Dry-Cured Ham

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CONTENTS
39.1 Introduction .................................................................................................................................. 673
39.2 Raw Material Selection and Handling .......................................................................................... 674
  39.2.1 Fat Content and Weight ........................................................................................................... 674
  39.2.2 Proteolytic Potential ............................................................................................................... 675
  39.2.3 Meat pH .................................................................................................................................. 676
  39.2.4 Shape of Hams and Types of Cut ......................................................................................... 677
  39.2.5 Refrigerated Versus Frozen–Thawed Raw Hams .............................................................. 678
  39.2.6 Elimination of Residual Blood .......................................................................................... 679
39.3 Ingredients and Additives ............................................................................................................ 679
39.4 Processing .................................................................................................................................... 680
  39.4.1 Pre-Salting Operations .......................................................................................................... 680
  39.4.2 Salting .................................................................................................................................... 680
  39.4.3 Washing ................................................................................................................................ 681
  39.4.4 Smoking ............................................................................................................................... 682
  39.4.5 Convective Drying ............................................................................................................... 682
    39.4.5.1 Post-Salting Period .................................................................................................... 682
    39.4.5.2 Drying-Maturation and Cellar Period ...................................................................... 683
39.5 Commercial Presentation ............................................................................................................. 684
  39.5.1 Boned Dry-Cured Hams ....................................................................................................... 684
    39.5.1.1 Freezing .................................................................................................................... 684
    39.5.1.2 High-Pressure Processing ..................................................................................... 684
  39.5.2 Sliced Dry-Cured Ham ........................................................................................................ 684
    39.5.2.1 Packaging in a Modified Atmosphere ................................................................ 684
Acknowledgments .................................................................................................................................. 685
References .............................................................................................................................................. 685

39.1 Introduction

Dry-cured ham is generally considered to be a typical product of the Mediterranean area. Spain and Italy are the main producers, although it is also manufactured outside Southern Europe. The Mediterranean types of dry-cured ham (e.g., Spanish “Jamón Serrano”, Italian “Prosciutto crudo”, or French “Jambon de Bayonne”) are characterized by dry salting and a long maturation period (from 7 to over 24 months). The Northern Europe types of dry-cured ham are characterized by smoking followed by a short maturation period (e.g., Westphalia hams in Germany).

Various technologies for the production of pork dry-cured hams exist, but basically all of them intend, on the one hand, to obtain a product that can be kept at room temperature without either jeopardizing health or involving any risk of alteration, and on the other, to facilitate the development of the desired sensory characteristics (texture, odor, and flavor). Despite there being important differences in the processing and sensory characteristics of dry-cured hams between countries, all the processes have two
operations in common: salting and drying. The main processing differences are due to specific raw material (specific breeds, weight, or trimming), specific treatments (e.g., different salting systems, smoking, etc.), and specific air conditions and duration of the drying process.

Innovations introduced into processing during the last century, such as the use of chilling chambers or artificial dryers, have improved the process standardization and, consequently, the control of the safety and quality of the final product.

In the last decades, research into this product has demonstrated the importance of raw material quality and of some processing parameters on the final quality. The current implementation of new methods for the selection of raw material or the control of the key-processing parameters are enhancing the safety and quality standardization of dry-cured hams.

The aim of this chapter is to describe the different steps of the elaboration process, from the selection of raw material to the commercialization of dry-cured hams, reviewing those aspects which have been demonstrated to have a major impact on the safety and sensory quality of dry-cured hams and how they can be accounted.

### 39.2 Raw Material Selection and Handling

Dry-cured hams are elaborated from the rear legs of pork carcasses. Therefore, the characteristics of the raw ham are partly linked to the carcass history: genetics, pig production (feeding, age, season, etc.), preslaughter treatments, slaughter conditions, and ham handling.

