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Technologies to shorten the drying period of dry-cured meat products

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Abstract

Dry-cured meat products are well-known for their unique sensory characteristics. However, the traditional process is very time consuming. The process can be shortened especially by accelerating the drying period, which is the most time consuming. This paper deals with some technological, safety and sensorial aspects for producing fermented sausages and dry-cured hams when the process time is shortened. Different techniques, such as temperature increase and thickness reduction, and the effects of some ingredients and additives are discussed. A Quick-Dry-Slice process based on a continuous system that combines both convective and vacuum drying could accelerate the drying of slices after the desired pH is reached in fermented sausages.

There are safety concerns when processes are shortened, but possible additional hurdles, such as the introduction of bacteriocin-producing starter cultures and high-pressure treatments at the end of the process, could reduce them. Methods to speed up the development of typical colour, texture and flavour and their limitations are also discussed.

Keywords: Fermented sausages; Dry-cured ham; Accelerated production; Technology; Safety; Sensory properties

1. Introduction

Fermented sausages and dry-cured hams are traditional products prepared since the earliest civilizations to preserve meat. Although nowadays meat can be preserved by freezing, refrigeration and thermal processing, the traditional fermented sausages and dry-cured hams are still produced in large quantities because they have a unique and much appreciated flavour. However, the traditional processes are very time consuming. They range from 1–2 weeks in small calibre fermented sausages to 1.5–3 years in Iberian hams (obtained from Iberian pigs fed and fattened with acorns). Drying is the limiting step of the process in terms of time. A shortening of the drying period would result in a reduction of the drying facilities, capital and labour, and would increase the profit margin and the product competitiveness while reducing some safety concerns, such as mould growth, lipid oxidation and mite infestation.

The aim of this paper is to present some technological, safety and sensorial aspects for producing fermented sausages and dry-cured hams when the process time is reduced.

2. Technological factors to shorten dry-cured meat production process

The process for manufacturing fermented sausages involves grinding of meat and fat, mixing with salt, spices and other ingredients and additives, and stuffing into casings. Natural casings are typically used in traditional products, whereas artificial casings are used in products to be sliced because they show higher water permeability and resistance, constant diameter and they are easily removed. Once stuffed, sausages are fermented to the desired pH and finally dried to the target water content, at the appropriate temperature and air humidity.

The dry-cured ham process is based on a salting-curing step where salt and other additives are absorbed, followed by a resting period at a temperature below 5 °C until water

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activity (a_w) decreases below 0.96 to prevent growth of undesirable microorganisms (Leistner, 1985). Finally, a drying period follows where the temperature is gradually raised as a_w decreases, to accelerate the drying process and the development of the typical aged flavour.

2.1. Fermentation step

In fermented sausages, the pH is a very important hurdle to stabilize the product and affects flavour and texture. The faster the pH decreases, the shorter the drying process can be. Carbohydrates, mainly dextrose, are the substrates used by lactic acid bacteria (LAB), added or not as starter cultures, to produce organic acids (e.g. lactic acid). To shorten manufacturing time, acidification can be produced by the addition of chemical additives, such as gluconodeltalactone – that hydrolyzes to gluconic acid, or encapsulated acids (e.g. lactic and citric acids), that have a mechanism for slow and targeted acid release by employing coating materials that take time to dissolve/break down (Gibbs, Kermasha, Alli, & Mulligan, 1999). The main advantage of using chemical acidification is in eliminating the 12–48 h fermentation period. However, it should be noted that using LAB cultures is very common because of its contribution to flavour.

Some ingredients help to speed up the fermentation process. For instance, addition of soy protein isolates has been shown to stimulate growth of starter cultures and thereby to accelerate fermentation (Hagen, Næs, & Holck, 2000). Moreover, the Mn^{+2} present in some spices accelerates pH drop and stimulates growth of lactobacilli (Vandendriessche, Vandekerckhove, & Demeyer, 1980; Zaika & Kissinger, 1984). The magnitude and perseverance of the stimulating effect produced by Mn^{+2} differs with the type of LAB starter (Hagen et al., 2000). Some LAB strains may also act as bioprotective cultures by producing antimicrobial compounds (bacteriocins), thus enhancing the safety of fermented sausages (Hugas, Garriga, Aymerich, & Monfort, 1995; Hugas, Neumeyer, Pagès, Garriga, & Hammes, 1996).

