Food Chemistry, Vol. 59, No. 4, pp. 505–510, 1997

0308-8146/97 $17.00+0.00

PII: S0308-8146(97)00011-3

ELSEVIER

Mediterranean vs northern European meat products. Processing technologies and main differences

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(Received 15 March 1996; revised version received 3 July 1996; accepted 3 July 1996)

The European Union (EU) meat industry mainly focuses its activity around the curing of pig meat. In Mediterranean countries the term 'cured' is usually applied to products which have undergone a long process of ripening, while in northern Europe products treated with nitrites are considered cured, although there are subtle differences which depend on the process of ripening. In this work the technological processes of curing normally used in the EU are described as a base for discussing the differences that exist between the techniques followed in the north of Europe and the Mediteranean region, and which perceptibly affect the sensorial characteristics of the products. The main differences are centered around dry-cured products, principally because of the diverse methods of curing and smoking in which concepts of preserving and the development of flavour are intimately connected. In the north of Europe, nitrite is used and smoking is considered an integral part of the curing process; in the Mediterranean regions nitrate and long ripening processes are used instead, and these differences are manifest in the sensorial characteristics of the products. Up to now, research has mainly focused around the effects of salt and nitrite as responsible agents in the development of cured meat flavour. Little attention has been paid to the effects of other components, like nitrate, and the microbial and muscular enzymatic systems, which constitute the flavour of dry-cured products. Therefore, further studies are required to evaluate the many factors that may contribute to the formation and differentiation of cured and dry-cured meat flavours. © 1997 Elsevier Science Ltd

INTRODUCTION

In all member states of the European Union (EU), pig meat is the most widely eaten meat, and in many cases a significant proportion of this is consumed as processed meat products (Fisher & Palmer, 1995). The European meat industry is primarily orientated towards the transformation of pig meat by curing techniques. The term 'cured' is applied to numerous meat products but its actual meaning varies according to country and product. In the Mediterranean region 'cured' is normally understood to describe product which has undergone a long ripening (aging) process, where complicated biochemical, proteolityc and lipolityc modifications take place, and which in turn are responsible for the distinctive flavours. In the north of Europe the term 'cured' has a more general meaning and it is mainly applied to meat products treated with nitrites, although they usually distinguish as dry-cured those products which have undergone a process of drying and ripening (Flores & Toldra, 1993).

Originally, curing was a way of preserving derived from salting, although nowadays this is not as important as it was because of refrigeration techniques, and it has acquired a new dimension as a method for obtaining a variety of sensorial characteristics from an extensive range of products (Gray & Pearson, 1984; Goutefongea, 1988). However, concepts of preservation and flavour development are intimately connected and it can be said that they constitute the basic fundamentals of the present curing techniques used in the European meat industry.

In this paper, the technical processes of curing most commonly used in the EU are discussed as a base for discerning the differences that exist between the techniques followed by the north of Europe and Mediterranean countries and which sensibly affect the sensorial characteristics of these products.

PROCESSING TECHNOLOGIES

There is a wide variety of cured meat products on the European market as a consequence of variations in the use of raw materials, formulations, and manufacturing processes which come from the habits and customs of the different countries and regions. From a global viewpoint, two technological processes can clearly be differenciated: dry-curing, and wet or pickled curing (Fig. 1). In the industry, there are multiple variations of curing techniques (Pearson & Tauber, 1984; Townsend & Olson, 1987; Incze, 1991; Flores & Toldrá, 1993) which remain modifications or combinations of the basic processes aformentioned but, as there is a great variety and many are of minor importance, these will not be discussed in detail.

Dry-curing

The dry-curing process is the oldest one and uses a mixture of curing ingredients mainly salt, nitrate and/or nitrite and sugars. Generally, the dry-cure is applied without any added water. Consequently, the curing agents are solubilized in the original moisture present in the meat and they penetrate by diffusion. The dry-curing process is applied to pieces and minced meats.

The pieces (Flores, 1989) are rubbed with a mixture of the curing ingredients and are left covered with dry salt in the salting chamber. The temperature in the salting room is held at 1–4°C for a period of time depending on the characteristics of the pieces, usually 1–1.5 days kg^{-1}. After salting is completed, the excess salt is washed off and the meat is placed under refrigeration (3–5°C) for 20–40 days for salt equalization. The objective of this post-salting phase is to achieve a complete and homogeneus salt distribution throughout the piece of meat. The next step involves time–temperature interactions. The stabilized pieces are placed in natural or air-conditioned drying chambers where the temperature is usually varied betwen 14 and 22°C at relative humidities between 90 and 70%. The ripening period varies with the type of ham for a minimun of 6 months (rapid process) and up to 12 or more months (slow process).