#### 39.2.1 Fat Content and Weight

The quantity of fat and the weight of the ham dictate the main criteria currently used in the selection of raw material, and determine the processing time of the ham. The weight of green hams ranges from 9 to 14 kg. While in Northern European countries consumers prefer lean hams, many consumers in some countries in the Mediterranean area accept a certain amount of infiltrated fat in this product. This fat prolongs the maturation time (Figures 39.1a and b), resulting in the particular sensory characteristics.

![Slices of dry-cured ham showing different fat content levels. (a) Lean dry-cured ham. (b) Fatty dry-cured ham.](image)
for which the product is highly valued. In dry-cured hams which have undergone a lengthy aging process, the presence of infiltrated fat and a certain amount of superficial fat slow down the drying process and impregnate the musculature. The latter enhances the mastication process during consumption, providing an oily sensation in the mouth and an aged flavor that is highly appreciated (a pleasant flavor associated with the oxidation of the fat (Antequera and others 1992). Hams that contain almost no subcutaneous fat should be avoided, as in these hams the salting and drying processes through the rind area are faster than in other hams. These hams have a saltier taste, a higher water loss and a low quality, and so are rejected by the majority of consumers (Cilla and others 2006; Morales and others 2008; Resano and others 2010).

Online systems based on electromagnetic scanning have been proposed for evaluating the fat content of fresh hams (Meseck and others 1997). Currently, fat content of raw hams can be assessed online by using the Ham Categorizator (JMP Ingenieros, Sotés, Spain; Figure 39.2). This equipment measures the disturbance that the ham produces when passing through an electromagnetic field, which has been related with the fat content (Figure 39.3).

39.2.2 Proteolytic Potential

It has been demonstrated that hams which have suffered an excessive proteolysis during processing have a disagreeable soft texture (Ruiz-Ramírez and others 2006) (Figure 39.4). Therefore, meat with a high proteolytic potential is less suitable for the elaboration of dry-cured hams, especially if a low salt content is desired (Virgili and others 1995).

The selection of raw material could be improved by the evaluation of the cathepsin B activity (Parolari and others 1994), which is one of the proteolytic enzymes that seem to be responsible for the development of soft texture. However, the current methodology has not yet been adapted for online measurements.

The selection of animals less prone to high proteolysis activity could be carried out at animal breeding or production steps. There are new technologies in the field of molecular genetics such as genetic markers that show promise for predicting the proteolytic activity of raw material (Skrlep and others 2010). Another easier approach could be the selection of older animals, which show a lower activity of proteolytic enzymes (Sárraga and others 1993).
39.2.3 Meat pH

The pH level of the meat on arrival at the industry (time postmortem > 24 h, pHₜ) is another important parameter that affects the maturation of ham. On the one hand, for microbiological safety reasons, the majority of authors recommend avoiding hams that have a pHₜ > 6.2 (Leistner 1986). A pHₜ higher than 6.2 also leads to an increase in the incidence of appearance problems, such as a shiny aspect of the lean meat and phosphate precipitates (Arnau and others 1998, Figure 39.5), and texture problems, such as a soft texture in the internal part of the ham (Guerrero and others 1999; Morales and others 2007) and a crust development at the lean surface (Ruiz-Ramírez and others 2006). The problem of soft texture is greater in hams of larger sizes.

On the other hand, hams with a pHₜ < 5.6 show higher proteolysis especially at low salt content (Ruiz-Ramírez and others 2006). Therefore, they are more prone to pastiness than hams with intermediate pH.

Furthermore, pH values vary considerably between the muscles of the same ham (Arnau and others 1995). Consequently, in order to carry out an easy measurement, which should be representative of the ham as a whole, it is advisable to measure it on an external muscle of considerable size, such as the Semimembranosus muscle.

The selection of hams by pH can be done with a meat quality scanner (TIMPOLOT, Olot, Spain) calibrated and adapted to the industrial scale (Figure 39.6).