Fermented sausages with small calibre (initial $\varnothing < 20$ mm) have a high surface/volume relationship that facilitates oxygen penetration, increases redox potential and hinders LAB growth and pH decline. In these products, the lower effectiveness of the so called traditional hurdles could be compensated by other hurdles, e.g. addition of organic acids and selected starter cultures, decrease of a_w and high-pressure treatment at the end of the process (Garriga et al., 2005).

In some Chinese traditional sausages, such as "Lup Cheong", which contains up to 20% of sugar, the pH remains relatively high (between 5.8 and 6.2) and is influenced by the amount of added soy sauce. "Lup Cheong" is neither fermented nor ripened, but dried quickly at temperatures up to 50 °C (Savic, Sheng, & Savic, 1988). The "Fuet Dolç" (a Spanish dry sausage) is another non-fermented product that is rapidly stabilized because it is produced by adding 10–20 g of salt, lemon zest and 800–1000 g of sacarose per kg of meat and attains a water activity between 0.83 and 0.85 just after stuffing. This allows a drying process at a high temperature without safety concerns (Arnau & Matas, 2004).

Fermentation is not typical in the traditional dry-cured ham process because no carbohydrates (or sometimes only small amounts) are added, and LAB are not the predominant microorganisms. In traditional hams, pH tends to increase during the process (Arnau, Guerrero, Casademont, & Gou, 1995), especially in the surface during the resting period if hams are submitted to high relative humidity (Arnau, Gou, & Comaposada, 2003).

2.2. Salting

Processing techniques for the Northern European ham types are characterised by brine immersion, followed by a drying and/or smoking period and ageing for 3–12 months. Other techniques, such as brine injection and vacuum tumbling, are also used for basic quality products. In contrast, Southern European products are non-smoked and mainly produced by means of salt rubbing on the surface. The ageing period is about 6 months in rapid processes and between 1.5 and 3 years in Iberian ham. For bone-in hams vacuum impregnation has been suggested to speed up salt diffusion (Chiralt et al., 2001). A simultaneous brine thawing/salting operation has been proposed for the processing of frozen hams which are salted after thawing (Barat et al., 2006; Barat, Grau, Pagán-Moreno, & Fito, 2004). The results from this study showed a significant reduction of thawing and salting time needed to reach a NaCl concentration, on a dry weight basis, similar to that obtained in the traditional pile salting method. In fact, the use of brine thawing/salting with saturated brine in fresh and thawed hams allowed 58% and 61% time reductions, respectively, compared with the traditional process (Barat, Grau, Ibáñez, & Fito, 2005).

In order to speed up the process for dry-cured hams, several additional production techniques have been proposed: boning and skinning pork legs prior to cure application (Montgomery, Kemp, & Fox, 1976), trimming of subcutaneous and intermuscular fat, blade tenderisation (Kemp & Fox, 1985) and tumbling (Kemp, Abidoye, Langlois, Franklin, & Fox, 1980; Marriott, Graham, & Claus, 1992; Marriott, Graham, Shaffer, & Phelps, 1987a; Ockerman & Organisciak, 1978).

The salting process can also be accelerated by using boned hams (trimmed of skin and subcutaneous fat and excised in several pieces) combined with the curing mixture in a tumbler under vacuum. Once the curing mixture has been absorbed, the pieces could be treated with transglutaminase and vacuum packed to facilitate binding. This process is currently under study to accelerate the stabilization of dry-cured hams treated with potassium lactate and a reduced amount of added salt, i.e. 15 g/kg of green ham (Serra, Gou, Fulladosa, Costa, & Arnau, 2007). The

enzyme transglutaminase (TGase; EC 2.3.2.13) has the property to form crosslinks between protein molecules and has been proven useful for binding food proteins (De Jong & Koppelman, 2002; Kuraishi et al., 1997; Motoki & Seguro, 1998). Kuraishi et al. (1997) reported a good binding strength in restructured pork meat obtained by the addition of TGase with either salt (to enhance myofibrillar protein extraction) or caseinate (a good substrate for TGase and acting as glue between meat pieces), and then stuffed into casings and kept at 5 °C for a period longer than 2 h.