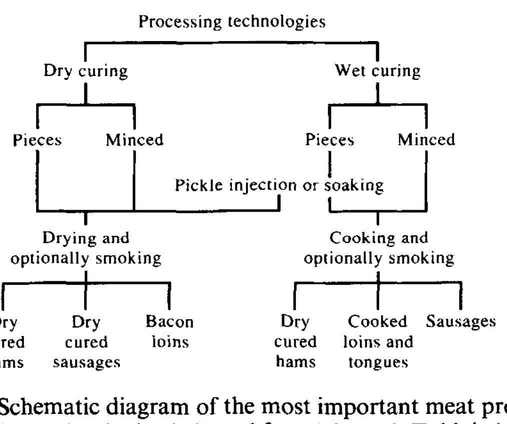

Fig. 1. Schematic diagram of the most important meat product processing technologies (adapted from Flores & Toldrá, 1993).

Complex biochemical reactions, mainly proteolitic and lipolytic, take place and characteristic flavour is developed (Demeyer *et al.*, 1986; Incze, 1991; Demeyer, 1992; Verplaetse, 1994; Dainty & Bloom, 1995; Toldrá *et al.*, 1995). In the Mediterranean area, the Spanish Serrano ham, Italian Parma ham and French Bayonne ham are the most representative products with variations on sensorial profiles depending on the technological parameters and conditions of each dry-curing process that differ among the countries. While, in the northern Europe countries, the hams are smoked after postsalting and subsequently aged only over a 1–3 months period, like German Westphalia ham (Baldini *et al.*, 1992; Campbell-Platt, 1995; Parolari, 1996).

The dry-curing of minced meats is used for the manufacturing of fermented sausages (Lüke & Hechelmann, 1987; Flores, 1989, 1990). Curing ingredients and adjuncts are mixed with the minced meat and, subsequently, stuffed into natural pork or veal casings, or made from reconstituted collagen. Sausages are placed into natural or air-conditioned drying chambers at 20–24°C for about 2 or 3 days to promote the development of the microbial flora responsible for fermentation. Starter cultures may be added to accelerate this process. Sugars are metabolized to lactic acid and the pH drops to 4.5–5.0, very close to the isoelectric point of meat proteins. Thus, three objectives are achieved:

1. selection of the microbial flora, eliminating the pathogenic micro-organisms;
2. reduction of the water-holding capacity of proteins, favouring drying; and
3. protein coagulation giving the sausage a characteristic texture.

The temperatures of the ripening period usually range from 10 to 16°C, with relative humidities from 90 to 70% and its length depending on the kind of product. Generally, three processes are distinguished:

1. rapid, that takes over 7 days;
2. regular, over 20 days; and
3. up to 2 or 3 months in the slow process.

Typical Mediterranean sausages include the Italian salami, Spanish chorizo and French saucisson sec, and northern European, German or Hungarian style salami (Campbell-Platt, 1995). Many sausage products are of either German, Italian, French or Spanish origin and, in fact, these countries account for aproximately 80% of estimated production of fermented sausages (Fisher & Palmer, 1995). The sensorial characteristics of these products are very different as a consequence not only of the technological conditions of each process but of the ingredients used in the distinct geographical areas.

Wet-curing

The ingredients for wet-curing are essentially the same as those for dry-curing and, as adjuncts, phosphates are usually added to aid water retention and increase yields. All of them are dissolved in water to form a brine or pickle which is used as a vehicle for cure diffusion into the meat. The wet-curing process is also applied to pieces and minced meat (Flores & Toldrá, 1993).

In the wet curing of meat pieces, two techniques, in essence, are used: brine soaking, and pickle injection. In brine soaking, the pieces of meat are inmersed in the curing brine until the cure has penetrated the entire piece. This process is slow and if large pieces are used, spoilage can develop. Thus, its primary use is in producing small items such as loins, tongues, etc. The other technique, pickle injection, allows a more rapid and uniform cure diffusion throughout the entire piece. It has numerous variants like artery pumping, stitch pumping and multiple needle injection pumping (Pearson & Tauber, 1984). The latter, being widely utilized today for producing cooked ham and shoulder, has three important steps: the multiple needle injection pumping, the mechanical tumblers for massaging to accelerate and improve brine uptake and, finally, the packing section where the pieces are stuffed or moulded before cooking. When producing loin or bacon, one important modification involves deleting massaging and, instead, allowing pieces to dry for a period and/or smoking.