FIGURE 39.4 Slice of dry-cured ham showing soft texture.
39.2.4 Shape of Hams and Types of Cut

The elaboration of cured hams is carried out using whole pieces or parts of the leg. The whole pieces can be presented in different ways. In some traditional dry-cured hams, the presentation with hoof included is usual (e.g., in Iberian and Serrano hams in Spain, in San Danielle ham in Italy and in Jinhua ham in China). However, the majority of the hams that end up boned are elaborated without the hoof (e.g., in Parma ham in Italy and Bayonne ham in France). The presence of the hoof does not significantly affect the salting and drying processes (Boadas and others 2001) and, though it can reduce the incidence of
color fading of the shank caused by the entrance of air, the main reason for the elaboration of hams with hoof seems to be mostly cultural.

In Spain, unlike other countries, it is usual to cut the rind into the shape of a V (Figure 39.7). The reason for this could be that the rind and part of the fat can then be used for other purposes. Moreover, a higher standardization of the thickness of the subcutaneous fat is achieved, and the retraction of the lean meat is facilitated during the drying process (Gou and others 2000) as well as during the shaping before slicing the ham. In addition, taking off part of the rind reduces the problem of whitish appearance observed at the rind surface zones when hams are dried at low air relative humidity (Arnau and Gou 2001).

In Spanish hams, the aitch bone remains, which means the morphology of the muscles remains intact, while in French (Jambon de Bayonne) or Italian hams (Parma and San Danielle), this bone is eliminated, leaving only a small part of it (“anchetta”) in order to avoid cavities which hinder the drying process. The elimination of the aitch bone allows a more rapid salt absorption and water losses, especially in the Biceps femoris muscle.

Pieces of ham are used for the production of Jambon d’Ardennes in Belgium, culatello and fiocchetto in Italy, or baiona in Spain.

In all cases, it is important to avoid damaging the structure, as this can facilitate the entrance of microorganisms thus causing deterioration in the product.

39.2.5 Refrigerated Versus Frozen–Thawed Raw Hams

While the use of refrigerated raw material is usual in areas where there are abattoirs and cutting rooms in abundance, frozen hams are more frequently used when long transportation is involved, as it ensures no break in the cold chain during transport.

The use of frozen–thawed hams makes the dissolution of salt on the surface, the migration to the inner part (Sorheim and Gumpen 1986; Poma 1989) and probably the diffusion of water toward the outside easier. Therefore, salting and drying processes have to be adapted to frozen–thawed raw hams to enable the production of dry-cured hams without affecting the sensory quality of the ham (Kemp and others 1982; Motilva and others 1994; Bañon and others 1999).

However, the use of frozen–thawed meat impedes the direct confirmation of the quality of the raw material, facilitates crystallization of the tyrosine formed during the maturation process, giving way to a higher number of white crystals (Arnau and others 1994), and produces some cracks/cuts in the product. If there
are many oscillations in temperature during the storage process, or the storage period is prolonged, super-
ficial dehydration can take place in the rind and the lean meat of the ham, which causes freezing burns. This 
can hinder the salting process and can damage the final appearance of the product. To prevent this, it is 
advisable to cover the ham with a close fitting plastic protection. To avoid problems of growth of undesir-
able microorganisms, it is desirable to ensure that at no point of the surface the temperature rises above 5°C 
during the thawing stage. On the other hand, if various days are necessary to complete a batch, which can 
be frequent in small cutting rooms of low production, it is preferable to freeze the hams than refrigerate 
them for an excessive period of time.

39.2.6 Elimination of Residual Blood

The elimination of residual blood from veins and arteries is advisable as it reduces possible microbiologi-
cal problems and improves the appearance of the cut surface. The best time to carry out this operation is 
during the cutting process, as the blood exits more easily. In the case of no reassurance that this operation 
has been carried out, it should be done when the raw material is received.