2.3. Drying-ageing

After the resting period in the dry-cured ham process, the drying rate can be sped up by increasing the temperature and reducing the air relative humidity. In restructured boned ham, drying can be favoured by reducing the ham thickness and trimming away subcutaneous and intermuscular fat. The use of water-permeable plastic bags for restructured-ham drying has been proposed to minimize handling to improve hygiene and binding, to start drying earlier and to prevent crusting, mould growth and mite infestation (Serra et al., 2007).

Several applications have been reported to shorten drying time in fermented sausages: reducing the product calibre (i.e. diameter) to reduce the distance for water to reach the product surface, freeze-drying of the meat to remove the highest amount of water prior to fermentation (Lu & Townsend, 1973) and using PSE pork (Pale, Soft, Exudative) to reduce water holding capacity (Townsend, Davis, Lyon, & Mescher, 1980). Moreover, Chin, Keeton and Lacey (1995) observed a 30% drying time reduction (from 18 days to 12 days), without noticeable quality defects in pieces of pepperoni dried under vacuum in laboratory conditions. Recently, a new drying-maturing process: Quick-Dry-Slice (QDS) has been proposed for sliced products (Comaposada, Arnau, Gou, & Monfort, 2004). Sausages are fermented to the desired pH, and are then frozen, sliced and dried in a continuous system that combines both convective and vacuum drying (Metalquimia, Girona, Spain; www.metalquimia.com). With the QDS system, the traditional drying process could be reduced to 30 min. The safety of fermented sausages manufactured with this system was similar to that of traditionally-dried fermented products. Moreover, bacterial counts (i.e. *Clostridium*, *Escherichia coli*, *S. aureus*, *L. monocytogenes*) and *Salmonella* occurrence in vacuum-packaged slices (15 days of storage at 4 °C ± 1 °C) were not different between QDS and traditional process. Challenge tests with the inoculation (100 CFU/g) of *L. monocytogenes*, *S. aureus* and *Salmonella* at the mixing step, showed a similar behaviour of pathogens in both systems, i.e. traditional and QDS. At the end of the process *L. monocytogenes* showed values <1.30 log UFC/g, fulfilling the microbiological criteria for these types of products (Commission Regulation, 2005). However, *Salmonella* was still detected in 25 g in both types of manufactured sausages. Moreover, promising results were obtained when *Salmonella* was inoculated at lower level (<3 MPN/g) and 2 g/kg of sodium acetate were included in the formulation (Garriga, unpublished results). These preliminary results will be further investigated.

Sausages fermented and dried with the QDS process had a less acid flavour than sausages dried with the traditional system. The reason for the lower acid flavour in the QDS process is probably because there is neither a further acidification during drying nor an acid gradient between the outer part and central part of the slice. Furthermore, volatile acids could be evenly removed during drying. For these reasons, in the QDS process, the pH could be decreased to lower values after the fermentation step than in the traditional process. Colour was more intense in the QDS process and some sensitive colorants (e.g. Ponceau 4R) did not fade during the process. The QDS product flavour was slightly different from the traditional product and improved during storage after packaging (Comaposada, unpublished results).

Osmotic dehydration is used in a continuous drying system in which a continuous flattened strip of minced meat (within a sealed film sheath) goes through a dehydrating solution bath. On exiting the bath, the sheath film is removed and the dried minced meat strip is cut and packaged (Sirami & Louthellier, 2002). The drying time required for this process (Osmofood system) is around 3 h. During the process water activity is reduced so that the bacteriological count is decreased by 2–3 logs (Anonymous, 2004).

3. Stabilization rate and safety concerns in dry-cured meat products with shorter production times

Pathogenic and spoilage microorganisms are generally inhibited in fermented sausages due to several hurdles: nitrite curing salt, decrease of redox potential, growth of competitive flora, pH decrease, a_w decrease and microstructure. In dry-cured ham, the hurdles are low pH and low temperature (in green hams and during resting) and a_w decrease (throughout the process). Both types of products are considered safe when produced and consumed according to the traditional system. However, some concerns exist about products that are produced more rapidly, or that are commercialized and/or consumed in a different way than the traditional system. Rapid fermentation might be useful to increase the microbial safety of the final products, because it has been shown that *L. monocytogenes* may grow when fermentation relies on endogenous flora (Garriga et al., 2005) and both *L. monocytogenes* and *E. coli* O157:H7 may grow during the early stages of the fermentation process even when starter cultures are added (Nissen & Holck, 1998). From a safety point of view, it may be better to store some fermented sausages at room temperature than in the cold (Leistner, 1995; Nissen & Holck, 1998), provided that the sensory qualities are retained and that similar results are obtained with other food pathogens.