In the case of wet-curing of minced meat, the curing ingredients and adjuncts are directly added to meat and fat and mixed into the products when preparing the paste or emulsion. Ice is also added to the mixture to cool the meat paste below 10°C, allowing emulsification of fat and preserving protein denaturarion which might break the emulsion. The meat paste is stuffed into cellulose, plastic or reconstituted collagen casings, heat treated and, optionally, smoked. Wet cured sausages are available in many varieties, but frankfurters and bologna sausages are well known (Flores & Toldrá, 1993).

MAIN DIFFERENCES

The main differences between meat products from the north and south of the EU can be seen in dry-cured products, principally, as a result of the curing and smoking processes. Typical Mediteranean type products are given a slow curing process where nitrite is not usually used and smoking is not applied, while in north European countries nitrite is used and the smoking is almost an integral part of curing (Cassens, 1994). Thus, for example, in Germany, roughly 95% of the raw sausages are smoked and only 5% are mould-fermented, whilst the situation, for example, in Italy, is exactly the reverse (Leistner, 1995). These cured and smoked treatments can be considered mainly responsible for the differences in the sensorial characteristics of the products. In the following discussion, attention is paid to the main differences of the dry cured technology commonly used in the north and south of the EU.

Curing

Salt, nitrate and/or nitrite are the main ingredients in the curing processes. Salt levels in meat products may vary between 3 and 6% although this is not high enough to exert a complete bacteriostatic action. Therefore, other preservation techniques such as refrigeration, acidification, dehydration, cooking and smoking are required. On the other hand, salt may cause undesirable effects in that it may accelerate oxidation of pigments and fats, resulting in brown off colours and rancid taste. Nitrate and nitrite play an important role in the prevention of these changes (Goutefongea, 1988; Wirth, 1989; Müller, 1991; Flores & Toldrá, 1993).

Nitrite is the active agent in the curing mixture and, in fact, all reactions taking place during curing have some kind of relation with nitrite chemistry. These chemical reactions have been studied extensively, but the results are not conclusive due to the high reactivity of nitrite, the complexity of the meat substrate and the type and method of processing of the product (Cassens, 1994).

Although nitrite is clearly associated with cured meat flavour in certain products, the chemical changes responsible are not entirely understood (Cassens *et al.*, 1979; Gray & Pearson, 1984, Goutefongea, 1988; Noel *et al.*, 1990). Nitrate is added as sodium or potassium salts, which is transformed to nitrite by bacteria with nitrate reductase activity, naturally occurring in meat or added as starter cultures. Because nitrate and nitrite can exert acute toxic effects and contribute to the total body burden of N-nitroso compounds, it has been recommended that exposure to these agents be reduced. Reduction in nitrite use should not compromise protection against botulism. The use of nitrate salts in curing should be eliminated, with the exception of dry-cured products, due to the great uncertainty of conversion of nitrate to nitrite (Cassens, 1995).

From a general point of view it could be said that cured meat products from the north European market are cured with nitrite, while nitrate is used exclusively for products which undergo long periods of ripening as in the Mediterranean countries. It is also interesting to note that some dry-cured hams are produced without nitrate and surprisingly develop a satisfactory colour (Luke & Hechelmann, 1987; Parolari, 1996). Nitrite and nitrate are used together in meat products but, in some countries such as Germany, this is not allowed (Leistner, 1992). These different ways of curing clearly influence the sensorial characteristics of the products.

Colour

When nitrite is added to the meat, numerous and complex chemical reactions take place which lead to the development of the cured pigments nitrosomyoglobin or nitric oxide myoglobin. The mechanisms of formation of this pigment still remains unclear and several mechanisms have been suggested (Möhler, 1973). Because nitrite reacts quicker and less is required for colour stabilization, it is widely used in place of nitrate. When nitrate is used it must first be reduced enzymatically to nitrite and the pH of meat should be in the range from 6.0 to 5.4 because a stronger degree of acidity would prevent bacterial enzymatic activities. This process is very time-consuming, difficult to control and it has not received as much attention as the sodium nitrite process. Alley *et al.* (1992) reported that nitrate as such may not affect colour but they observed that the surface colour of sausages was found to be darker with increasing levels of nitrite. It is a proven point that colour, tone and intensity, of products vary perceptibly according to whether they are cured with nitrite or nitrate (Durand, 1990).

Flavour

The nature of the components contributing to cured meat flavour and the role of the curing ingredients in flavour development have been described by Gray and Pearson (1984).

