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Dry-Cured Ham and Fermented Meat Products: Formulating for Flavour

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SUMMARY

Fermented sausages and dry-cured ham are traditional products produced in order to preserve meat. Nowadays, they are well appreciated for their sensorial characteristics. Flavour is one of the most important sensory attributes. The manufacturer has the possibility to prepare the product with different lean meat, fat, ingredients, additives and starter cultures, and guides the process to get different products with different Ðavours. This review will describe how Ðavour of fermented sausages and dry-cured hams is inÐuenced by raw material properties and by the combined effect of ingredients and additives, and processing methodology.

Keywords

dry-cured haw, fermented sausage, meat products, spices, moulds, yeasts

INTRODUCTION

Fermented sausages and dry-cured ham are traditional products obtained since the beginning of mankind in order to preserve meat. Fermented sausages consist of raw, Ýnely chopped meat and fat, which is mixed with salt, spices and other ingredients and additives, put into casings and fermented and dried at the appropriate temperature and air humidity. The dry-cured ham process is based on a salting and resting step at low temperature (<5 ŠC) that stabilises the product and a drying period where temperature is gradually increased relative to the decrease in water activity (a_w), in order to accelerate the drying process and the development of the typical aged Ðavour. Nowadays, both fermented sausages and dry-cured ham are well appreciated for their sensorial characteristics. Flavour, that is deÝned as the combination of taste, aroma and mouthfeel, is one of the most important sensory attributes of meat products because, unlike other quality traits which initiate the purchase of a product for the Ýrst time (appearance) or the rejection of a product (e.g. texture), it is the feature that convinces the consumer to buy the product again (Verplaetse, 1994).

The Ðavour of the Ýnal product obtained is the result of desirable and undesirable nuances, and depends on the raw material characteristics, the ingredients and additives added, and the physical, microbial and biochemical changes produced during the process.

The manufacturer has the possibility to prepare the product with different lean meat, fat, ingredients, additives and starter cultures, and steer the process to get different products with different Ðavours.

In recent years a lot of research has been done on cataloguing Ðavour volatiles and non-volatiles, steering processes with enzymes and microorganisms and clarifying several pathways. Some excellent reviews on factors affecting the Ðavour have been published in the last decade (Buscailhon and Monin, 1994a,b; Toldr· and Flores, 1998; Montel et al., 1998; OrdoÒez et al., 1999).

In this review, sensorial attributes will be discussed in relation to the raw materials, ingredients, additives and processes.

1. RAW MATERIALS

Even though raw meat has little aroma and only a slightly bloody taste, it is a large store of compounds with sapid properties and precursors of Ðavour. It is well known that different raw materials bring different Ðavours to fermented sausages and dry-cured meat products. In general, pork and beef are the most common raw materials, but other animal species (turkey, duck, sheep...) are also used in different countries. In Europe pork is the most important raw material for fermented sausages and dry-cured ham. Some of the characteristics of the raw material are important for the Ðavour of dry-cured ham and fermented sausages:

a) The subcutaneous and intramuscular fat content determine the time necessary for ham drying and consequently affect Ðavour development (Guerrero et al., 1996). Iberian and Duroc breeds are traditionally appreciated in Spain because of the high amount of intramuscular fat that makes its hams suitable for long ageing periods (12-36 months). Recently, the Hungarian Mangalitza breed has been introduced for the production of long aged dry-cured hams (De Miguel, 1999). Long aged hams have a more complex Ðavour that is appreciated by connoisseurs and are more valuable in the market. On the other hand, lean pigs allow the production of dry-cured hams with shorter drying periods (<6 months) that are typical in North European countries. The lean content of hams can be estimated in the industry using automated electromagnetic scanning, also referred to as TOBEC (total body electrical conductivity) (Meseck et al., 1997).

The amount of fat added and the intramuscular fat content of the lean tissue could also affect the Ðavour of fermented sausages. The standardisation of fat content is a basic requirement for constant product quality and reproducible ripening. Rapid methods, such as near infrared (NIR) (Berg and Kolar, 1991), X-ray (Hansen et al., 2003) and electrical impedance (Chanet et al., 1999), for measurement of fat content in meat batches enables the meat processing plants to increase accuracy, resulting in more consistent products. A Ýrm fatty tissue (stored cold or frozen for only a short time) would be preferred in general in fermented sausage due to its lower susceptibility to rancidity. Usually, lipids are the major component of dry-fermented sausages, and the sensory characteristics are closely related with lipid breakdown (hydrolysis and oxidation) and transformation during ripening. The inÐuence of free fatty acids on Ðavour has not been demonstrated. Short-chain fatty acids have a sour taste like cheese. However, the more the chain lengthens, the weaker the sensory characteristics are. In fact, free fatty acids seem to be less important for taste, and are mainly precursors of aroma molecules (Talon et al., 2002).