Several authors have reported the antilisterial effect of bacteriocin-producing LAB strains in fermented sausages. A suitable starter culture: *Lb. sakei* CTC494 (Garriga et al., 1996), was able to suppress the growth of *Listeria* (initially spiked at 9×10^3 CFU/g) and to reduce initial counts by 2.64 log in dry sausages (Hugas et al., 1995). Pediocins produced by *Pd. acidilactici* during fermentation and enterocins produced by *Ent. faecium* CTC492, included in the meat mixture, provide an additional hurdle against *Listeria* proliferation in different types of fermented sausages (Aymerích, Garriga, Jofré, Martín, & Monfort, 2006).

High-hydrostatic-pressure (HHP) processing is a non-thermal food preservation technology with more prospects nowadays for its application in the meat industry (Hugas, Garriga, & Monfort, 2002). HHP has been recommended to produce low-risk and high-quality slightly fermented sausages (Garriga et al., 2005; Marcos, Aymerich, Guàrdia, & Garriga, 2007) and some companies use it as an additional hurdle to decrease pathogen-related concerns, both in dry-cured hams and fermented sausages.

In challenge studies, a reduction of *Salmonella,* inoculated in sausages at the time of manufacturing, was observed during ripening, irrespective of the addition of starter cultures. Moreover, HHP treatment at 400 MPa and 17 °C for 10 min on ripened sausages ensured the absence of the pathogen in slightly fermented sausages. Selected starter cultures proved to be useful to control enterococci population and biogenic amine content in both types of sausages (''fuet'' and ''chorizo'') whereas HHP might be considered an additional hurdle only in ''fuet''. *L. monocytogenes* decreased significantly in starter batches, but no additional reduction was recorded after HHP treatment. Pressurization after ripening diminished the inoculated *Listeria* in the non-starter batches, although the starter cultures used were more effective than HHP treatment (400 MPa) to reduce *L. monocytogenes* in these types of sausages (Garriga et al., 2005). Complying with the good manufacturing practices, the combination of the appropriate starter culture(s) and HHP treatment after ripening will improve the safety of slightly fermented sausages.

Some studies have also been done on other types of cured meat products. Vacuum-skin-packaged dry-cured ham slices treated at 600 MPa for 6 min showed a significant reduction in spoilage endogenous microflora and counts were kept at low levels during the 120-day storage period. *L. monocytogenes* was present in one of the control samples but absent in all HHP-treated samples during the whole storage period studied. *Salmonella* and *Campylobacter* were not detected in any samples either control or HHP-treated (Garriga, Grèbol, Aymerich, Monfort, & Hugas, 2004). Different inactivation levels after HHP treatment were observed in dry-cured ham spiked with *L. monocytogenes*, depending on the equipment used (Hugas et al., 2002), which suggest that further research is needed to achieve the desired levels of microbial inactivation and shelf life extension.

4. Sensory properties of dry-cured meat products with a short production process

4.1. Colour

The typical cured colour is usually obtained by the addition of nitrate for long processes, or by nitrite in fast processes. Nitrate by itself does not produce the cured colour and has to be reduced to nitrite by some nitrate reductase microorganisms. So, this process could be accelerated by adding some starter cultures, such as *Staphylococcus* and *Kocuria*. If nitrate reduction is necessary, then fermentation must occur slowly to allow these bacteria to grow. The pH of the mince should be from 6.0 to 5.4, because a lower pH would prevent nitrate reductase activity. Nitrite is reduced by ascorbate and some reductive substances of meat to nitric oxide, which finally reacts with myoglobin (Mb) to produce the nitrosylmyoglobin complex (MbFe(II)NO). This complex is the main contributor to the characteristic cured colour. In fermented sausages curing agents are added to the mixture, but in dry-cured ham the curing salts have to diffuse through the muscle (Fox, 1980). In order to speed up this diffusion process, vacuum impregnation (Chiralt et al., 2001) and brine injection could be used. Nitric oxide has been proposed to reduce curing time of boneless pork legs (Marriott, Tracy, Kelly, & Graham, 1983). However, its use needs further study to determine potential limitations and applicability to existing industrial processes.