The contribution of nitrite to cured meat flavour is well established but the nature of flavour development is not so clear (MacDougall *et al.*, 1975; MacDonald *et al.*, 1980; Noel *et al.*, 1990). Some authors indicated that the effects of nitrite are due to prevention of oxidation, while others indicated that the nitrite interacts with the tissue components to produce the characteristic cured-meat flavour. However, the effects that nitrate might have on the development of cured flavour have not been studied. Some authors have indicated that the quickness of nitrite in slow dry-curing processes does not permit the development of typical sensorial characteristics. In these products it is considered that curing with nitrate is indispensible because, among other factors, it directs the microbial development towards the growth of favourable germs, especially acido lactic bacteria and micrococci to produce oxidized derivates, aldehydes and cetones, which together with nitrated and nitrosed compounds contribute decisively to the flavour (Durand, 1990). This observation was already described in 1945 by the American Meat Institute (Gray & Pearson, 1984), which stated that nitrate is changed to nitrite by the action on micro-organisms, and it is probable that these organisms have an important bearing on the characteristic flavour produced. In addition, these nitrate-reducing organisms, usually micrococci or coagulase negative staphylococci, make an important contribution to the flavour of the products and also produce catalase which removes H_2O_2 produced by the lactobacilli, and which can cause colour problems (Marchesini *et al.*, 1992).

It is generally recognized that cured flavour is the result of multiple components, like flavouring agents or enhancers which are added, and treatments like smoking may contribute significantly to that flavour. In dry-cured products like hams and sausages, where only curing agents are used, the flavour noticeably differs according to the use of nitrate or nitrite (Durand, 1990).

Bacterial inhibition

Numerous studies have shown different sensitivities of bacteria to nitrite. Gram positive bacteria, such as those of the genus *Lactobacillus* and family *Micrococaceae*, which play an important role in fermentation of sausages, are more resistant to nitrite. Thus, in dry-cured sausage manufacture, nitrite is very important because it helps the selection of an adequate fermentation flora. However, the most important function of nitrite is to inhibit the outgrow and toxin formation of *Clostridium botulinum*, a bacterium that produces a highly potent and dangerous toxin. Nitrate is not an antiseptic in the sense ordinarily understood by this term but it may exert a bacteriostatic action on meats if it is first reduced to nitrite (Roberts, 1975; Gray & Pearson, 1984).

The studies produced on the antibacterial properties of nitrates have focused on pathogen and spoilage causing germs, but they have not touched on the effect of the flora which is responsible for flavour, and which in turn is very pertinent to Mediterranean area products.

Smoking

The origin of the smoking of meat products, as with salting and curing, is lost in history. Smoke is a complex mix of high and low molecular weight components, the composition of which depends on factors such as: the type of wood used, humidity, combustion temperature, quantity of oxygen, etc. The components of the smoke come into contact with the product by condensation or adsorption, depending on the surface characteristics and the process conditions, and affect the aspect and sensorial characteristics of the product. Smoking is commonly used in the north of Europe where it is considered almost an integrated part of curing (Cassens, 1994). In the Mediterranean area it is very seldom used (Leistner, 1992).

Bacterial inhibition

Smoking has antibacterial and fungicide effects, mainly because of its formaldehyde content and phenolic components (Girard, 1988; Toth & Polthast, 1984). Generally, these effects take place on the surface of the meat products, although in some cases, such as in thinner products, the effect can be deeper. Normally, smoked products are free of mould on the surface in short ripening processes, while those untreated become covered with a fungous flora (natural or produced with a starter) whose enzymatic metabolism clearly conditions its sensorial characteristics (Marchesini *et al.*, 1992).

Colour and flavour

Smoked products have a characteristic colour and flavour which vary according to the type of wood used and the parameters of the processing and smoking. The typical colour and flavour of smoke-treated products are not fully explained by a deposition of smoked constituents on the surface but a great number of smoked compounds may react with food constituents. These reaction products provide a different taste from that of the original reaction components (Toth & Potthast, 1984; Muller, 1991).

The flavour of the unsmoked products is directly related to the biochemical, proteolytic and lipolytic mechanisms which take place during ripening (Flores & Bermell, 1996). The mould-ripened dry sausages owe their typical appearance and flavour, chiefly, to their surface flora, particularly moulds and yeasts. These unsmoked dry sausages are normally ripened for a long time and are often preferred in the Mediterranean area. The surface is usually inoculated by dipping in a suspension of mould spores or by spraying. This largely avoids colonization by those moulds that cause faults in the appearance and aroma of the products and can produce mycotoxins (Lücke & Hechelmann, 1987).