Fat is also an excellent solvent for aroma compounds. Most of them are of low molecular weight and apolar, and are thus likely to diffuse into either the gaseous or fat phases. The presence of some fat is, therefore, desirable in order to preserve the aroma in fermented sausages and dry-cured meat.

During drying, fat particles are affected by shrinkage stresses that cause pressure on them and can result in the exudation of oil inside the product (sweating). In fermented sausages the higher the temperature and the Ýner the fat particles the higher the oil exuded (Ten Cate, 1969). The rupture of the fat cells results in an oily aspect, facilitates the interaction between fat and proteins (Ventanas, 2001), and could affect Ðavour and drying kinetics.

b) Animal feeding is very important, because it affects antioxidants and fatty acids composition, and provides the animal with other compounds that may contribute to the overall Ðavour of the fermented sausage and dry-cured ham. Typical examples are Iberian pigs fed and fattened with acorns (**Quercus Ilex L)** in the South-West of Spain and Portugal (LÛpez-Bote, 1998), Corsican pigs fattened with chestnuts (Secondi et al., 1992) and traditional pigs fed with Ýgs to prepare the ìSobrassadaî (a spreadable dry sausage typical of Majorca). As a consequence of these feeding systems, adipose and muscle tissues acquire their typical chemical traits which are characterised by an increase in intramuscular lipid content and a large development of subcutaneous adipose tissue leading to a raw matter very different from that of industrial pigs (LÛpez-Bote, 1998).

c) The weight of the green hams affects the Ðavour characteristics of dry-cured ham. Heavy hams show better Ðavour (Desmoulin et al., 1983), maybe because of the longer periods needed for drying. Heavy pigs present lower proteolytic activity (S·rraga et al., 1993) and consequently are more appropriate for longer ageing periods.

d) pH of meat affects appearance, texture and Ðavour. PSE (pale, soft, exudative) muscles absorb more salt in dry-salting (Arnau et al., 1995) and according to Buscailhon et al. (1994b) low pH hams show a Ðavour of dry-cured ham more developed than high pH hams. A low initial pH in muscles favours lipid oxidation in dry-cured hams and facilitates the activity of acid proteases. In fermented sausages, the effect of PSE meat and muscle pH is not as important as in ham, because there is usually a mixture of trimmings from different pigs.

e) There is also a sex effect on flavour: consumers prefer dry-cured ham from carcasses of barrows (Diestre et al., 1990) to avoid boar taint problems detected in hams from entire males. The boar taint problem is lower in fermented sausages, because there is a dilution with non-tainted fat and meat. Hams from barrows have higher marbling and lower processing weight losses than those from gilts in dry-cured ham (Gou et al., 1995a) and as a consequence, flavour could be affected.

f) The prefreezing/thawing of hams previous to dry curing was observed to affect lipolysis (Motilva et al., 1994), and proteolysis (De Smet et al., 2002) and facilitates the NaCl absorption.

g) The way the product is trimmed is also important in dry-cured ham. In Italian and French hams the products contain the skin, whereas in "Serrano ham", it is usually partially removed. When dry-cured hams are manufactured with the skin partially removed, the aged flavour is increased (Gou et al., 2000). The amount of fat covering the lean tissue could also affect the drying kinetics, and the length of the drying process.

The structure of the ham should be kept in order to avoid the penetration of undesirable microorganisms inside the product (Carrascosa et al., 1994) that could spoil it or negatively affect the flavour.

h) The bacterial population of the meat should be kept as low as possible for safety reasons and for the effect on the final flavour, especially in traditional products where starter cultures are not used.

2. INGREDIENTS AND ADDITIVES

NaCl

Common salt has been used traditionally to stabilise dry-cured meat products and fermented sausages. NaCl is the main substance that affects saltiness and enhances the flavour. In dry-cured ham, it has been suggested that glutamic acid produced during proteolysis might increase saltiness (Careri et al., 1993) and that added dextrose might decrease it (Boadas et al., 2000). During the drying process, there is a tendency to equilibrate the NaCl/water relationship, increasing the concentration in the inner part of dry-cured ham (Arnau et al., 1995) and fermented sausages (Rödel and Hofman, 1982). This could be the reason for the higher saltiness inside the product at the end of the process. So, in order to get a homogeneous salty taste it is advisable to perform a homogeneous drying.