In products prepared using only NaCl, such as Parma ham and some Iberian hams, colour is due to a slow formation of the Zn-protoporphyrine IX complex, believed to originate from Mb in which Fe has been substituted by Zn and the heme group separated from the native heme-protein (Møller, Adamsen, Catharino, Skibsted, & Eberlin, 2007; Wakamatsu, Nishimura, & Hattori, 2004a). This complex is not formed if there is any contact with oxygen or curing substances (Adamsen, Møller, Laursen, Olsen, & Skibsted, 2006; Wakamatsu, Okui, Ikeda, Nishimura, & Hattori, 2004b). Three possible substitution patterns have been suggested: (i) a non-enzymatic reaction in which Zn(II) substitutes Fe(II) under anaerobic conditions with concomitant dissociation from the heme; (ii) a bacterial enzymatic reaction where bacteria degrade the pigment, or (iii) an enzymatic reaction where an endogenous ferrochelatase interchanges the two metals (Adamsen et al., 2006; Wakamatsu et al., 2004). More knowledge about these mechanisms and how to speed up the formation of the stable red pigment in Parma ham would enable the manufacturing of meat products with a desirable and stable red colour without the use of nitrite and nitrate.

Apart from the above-mentioned reactions, some ingredients (e.g. paprika) and colorants could contribute to the colour of fermented sausages. The differences in colour caused by the use of a variety of ingredients in fermented sausages (e.g. non-meat proteins) could be compensated

by using colour-intense raw materials and colouring agents.

4.2. Texture

The consistency of fermented sausages increases due to acidification and drying. During fermentation the pH declines and the myofibrillar proteins aggregate to form a gel. After gelation, drying is a major factor affecting binding and rheological properties. Non-meat proteins, such as wheat, soy isolates and whey proteins, and freeze-dried meat could also increase consistency (Stiebing, 1999). The more rapid the pH declines, the firmer the sausage is. Therefore, the addition of rapidly acidifying starter cultures and the presence of microelements promoting microbial development, such as Mn^{+2}, could shorten the production time because they harden the sausages.

A relationship between hardness and water content has been reported in dry-cured ham and loin (Fig. 1). Dry-cured ham hardness increases slightly with the decrease in water content until it reaches around 0.6 g H_2O/g of dry matter. However, below this critical water content there is an important increase in hardness, that could be related with the crust development at the surface which is the most important texture problem in the external zones of the dry-cured hams (Serra, Ruiz-Ramírez, Arnau, & Gou, 2005).

The first approach to obtain an acceptable texture with a short drying period in dry-cured meat products is to accelerate the drying process by decreasing the relative humidity and increasing the temperature of the drying air. However, this implies a reduction in the water activity, and consequently in the water content at the surface. To avoid the crusting problem, precise control of water content at the surface should be maintained.

The relationship between hardness and water content in dry-cured hams is also affected by proteolysis index (PI), pH and salt content (Ruiz-Ramírez, Arnau, Serra, & Gou, 2006). Hams with higher salt content and hams with higher initial pH showed lower PI. Hams with lower PI achieved the same level of hardness with higher water contents than those with higher PI (Fig. 2). Therefore, the critical water content during drying at the surface will depend on the initial pH and the added NaCl level.

The most important texture problems in the inner zones of dry-cured ham are excessive softness (Parolari, Virgili, & Schivazappa, 1994; Virgili, Parolari, Schivazappa, Bordini, & Borri, 1995) and pastiness (Arnau, 1991; Arnau, Guerrero, & Sárraga, 1998; García-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 2000; García-Rey, García-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 2004). Softness is associated with proteolysis (Parolari et al., 1994; Virgili et al., 1995), which depends on moisture content, salt content and temperature. Therefore the proteolysis activity should be considered when the temperature is increased to accelerate the drying process, especially in the first steps of the process and when low salt products are elaborated. High pressure affects the relationship between hardness and water content and could be useful to decrease softness and pastiness in dry-cured hams. Serra et al. (2006) observed that pressurization improved the sensory texture of pasty dry-cured hams by increasing hardness and reducing pastiness. This could be useful for producing low salt dry-cured hams.