39.3 Ingredients and Additives

Salt is essential for the elaboration of cured ham and it is the only substance that is permitted for the 
elaboration of some hams, for example, the Parma ham. It contributes to the reduction in water activity 
and to the sensory characteristics of dry-cured hams (e.g., safety and sensory quality), but an excessive 
sodium intake can produce adverse cardiovascular effects related to hypertension (Kaplan 2000; WHO 
and ISH 2003; FSAI 2005). Therefore, the tendency during recent years has been to reduce salt content 
to the minimum level without having a negative impact on safety and sensory quality.

Hams are often cured with nitrifying agents (nitrates and nitrites). Both nitrite and nitrate are used to 
obtain the desired red color in dry-cured hams. Nitrate is present at very low levels in meat and has been 
the preferred nitrifying agent in products of lengthy aging, as it is slowly transformed into nitrite by 
bacterial action. Nitrite plays an important role in color development and as a preservative, exerting an 
antclostridial effect in cured meat. Nitrite is reduced to nitric oxide, which is combined with the pigment 
myoglobin forming nitrosylmyoglobin, responsible for the stable red color of cured meat. The reduction 
of nitrite to nitric oxide increases as pH decreases (Wirth 1984).

Cured color is obtained faster with nitrite than with nitrate and therefore is preferable in fast elaboration 
processes. However, nitrite causes the appearance of concentric red rings and paler core in sliced dry-cured 
ham (Figure 39.8) if it is added at very low levels in hams with low pH (Arnau and others 2003b).

Ascorbate is added to accelerate the transformation of nitrite into nitric oxide. It prevents greenish 
colorings which are the result of the reaction of nitric oxide with oxygen (Arnau 1998) and restrains the 
formation of nitrosamines in lean meat (Pegg and Shahidi 2000).

![Figure 39.8](image-url)  Concentric red ring and paler core defect in dry-cured ham with low pH (pH < 5.6).
Sugars, on the one hand, favor the implantation of surface flora and lend a light sweet flavor, but on the other hand, they can bring about acidic flavors in the case where lactic flora develops in the internal parts of the ham (Boadas and others 2000).

Parma ham usually has pepper added to the head of the femur or to the fat which is used to cover the ham. In pieces of ham that are elaborated by means of a short duration process, it is usual to add spices to improve their sensory quality.

39.4 Processing

Although salting and drying are the main processes involved in dry-cured ham manufacturing, there are many other operations, some of them specific of a certain types of hams. The different steps of the whole process, described in chronological order, can be found below.

39.4.1 Pre-Salting Operations

During the different operations before salting (trimming, shaping, pre-salting and curing), a low internal temperature \( T < 3°C \) must be assured.

Trimming is a vital operation for salt uptake; therefore, it must be performed and controlled by trained personnel, in order to achieve a similar lean surface on hams from the same class and to avoid damages to the structure. When skin is partially removed (“V” shape, only in the fattiest hams) special attention must be paid to maintaining a minimum thickness of subcutaneous fat, because it can modify the salt uptake and the drying (Garcia-Gil and others 2009a,b).

In order to facilitate the penetration of the curing salts (in hams where nitrifying agents are used), to eliminate the blood that could be present in the veins and arteries and to mould the ham, a massage of the surface is carried out using a mixture which contains salt, nitrate, nitrite, ascorbate, and sugars. Although the massage can be done manually, it is normally carried out by continuous machines or in drums. In this way, the absorption surface is increased and penetration of the salt is enhanced.

39.4.2 Salting

The aim of salting is to incorporate the correct amount of salt to the raw ham. The amount of salt used depends on both the raw ham characteristics and the salting conditions.

Salting must be carried out as soon as the temperature in the core of the ham reaches a level of between 1°C and 3°C, as in this way not only is the growth of undesirable bacteria hindered but there is also a reduction in the percentage of nonedible hams at the end of the process. Temperature should be maintained at a low value during salting.

In Mediterranean countries, the dry salting process is used, while in Northern Europe this process is also used as well as salting in brine. In the dry salting process, a higher level of osmotic dehydration is obtained, whereas with salting in brine, there is a lower consumption of salt.