In high fat meat products, the intensity of perceived salty taste is lower than in lean products for a given salt concentration. However, for a given saltiness level an increase in salt content is more noticeable in fatty products than in lean ones (Hammer, 1981).

In dry-fermented sausages and dry-cured ham, NaCl content could be reduced if other hurdles such as a reduction of the ripening temperature are considered (Baldini et al., 1984; Wirth, 1989). Alternatively, from 30 to 40% of the NaCl could be substituted by KCl in dry-cured ham (Keeton, 1984) or by KCl and potassium lactate in fermented sausages without any important off-flavour (Gou et al., 1995b). In the products where KCl is added, a different pattern of drying process is expected to be needed, because it precipitates at a_w<0.85 (25 ºC) and facilitates fat exudation when environmental relative humidity (RH) is lower than 85 % (Arnau et al., 2003b).

Cathepsin activity decreases with salt concentration (Sárraga et al., 1989). In dry-cured hams, the lower the salt content and the longer the processing time the more important are the proteolytic changes. It is likely that due to the positive influence of temperature on proteolysis, the inhibition effect of salt is less pronounced at a high temperature (Waade and Stahnke, 1997). High proteolytic index (> 30 %) is not desirable, because a bitter taste related to hydrophobic amino acids and peptides is detected (Virgili et al., 1998). In fermented sausages, peptides, free amino acids and ammonia concentrations are lowered with increasing addition of salt. The data suggest that salt concentration affects initial activity of muscle cathepsins (Demeyer et al., 2001) and also to aminopeptidase activity (Sanz et al., 2002).

High salt percentage increases the content of oxidation products in dry-cured hams (Coutron-Gambotti et al., 1999). But, the use of low prooxidant salt formulations retards the oxidative rancidity of dry-cured hams (Olson et al., 1973). In addition, a high salt/water relationship slows down the acid formation in fermented sausages.

In dry-cured ham the addition of salt is recommended as soon as the temperature inside the product is between 1 and 3 ºC. Processing techniques for the Northern European types of ham are characterised by brine immersion followed by a drying and/or smoking period and aged for a period of from 3 to 12 months. Other techniques such as brine injection and vacuum tumbling are also used for basic quality products. Southern European products are mainly produced by means of salt rubbing on the surface, they are non-smoked and aged from 6 months in rapid processes to 2-3 years in Iberian ham. During the salting step, brine should form on the surface of the ham to facilitate NaCl absorption. Consequently the RH of the salting room should be slightly higher than 75 % to avoid the drying of the NaCl. During resting a RH slightly higher than 75% also prevents NaCl crystallisation and slows down the growth of microorganisms that could produce off-flavours. If RH is higher than 85 %, undesired microbial and mould growth could negatively affect the sensory characteristics of the final product (Spotti et al., 1988; Arnau et al., 2003b). Temperature should be lower than 5 ºC until a_w<0.96 to avoid the growth of pathogenic microorganisms (Leistner, 1985). During the resting period NaCl content decreases on the surface, because it diffuses towards the inner part of the ham. During the drying period the temperature is increased slowly and RH is lowered to values below 75 % to facilitate oil drip (Arnau and Gou, 2001). In this case a decrease in water activity to less than 0.75 in salted fat tissues could produce a marked drop in moisture content, similar to that observed in salted meat (Comaposada et al., 2000). Most of the water in fat tissue is associated with the fat cell membranes and thus a drop in moisture content damages the cell membranes, allowing oil drip, that covers an important part of the lean tissue, facilitates fat oxidation and increases the typical aged ßavour of traditional Spanish hams (S·nchez-Molinero et al., 2000a).

Carbohydrates

Carbohydrates, mainly dextrose, are the main substrate used by microorganisms to produce organic acids, which are mainly responsible for the acid ßavour. Thus, if no sugar is added the acid ßavour will rely only on lactic acid content of raw material and the carbohydrate content of spices. Some examples of these products with very low acid ßavour are ìllonganisa de Vicî (Ferrer and Arboix, 1986), ìsobrassadaî and some chorizos produced with only salt and spices (Arnau et al., 2002; Lois et al., 1987). Processing of these dry-sausages needs an initial drying period at low temperature (<10 ŠC) to compensate for the higher pH. Afterwards, the temperature is increased in order to improve the typical ßavour. These products, which are very much appreciated in the Mediterranean countries, have longer maturing periods to obtain the desired consistency, and are marketed with lower water activity than low pH fermented sausages.