4.3. Flavour

The flavour characteristics of dry sausages are thought to result from a combination of spices, meat endogenous enzyme activities, microbial activities, autoxidation

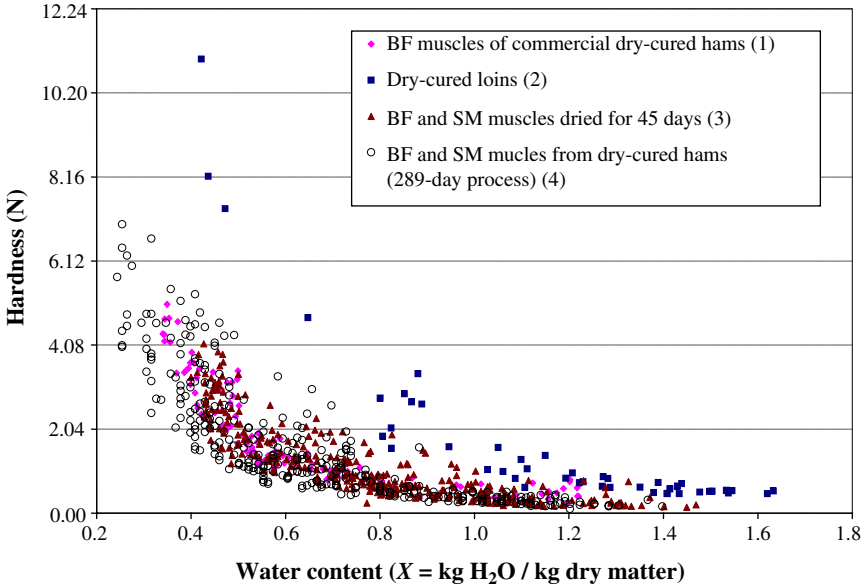

Fig. 1. Relationship between water content and TPA hardness: (1) Serra et al. (2005); (2) Ruiz-Ramírez et al. (2005b); (3) Ruiz-Ramírez et al. (2005a); (4) Ruiz-Ramírez et al. (2006); BF: *biceps femoris*; SM: *semimembranosus*.

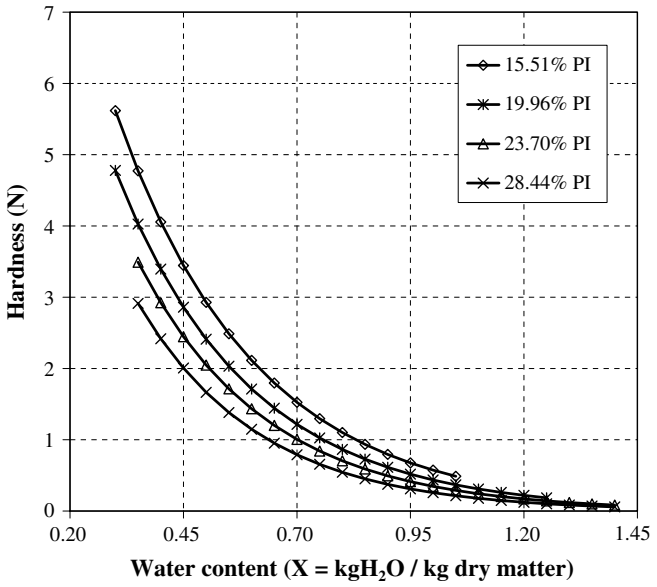

Fig. 2. Predicted TPA hardness versus water content (X) according to the proteolysis index (PI) of dry-cured hams (Ruiz-Ramírez et al., 2006).

processes and the interaction among odorous compounds, whose relative importance varies from product to product (Ordóñez, Hierro, Bruna, & De la Hoz, 1999).