The dry salting process can be carried out using two different methodologies:

1. Salting of the hams by covering them in salt. This can be done by individual salting of the hams (San Danielle) or by piling them in stainless-steel containers for a time period of approximately 1 day/kg for the refrigerated hams, and some days less for the frozen–thawed ones (typical of Serrano and Iberian hams). The salt used is normally humid to ensure correct salting, and the atmospheric humidity is high to avoid drying out and to facilitate the formation of saturated brine on the surface of the ham. For this operation, maintaining a high level of atmospheric humidity is recommended, at a level which should not be below 75%, as this would result in the dehydration of the salt. The piling up of the hams induces a pressure which is especially high in the lower strata, facilitating the loss of water.

2. Salting by means of a quantity of salt which is in proportion to the weight of the ham. The most well-known example of this method is found in Parma ham, in which the relative humid-
Dry-Cured Ham

681

ity is maintained between 70–75% minimum and 85–90% maximum. Using this method, the salting process of the areas covered in salt is ensured while at the same time allowing the drying of those areas which are not covered by salt. In this case, the hams remain in a horizontal position for a period of 3–4 weeks, which results in the thickness being less than it would be if they were left hanging. With this process, the penetration of salt and the evacuation of water from inside are enhanced. In other cases, salting takes place in salting drums, with a posterior post-salting period in containers where the ham is in contact with the exuded brine. It is important to treat the ham with salt twice so that the parts of the ham which have been less salted during the first treatment are treated again a second time. In this type of process, the post-salting period should not be excessively prolonged, as the exuded water can be reabsorbed therefore encouraging the growth of undesirable microorganisms in those areas which are not covered by brine.

The amount of salt (in salting systems that use a fixed amount of salt per kg of ham) or the duration of salting (in “salt pile” systems) have to be adjusted to each class of ham (according to weight, fattiness, and fresh/frozen origin). Models of salt uptake should be constructed for each class of hams and salting conditions before selecting the correct time. For example, Figure 39.9 shows three salt uptake models corresponding to three different classes of ham at specific salting conditions (Serra and others 2010).

39.4.3 Washing

In former times, the Spanish Serrano hams were desalted by immersing them in running water to eliminate the excess salt acquired during the long salting process. However, nowadays, because a temperature of between 1°C and 5°C can be maintained during the post-salting phase, it is possible to reduce the quantity of added salt. Therefore, the main objective of washing is to remove any salt crystals that remain from the salting process.

Italian hams are usually washed after the post-salting period and therefore, during this stage, it is possible to maintain the head of the femur at a lower water activity. In this case, firstly, washing removes not only crystals of phosphate and salt, but also the slime which can form on the surface of the joint. Secondly, this method ensures that a later drying process can be achieved faster than in Serrano ham because drying is carried out at a temperature which is higher than can be used after the washing of Serrano ham.

**FIGURE 39.9** Salt uptake models to predict the final salt content on a desalted-dry-matter basis (%DSDM) in three classes of ham.
From a technological point of view, washing is more effective using warm water than cold water. The ideal moment to carry out the washing can also be conditioned by the cost of the handling that is involved and the dehydration capacity of the post-salting or drying rooms.

At the end of the salting process, the blood vessels usually contain a certain amount of brine, so that it is advisable to perform a light pressing operation to eliminate it together with any residual blood. By pressing and forming the ham, it is also possible to improve the evenness of the cut of the product. However, the ham structure should not be damaged, because this facilitates the entrance of microorganisms that can spoil the ham. Regardless of the moment at which the washing is performed, a quick drying of the lean meat of the ham is always recommended to prevent the growth of undesirable flora. However, it must be taken into consideration that an excessively fast-drying process can produce a reduction in the surface water activity, to values lower than 0.75, which causes a local crystallization of the salt. This facilitates the drying up of the lean meat and causes white-colored stains on the rind, resulting in a deterioration of the appearance of the ham (Arnau and Gou 2001).