Acid ßavour is not typical in the traditional dry-cured ham because no carbohydrates, or sometimes only small amounts, are added and lactic acid bacteria are not the predominant microorganisms. Careri et al. (1993) consider that the slight acidity present in Parma ham could be produced from substances derived from proteolysis (phenylalanine and isoleucine). In traditional hams the pH tends to increase during the process (Arnau et al., 1995), especially in the surface during the resting period if they are submitted to high RH (Arnau et al., 2003b). However, acid taste could be detected sometimes when deboned green hams are used, or when sliced dry-cured hams are commercialised in vacuum or modiÝed atmosphere, because carbohydrates could be fermentated into acids by lactic acid bacteria.

In contrast, acid ßavour is typical of fermented sausages where starter cultures and carbohydrates are added. The acids come from raw material (lactic acid) and fermentation of sugars by microorganisms to acids (volatiles and non volatiles) such as DL-lactic, acetic...

For shorter manufacturing times, the acidiÝcation is sometimes produced by the addition of chemical additives such as gluconodeltalactone that hydrolizes to gluconic acid, and encapsulated lactic or citric acids that have a retarded or slow acid release until the hydrogenated vegetable oil or mono and diglycerides have melted during heat processing (Hoogenkamp, 1998).

Other carbohydrates such as lactose are added sometimes at higher amounts and could increase sweetness if they are not transformed to acid.

In some traditional sausages the sweet taste is very much appreciated such as Lup Cheong in China that contains up to 20 % of sugar. The pH remains relatively high at pH 5.8-6.2, but is inßuenced by the amount of soy sauce added. Lup Cheong is neither fermented nor ripened, is quickly dried at temperatures up to 50 ŠC and almost always cut into small pieces and cooked, acting as ßavouring matter to different meals, rather than ready to eat products in uncooked form as European dry sausages are (Savic et al., 1988). Another strong sweet-lemon zest ßavoured dry-sausage is ìfuet dolÁî. This dry-sausage is produced in Catalonia (Spain) by adding 10-20 g salt and 0.8 to 1.0 kg of sacarose per kg of pork meat and then dried at room temperature.

Nitrite and nitrate

Nitrite plays a signiÝcant role in the development of speciÝc ßavour notes participating in the desirable overall ßavour of dry sausages (Bailey and Swain, 1973; Noel et al., 1990) and acts as an antioxidant (Mac Donald et al., 1980). Several nitriles, nitro-alkanes have been identiÝed in fermented sausages, but the exact effect in the ßavour is not known (Stahnke, 1995).

On the other hand, some traditional hams such as Parma ham are produced without nitrite or nitrate addition. In this case, the only ingredient that affects ßavour is salt.

Nitrate is transformed to nitrite by nitratereductase activity of some microorganisms such as **Staphylococcus** and **Kocuria.** If nitrate reduction is necessary, fermentation must occur slowly to allow these bacteria to grow. The pH of meat should be in the range of from 6.0 to 5.4 because a stronger degree of acidity would prevent bacterial enzymatic activities. Furthermore, Waade and Stahnke (1997) found that nitrate decreased the level of free amino acids in fermented sausages, either by inhibiting the proteolytic activity in the mince or by increasing the breakdown of amino acids.

Fermented sausages and dry-cured ham produced with nitrate are sometimes considered to have better ßavour than when they are manufactured with the usual amount of nitrite. This could be due to the usual longer processing time of the nitrate treated products, or to the preservative effect of nitrite on some microorganisms involved in ßavour development.

Lactate

Sodium and potassium lactate, due to their ability to decrease a_w, and the speciÝc properties of lactate ion could be useful to prevent overacidiÝcation in medium-high calibre fermented sausages (S·nchez-Molinero, personal communication) and also to prevent pH decrease in products such as low caliber fermented sausages where the acid taste is not typical (Gou et al., 1995b; Gou et al., 1997). Sodium lactate increases salty taste, but has no effect on sour or bitter taste (Brewer et al., 1993). Thus, when sodium lactate is added, NaCl content should be slightly reduced to avoid excessive saltiness.

Sulphite

Sulphite and metabisulphite were traditionally used to delay deterioration and to preserve the typical colour of meat. Even though it could be useful to obtain non-acid sausages (Gou et al., 1997), they are not allowed in fermented sausages in the European Union (EU).