The pH pattern in the core of firm dry sausages is definitively accelerated by adding *lactobacilli* starter cultures. They are used today when manufacturing on a large industrial scale in order to standardize the production process and the quality of the product. When these meat products are treated with smoke, their sensorial characteristics fundamentally depend on the intensity of the smoking and fermentation processes. In the Mediterranean area, many dry sausages exhibit mould growth on the product surface and the manufacturers feel these moulds are essential to achieve the typical sensorial characteristic of their products. The moulds have an important role on the flavour of the sausages due to the enzymatic attack on the proteins and fats. A common type of enzymatic attack on amino acids is the oxidative de-amination to ammonia and the corresponding alpha-keto acid. Large ripening chambers can have a strong ammoniacal smell resulting from proteolytic action on meat proteins and many processors utilise the mould growth as an indication of the proper drying conditions (Bacus, 1984; Demeyer *et al.*, 1986).

The liberation of ammonia raises the pH of the sausages. The pH curves of the unsmoked and smoked sausages are showed in the Fig. 2 (Marchesini *et al.*, 1992). The pH of the smoked product fell from the initial value of around 5.8 to just below 4.8 after 28 days. The pH of the unsmoked product fell but only to values of around 5.3 after 15 days. The pH then began to rise again, finishing at a value of nearly 6.2, higher than the initial value. This rise in pH coincided with the abundant appearance of moulds. The pH curves of the batches with and without starter (lactobacilli) were virtually identical. A strong pH gradient from the centre to the outside in the unsmoked sausage is observed, the outside being at a higher pH than the centre. In the smoked product, no such pH gradient was observed, and there was no mould growth. The smoked sausage is characterized by a sharp, acidic flavour and a strong smoke flavour which masks all other flavour notes. The unsmoked sausage has a milder, less acid flavour which allows meaty flavours to dominate the overall flavour profile. These differences result basically from the smoking process which prevents the surface mould growth and which is an essential part of the flavour of the Mediterranean area sausages (Marchesini *et al.*, 1992).

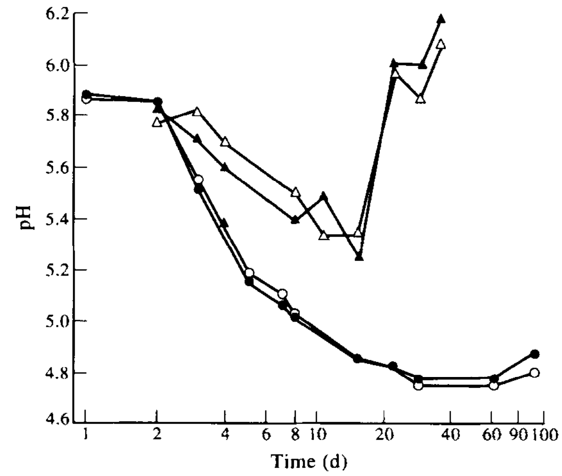

Fig. 2. pH development of smoked (○ with and ● without starter cultured) and unsmoked salami (△ with and ▲ without starter culture). From Marchesini *et al.*, 1992. By permission of Blackwell Science Ltd, Oxford.

CONCLUSIONS

The main differences between meat products from the north and south EU countries can be seen in dry-cured products, as a consequence of the curing and smoking processes. In Nordic countries curing is carried out with nitrite, and smoking is almost an integral part of the dry-cured process, while in the Mediterranean area nitrate is prefered and long ripening processes are applied instead of smoking.

Industrial experience indicates that there are marked differences in the sensorial characteristics of meat products cured with nitrite or nitrate. Research on cured meat products has mainly centred on the effects of salt and nitrite on colour and flavour. Other components, such as nitrate, and factors such as mould covering, have not been convincingly studied. The studies produced on nitrates have focused on pathogen and spoilage-causing germs, but they have not touched on the effect of the microbial flora which is responsible for colour and flavour. Neither has sufficient attention been paid to the muscular and microbial enzymatic systems that increase peptides, aminoacids, free fatty acids and volatile compounds which (together with their interaction products), form the sensorial characteristics of the long ripening dry-cured products. Therefore, further studies are required to evaluate the many factors that may contribute to the formation and diferentiation of colour and flavour in the two principal dry-cured processes.

ACKNOWLEDGEMENTS

The author wishes to thank the Spanish Comision Interministerial de Ciencia y Tecnología (Grant ALI 94-0723) for its financial support and M. Angeles García for typing the manuscript.

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