Attempts to accelerate flavour development, by means of enhancing lipid and protein breakdown, have been carried out on cheese by using genetically modified starter cultures, ripening at high temperature and with the addition of enzymes or slurry systems (El Soda & Pandian, 1991). In a similar way, current understanding of reactions occurring during the process of fermented sausages has led to the acceleration of ripening and flavour through the addition of lipases and proteinases, e.g. lipases from *Candida cylindracea* and *Rhizomucor miehei* (Zalacain, Zapelena, Astiasarán, & Bello, 1995, 1996; Zalacain, Zapelena, Paz de Peña, Astiasarán, & Bello, 1997a; Zalacain, Zapelena, Paz de Peña, Astiasarán, & Bello, 1997b), pancreatic lipase (Fernández, De la Hoz, Díaz, Cambero, & Ordóñez, 1995), serine proteinase from *Lactobacillus paracasei* (Blom et al., 1996; Naes, Holck, Axelsson, Andersen, & Blom, 1995), pronase from *Streptomyces griseus* (Díaz, Fernández, García de Fernando, De la Hoz, & Ordóñez, 1993), aspartyl proteinase from *Aspergillus oryzae* and papain from *Carica papaya* (Díaz, Fernández, García de Fernando, De la Hoz, & Ordóñez, 1997). Results have shown that it is possible to accelerate proteolysis and lipolysis, but only a slight flavour improvement was obtained in some cases. The softening effect of proteases is more important than their effect on flavour, and at high concentrations, an excessive softening is observed. Lipase addition increases the hydrolysis of triglycerides to free fatty acids, producing a more intense oxidation, and when high amounts are added an oily texture may appear (Fernández, Ordóñez, Bruna, Herranz, & De la Hoz, 2000). The use of either lipases or proteases does not affect the drying rate, and pH values and microbial counts are usually normal for these products. However, pH can decrease slightly due to fatty acid release by lipases, and increase slightly because of the addition of proteases (Fernández et al., 2000). So, the addition of proteinases and lipases alone is not appropriate for shortening the ripening period (Ordóñez et al., 1999). Thus, it is necessary to find appropriate environmental conditions, or to add either an efficient starter culture, or other types of enzymes (e.g. crude extracts obtained from non-toxigenic moulds), so that volatiles may form from amino acids and fatty acids faster than usual (Bruna, Fernández, Ordóñez, & De la Hoz, 2002; Fernández et al., 2000; Herranz et al., 2004). Otherwise, a much longer time is necessary for transformation of free amino acids and fatty acids through microbial and chemical reactions into the compounds responsible for the flavour.

In the QDS process (Comaposada et al., 2004), the flavour obtained in slices of sausages dried after fermentation (to the same drying level as obtained by traditional process) was considered satisfactory: (i) when selected aromas were added together with the typical ingredients, additives and starter cultures, or (ii) when these aromas were added at the end of the ageing process and the sliced product was then kept packaged in anaerobic conditions for several days.

The aroma of Serrano and Iberian hams has a lipid oxidation base and many aromatic nuances from amino acids originated through Maillard reactions and Strecker degradation. Nevertheless, compounds from the feeding and of microbial origin could also contribute to the overall flavour (Flores, Grimm, Toldrá, & Spanier, 1997; García et al., 1991; Ruiz, Muriel, & Ventanas, 2002; Toldrá & Flores, 1998; Toldrá, 1998; Ventanas et al., 1992). The leaner products have a shorter drying process. However, the presence of some fat is desirable because it is an excellent solvent for some aroma compounds and helps to preserve the typical aroma of fermented sausages and dry-cured ham.

Rogers, Kemp and Varney (1965) attempted to accelerate flavour development in dry-cured ham through the injection of pancreatic lipase and papain into fresh pork legs. Conventional dry-cured hams were preferred to both enzyme-treated samples, and the papain-treated hams were considered too mushy. The use of starter cultures to improve the quality and safety of dry-cured hams has also been studied (Bartholomew & Blumer, 1977; Marriott, Phelps, Graham, & Shaffer, 1987b; Sánchez-Molinero & Arnau, 1998). In general, the expected effect of starter cultures on dry-cured hams is lower than in fermented sausages due to the low temperature and superficial water activity of the product during both salting and resting periods. In addition, problems could arise in the ham structure if they were injected. So, greater knowledge about the ability of the starter cultures to develop appropriate aromas and how they can be used in new processes in the meat industry will lead to meat products with improved flavour.

5. Conclusions

To sum up, a lot of effort has been made over the last decades, from a technological, safety and sensorial point of view, to shorten the manufacturing process of fermented sausages and dry-cured hams. However, further studies should be focussed on the combination of different technologies, which seem to offer the possibility of producing rapid dry-cured meat products and to meet the consumer demand for quality and safety.

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