Sorbate and natamycin

Leistner et al. (1975) recommended to dipping smoked fermented sausages in 10-20 % potassium sorbate solutions to prevent unwanted mould growth. Stiebing et al. (2001) found that dipping sausages for 3 seconds in natamycin (0,5 % Premi Nat, DSM) had a more lasting antifungal action than potassium sorbate (10 % solution). Natamycin had no effect on bacterial starters used in sausage manufacture, whereas potassium sorbate showed inhibitory activity against **Staphylococcus** and **Kocuria.** Neither treatment signiÝcantly inÐuenced Ðavour. However, in dairy products, sorbate could be metabolised by certain moulds, lactic acid bacteria (Horwoord et al., 1981) and yeasts (Sensidoni et al., 1994) to trans-1,3-pentadiene, producing a kerosene ìoff-Ðavourî. From the authorís personal experience, this off-Ðavour is also detected when sorbate is added to non-smoked fermented sausages. Thus, the addition of sorbate to prevent mould growth should be evaluated carefully to avoid kerosene ìoff-Ðavourî.

Antioxidants

Ascorbate and erythorbate are used to speed up the reduction of nitrite to nitric oxide and to stabilize red colour. However, when these additives oxidise they produce carbonyl compounds that could react with amino acids producing browning reactions that have not been studied in long matured products.

Rosemary extract could be used in fermented sausages to slow down fat and paprika oxidation. Typical colour is stabilised and off-Ðavours are delayed.

Butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) could be useful to delay the degradation of the fat used to protect the outside of hams from excessive drying.

The recommended tendencies to improve the antioxidant potential of meat and fat are to add tocoferols to the feedstuff in order to allow its accumulation in the lipid membrane (Chizzolini et al., 1998) and to decrease oxidation of dry-cured hams (Ruiz and LÛpez-Bote, 2002).

Phosphates

Phosphates are typical additives used in cooked meat products. However, their interest in fermented products is lower. They reduce viscosity of the sausage mix and decrease TBA values (Klettner, 2000), but are not recommended in products with a high Ýnal pH, because when these products are refrigerated, the precipitation of Na_2HPO_4 increases, which impairs the appearance and texture, giving a fresh, slightly saline taste (Arnau et al., 1997a).

Starter cultures

In fermented sausages, lactic acid starter cultures are added to the meat mix to boost the fermentation process and to accelerate the ripening. The lactic acid bacteria (LAB) used for fermented sausages are always homofermentative. Heterofermentative LAB would also form acetic acid and carbon dioxide, which are undesirable with respect to Ðavour and appearance (porosity). Lactic acid bacteria have a strong inÐuence on the production of L-lactate, but especially of D-lactate, an acid of purely bacterial origin. Furthermore, LAB must not form peroxides, which may lead to discoloration and rancidity. The LAB used in raw sausage as a starter and as a protective culture belong mainly to the following species of microorganisms: **Lactobacillus sakei, L. curvatus, L. plantarum, Pediococcus pentosaceus** and **P. acidilactici** (Hugas, 1998). However, there are also some lactobacilli strains isolated from meat origins which could produce satisfactory Ðavour and are good candidates as starter cultures in the manufacture of dry-fermented sausages (Garriga et al., 1996).

Staphylococcus and **Kocuria** could also contribute to the Ðavour of fermented sausage because of their proteolytic and lipolytic activities and nitrate reduction. They also prevent or retard the development of discoloration and rancidity by forming catalase and superoxid dismutase (Talon et al., 2002). At higher redox potential they tolerate a lower pH better, and they can therefore be detected, particularly close to the edges of raw sausages. **Staphylococcus carnosus, Staph. xylosus** and **Kocuria varians** are among the more used starter cultures (Hammes and Hertel, 1998).

The Ðavour characteristics of dry sausages are thought to result from a combination of spices, meat endogenous enzymes activity, microbial activities, autooxidation processes and the interaction between odorous compounds, whose relative importance varies from product to product (OrdÛÒez et al., 1999). The end products of proteolysis are amino acids and peptides that form part of the non-volatile fraction that contributes to the sapid properties of dry- fermented sausages. The degradation of amino acids into volatile molecules plays an important role in the Ðavour of dry sausages. Aldehydes, alcohols and acids resulting from the degradation of branched-chain amino acids (valine, isoleucine or leucine), phenylalanine and methionine have very low threshold values and can be affected by the type of Ðora present in the meat, and modulated by the type of Ðora inoculated (Montel et al., 1998). Phenylacetaldehyde impart a Ðoral odour (hyacinth) (BerdaguÈ et al., 1991) characteristic of some sausages, and has been detected in some speciÝc processes in dry-cured ham (S·nchez-Molinero and Arnau, 1998). This Ðoral attribute was reproduced in dry-cured ham by injecting a speciÝc lactic acid bacteria strain (Arnau and Garriga, unpublished results).

