1998) and thus could be tailored as part of starter cultures to increase nutritional value of fermented meats (Leroy et al., 2006).

10.8   Conclusions

The market for fermented meats is both global and considerable in scope. However, challenges remain for them to continue as a part of our diets, most notably, the issue of health. Research has demonstrated that fermented meats have the capacity to become vehicles for health promoting compounds, such as probiotics and micronutrient-producing organisms. Furthermore, synergistic combinations of novel processing (HPP) and starter culture selection could reduce the need for such high levels of salt and nitrite, with the former acting as a microbial hurdle and the latter forming the pigments associated with fermented meats. Studies have improved our understanding of the mechanisms controlling the fermentation process in order to improving consistency, speed of production and convenience without compromising product authenticity.

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