Free fatty acids can act as precursors of methyl ketones, involved in the aromatic properties of fermented products, via an incomplete β-oxidation. Usually β-oxidation degrades saturated fatty acids into acetic acid by successively eliminating acetyl CoA groups. However, intermediate CoA esters can be freed; such as β-keto or β-hydroxy-CoA esters. They are successively converted into β-ketoacid or β-hydroxyacid via a thioesterase and then into methyl ketone or secondary alcohol via a descarboxylase activity (Talon et al., 2002).

Ethyl esters are probably created in two steps. First the carboxylic acid and alcohols are produced, and they are subsequently linked with an ester bond (Molinari et al., 1996).

Carbohydrates also affect the Ðavour. The buttery or dairy product aroma of certain sausages is related to the presence of diacetyl and acetoin, which may result from the metabolism of pyruvate by the staphylococci (BerdaguÈ et al., 1993).

Starter cultures are only one element of production control and quality assurance. Even starter cultures cannot offset great production faults. Thus, to produce stable, safe and high quality fermented sausages, good raw material and the effective control of temperature, RH and air velocity are also important.

Some authors have studied the use of starter cultures to improve the quality and safety of dry-cured hams (Bartholomew et al., 1977; Marriot et al., 1987). In Spanish dry-cured hams, the superÝcial inoculation with a mixed starter culture (**Lactobacillus sake, Staphylococcus carnosus, Staphylococcus xylosus** and **Debaryomyces Hansenii**) showed lower sweetness, aged Ðavour and acceptability than non-inoculated hams (S·nchez-Molinero and Arnau, 1998). In general, the expected effect of starter cultures is lower than in fermented sausages due to the low temperature and superÝcial water activity of the product during salting and resting periods, and to the problems that could arise in the structure if they were injected.

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 Ðavour.

Moulds and yeasts

For the European mould-fermented foods, mainly selected species (neither pathogenic, nor toxicogenic, nor antibiotics producers) of the genus **Penicillium** are employed as surface starter cultures (Cook, 1995). Penicillia affect the appearance, aroma and taste, and preservation of mould-fermented sausages. They contribute to characteristic Ðavour development, and delay rancidity of the products (Racovita and Racovita, 1968; Leistner, 1984). Examples of typical compounds produced by **Penicillium** strains are 1-octen-3-ol and octan-3-one, which are responsible for the mushroom-like Ðavour. However, the growth of undesirable moulds on fermented sausages must be avoided, because they could form mycotoxins and cause a musty smell as well as defective casings in raw sausages. In dry-cured hams the dominant moulds depend on the ecological conditions at the surface of the product. At the beginning of processing, **Penicillium** is the most abundant mould, but **Aspergillus** and **Eurotium** spp. become dominant when the surface a_w decreases. In serrano hams a musty Ðavour could be detected when moulds grow inside the aitch (Arnau, 2000), and in Parma hams the phenic acid Ðavour was described when **Penicillium commune** grows inside the aitch (Spotti et al., 1988). To avoid this problem, RH lower than 85 % is recommended.

Positive side effects of moulds on meats are the reduced moisture loss due to the mycelial covering, antioxidative effects because of catalase activity, oxygen consumption and reduced oxygen penetration through the mould layer (Bacus, 1986).

In fermented sausages, rapid lowering of pH through the use of very competitive lactic bacteria starter cultures and the addition of carbohydrates to meat mix could lead to excessive acidity that makes the end product less pleasant. Therefore, acidity can be reduced by selected moulds growing on the casings. The de-acidifying action occurs from the outside towards the centre (Papa et al., 1995), probably due to the formation of ammonia (Demeyer et al., 1979). The purpose is to achieve full compliance between health and hygiene parameters and good sensorial qualities.

Moulds are considered to affect the Ðavour of dry-cured ham (CÛrdoba et al., 2002), but probably to a lesser extent than in small calibre fermented sausages. The use of moulds as starter cultures have been proposed, but the appropriate time for inoculation must be established, to ensure a proper development over the natural fungal population (CÛrdoba et al., 2002). However, the need to use low RH to prevent mite infestation makes its use more difÝcult.

Yeasts occur frequently in and on cured dried meat products. Yeasts population reach the highest counts on dry-cured hams during the resting stage and Ýrst months of drying. Today multi-strain starter cultures used for fermented sausages often contain **Debaryomyces hansenii.**

Non-meat proteins

Non-meat proteins such as soya isolates and caseinates can be utilised as lean meat extenders. They are used as dry proteins or in gel form. Soya proteins positively affect the performance of the lactic acid bacteria and the corresponding drop in pH. They could give the product a slightly cereal-like Ðavour, which decreases during drying (Stiebing, 1999). Milk proteins could affect the Ðavour specially when used in high dosages.

Milk powder gives the fermented sausages a sweet taste and sometimes other nuances according to its Ðavour.

Spices, seasonings and fat alternatives

The addition of spices is very useful in the manufacture of dry-fermented sausages. This is mainly done to give the product a characteristic Ðavour and odour and occasionally, as is the case of paprika in ìchorizoî or ìsobrassadaî to give it a speciŸ c colour. In the manufacture of dry-fermented sausages, spices can be used in their natural form (whole, coarsely ground and as powder) or as extracts (essential oils and oleoresins). Sometimes they are used stuck to the surface of the fermented sausage to give a particular aspect.

Pepper (**piper nigrum**), which is probably the most used spice in the manufacture of fermented sausages, gives pungency and contains Mn that accelerates pH drop and stimulates growth of lactobacilli (Vandendriessche et al., 1980). The magnitude and perseverance of the stimulating effect differs however with the type of lactic acid starter.

Pepper is also used on the surface of dry-cured hams or in the fat mixture applied on the surface to slow down drying.

Paprika (**Capsicum annuum**) is used in dry-fermented sausages not only for its sapid and aromatic qualities but also because it gives some of these products their characteristic colour. It is added to ìchorizoî (1-3 %), and ìsobrasadaî (4-7%). Hot Ðavour depends mainly on the capsaicin content (Kirschbaum-Titze et al., 2002), the main component of hot paprika that contributes to pungency of the product and is affected by oxidative processes.

Garlic (**Allium sativum**) is another important ingredient used in the manufacture of some dry-fermented sausages such as ìchorizoî and also to prepare the paste that covers the typical Turkish pastirma.

Other spices such as oreganus, nutmeg, cardamom... are also used in some fermented sausages. In dry-cured hams, spices could be useful to improve the Ðavour of hams with short ageing periods.

Wines are also used to improve the Ðavour of some traditional fermented sausages (Frentz, 1982) and soya sauce is a traditional ingredient in traditional Chinese dry sausages such as Lup Cheong. Moreover, monosodium glutamate is sometimes used as a Ðavour enhancer. It produces an umami taste that could be useful in rapidly fermented sausages. However, it is not necessary to include it in long process fermented sausages and dry-cured ham, because amino acids are produced during ageing due to the activity of aminopeptidase enzymes. The addition of proteinases and lipases was suggested as being useful in providing substrates, which must be transformed into aromatic compounds (OrdÛÒez et al., 1999).

In recent years alternative ingredients have been proposed for their nutritional advantages or alternative Ðavours: Guinee at al. (1994) suggested the addition of cheese to salami products. Arnau (1993) proposed the substitution of part of the fat by almonds, hazelnuts, pine kernels, walnuts, peanuts ... Muguerza et al. (2001) found that it is possible to substitute pork backfat with pre-emulsiŸed olive oil (containing soy protein isolate) at levels up to 25 % without affecting sensory properties, and Severini et al. (2003) added 5 % extra-virgin olive oil in salami with sensorial characteristics similar to the traditional products.

Smoking

In North European countries raw sausages are usually smoked, whilst in Latin countries unsmoked products are preferred. The raw sausages in Hungary (ìwinter salamiî) are lightly smoked at the start of fermentation, before mould colonisation. The smoke gives the products their characteristic aspect and Ðavour, which vary according to the type of wood used and the parameters of the processing and smoking (M˜hler, 1978; TÛth, 1980). Likewise, smoking delays rancidity in sausages and also prevents growth of bacteria, yeasts and moulds. The sausages could be slightly smoked during fermentation, but not so much as would affect the microbial fermentation process inside the sausages. The actual smoking is performed after fermentation is completed. The smoked sausage is characterised by a sharp, acidic taste and a strong smoke Ðavour, which masks in part the other Ðavour notes.

3. PROCESS

Fermented sausages

The process for the manufacture of dry-fermented sausages involves the preparation of the lean meat, fat and non-meat ingredients at the right temperature, according to the grinding system used. During processing, smearing must be minimised because it has deleterious effects on texture, colour, colour stability, drying and Ðavour. The smearing is affected by grinding, mixing and stufŸng methodologies, as well as by the temperature of the raw material and texture of the fat.

The type of casings used affects the drying rate. Quickly fermented products are produced using collagen casings and traditional products are produced with natural casings that have lower permeability.

After stufÝng into casings, the product is fermented in a controlled temperature (18-26 ŠC) and RH around 90% for 1-3 days and then ripened-dried at lower T and RH. Temperature and RH are regulated according to the desired product characteristics.

The calibre of the sausages affects the Ðavour, maybe because of the easier free diffusion of atmospheric oxygen throughout the sausage mass which could increase the amount of carbonyl compounds in the volatile fraction of reduced calibre products (Edwards et al., 1999).

The production of acids in dry sausages depends not only on the starter culture and type and concentration of sugars added to the mixture, but also on the water activity. Thus a large diameter of the sausage (R˘del and Klettner, 1981) and smearing of fat will facilitate acidiÝcation. A rapid drying of the sausage in the initial steps of the process delays acidiÝcation, especially for low calibres. However, an excessive drying after the decrease of pH could produce a water gradient between inside and outside that facilitates diffusion of acids to the centre of the product, and as a consequence acid Ðavour could increase in the inner part. The temperature of the drying room is another parameter that affects the rate of acid production. Furthermore, if the sausage is commercialised with a high water content in the core, an additional acidiÝcation could take place especially if it is stored at high temperatures.

Currently, an important part of fermented sausages are commercialised in a vacuum or modiÝed atmosphere. In this case the texture and Ðavour tends to homogenise.

Dry-cured ham

The process of dry-cured ham manufacture involves a Ýrst step where they are stabilised to prevent the growing of undesirable microorganisms. Both a rapid refrigeration of the green hams and curing as soon as the temperature in the core of the product attains 1-3 ŠC are recommended. Hams are washed with water after salting (Serrano hams) or after resting (Parma hams). Then they are hung at a temperature below 5 ŠC until a_w<0.96, to prevent growth of deteriorative microorganisms (**Enterobacteriaceae,** LAB...) and to make the product safe for consumption (Leistner, 1985). The temperature, a_w and pH select a population dominated by Gram-positive catalase positive cocci, yeasts, and moulds. During resting, RH should be maintained between 75 and 80 % to slow down mould growth and avoid NaCl precipitation. At the end of this phase, RH is decreased below 75 % to slow down mould growth and to facilitate fat sweating that protects against excessive drying and facilitates slight fat oxidation that improves the Ðavour.

When the ham is stabilised, the temperature is increased to facilitate drying, proteolysis and lipid oxidation (Toldr· and Flores, 1998). However, when hams are exposed for too long time to high temperatures the pastiness incidence increases and some Ðavour nuances increase too much and could become unpleasant (e.g. picantness) (Arnau et al., 1997b).

Low RH and high temperature during ageing also facilitates crustiness. In order to avoid this and off-Ðavours produced by the formation of cracks in the muscles around the coxofemoral joint, a layer of fat is applied at around 4-7 months (Arnau, 1998).

In hams, the expected action of microbial lipases and proteases is reduced due to the low numbers of microorganisms usually found inside the hams and the environmental conditions that limit bacterial growth (Toldra and Flores, 1998).

Traditionally, the ageing process has been carried out in an atmosphere with oxygen. However, recently (Grupa, 1998) proposed the ageing of dry-cured ham and fermented sausages in modiÝed atmosphere, but S·nchez-Molinero et al. (2000b) found that the typical Ðavour of Spanish dry-cured ham was higher when they were dried in air than in an atmosphere with an oxygen content from 0 to 3 %.

At the end of the process, the product is often deboned and vacuum packaged. Before slicing, the external part of the ham is trimmed to remove the rancid layer. Currently, there is an increasing tendency to commercialise the product in thin slices under vacuum or modiÝed atmosphere that makes the texture and Ðavour more uniform.

Dry-cured hams produced through a long ripening process have the highest amounts of all kinds of compounds generated through both lipid and amino acid degradation (Ruiz et al., 2002). Sweetness usually increases as the ageing period increases (Gu‡rdia et al., 1999) and it has been positively related with aged Ðavour (S·nchez-Molinero and Arnau, 1998). Metallic Ðavour decreased with the ageing time and is higher in the inner zones with the highest moisture content (Arnau, 2000).

The aroma of Serrano and Iberian hams has a lipid oxidation base, and many aromatic nuances from amino acid origin through Maillard reactions and Strecker degradation. Nevertheless, compounds from the feeding and compounds with a microbial origin could contribute to the overall Ðavour (Garcìa et al., 1991; Ventanas et al., 1992; Flores et al., 1997; Toldr·, 1998; Ruiz et al., 2002).

CONCLUSION

Flavour of dry-cured ham and fermented sausages is very complex and is affected by chemical composition, structure and microbial Ðora of the raw material, ingredients, additives and starter cultures added and the manufacturing process used. The current technologies, despite being imprecise, allow many variations provided a combined evolution of some parameters (pH, Aw, microbial Ðora, ingredients, additives, temperature, structure) makes the product safe and avoids deterioration.

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