39.4.4 Smoking

In countries with a cold damp climate, hams have traditionally been smoked. The smoke provides a typical color and smoky flavor, an antioxidant action and also impedes the growth of surface flora (Lenges 1986).

39.4.5 Convective Drying

The aim of drying is to reduce the water content of ham to a level at which the dry-cured ham stability is assured. However, the sensory quality of the final product depends on the drying conditions (temperature, drying ratio) used in the process.

Hams are dried in “natural” or in “industrial” dryers, using dry air at different temperatures. “Natural” dryers use air from the outside, which must be dry. These dryers are placed in zones where the outside air has a low relative humidity (RH). Their main problem is a poor control of drying conditions.

Industrial dryers, however, have an air-conditioning system to control the temperature and the RH, working in discontinuous RH cycles. An interval of RH is fixed, thus when the upper limit is attained, a cooling device is activated until RH drops to the lower limit. The speed at which air RH rises depends on both the ability of the hams to transfer water into the air and on the amount of product in the dryer (load of the dryer). In order to have a regular drying process, the quantity of water which evaporates must be compensated by the diffusion of water from the inner part to the outer part of the ham. However, due to discontinuous control, the lower limit is frequently exceeded, which can produce excessive dehydration at the ham surface.

Depending on the air temperature, two drying periods can be defined (see below).

39.4.5.1 Post-Salting Period

During this period, hams are dried at a temperature lower than 5°C, until the water activity \( (a_w) \) all through the ham decreases to values which do not permit the development of pathogenic microorganisms \( (a_w < 0.96) \) (Leistner 1986).

The \( a_w \) at the surface mainly depends on both the drying capacity of the air and on the capacity that the ham has to release water from the internal zones to the surface. Therefore, on the external part of the ham, the flora is affected by environmental humidity conditions, and a growth of fungal flora can often be observed. At this stage, it is advisable to carry out a more energetic dehydration during the first and second weeks, as it is important to reduce the surface water activity to hinder the growth of undesirable microorganisms that give to the ham a slimy appearance.

To avoid whitening of the rind brought about by the crystallization of the salt in its interior, a relative atmospheric humidity of above 75% is recommended. Once the majority of the salt from the rind has
penetrated through the fat to the lean of the ham, the atmospheric humidity level can be reduced to below 75% to promote the sweating of the fat (Arnau and others 2003a).

In the internal part of the ham, the gram (+) catalase (+) cocci become the dominant flora. The reduction of the $a_w$ in this zone is due, in part, to the increase of salt content due to the tendency to equilibrate the NaCl/water relationship within the whole piece (Gou and others 2004). Additional reduction is achieved by reducing the water content. This could be the reason for the higher saltiness inside the product at the end of the process. So, in order to achieve a homogeneous salty taste it is advisable to perform a homogeneous drying.

The duration of the post-salting period varies according to the size of the piece, the surface of the exterior lean part, the type of trimming, the intermuscular and intramuscular fat, etc. In small-sized hams, a minimum period of 1 month is recommended. In the case of Parma ham, it is necessary to prolong this period, sometimes for 3 months because of its low salt content and absence of nitrite. In Serrano ham, this period should be higher than 40 days.

In Iberian hams this period is 2–3 months due to the high content of fat that hinders salt and water diffusion.

If salt content is reduced, technologies such as computed tomography based on x-ray can be used to monitor the local salt content in the inner parts of the ham and to adjust the post-salting duration. This technology permits the estimation of salt and water content distribution within the dry-cured ham during the process (Fulladosa and others 2010b; Santos-Garcés and others 2010).

### 39.4.5.2 Drying-Maturation and Cellar Period

In the drying-maturation phase, dehydration and the phenomenon of proteolysis and lipolysis, which determine the aroma, continue. In Serrano hams, temperature is slowly increased from 10°C to 12°C until it reaches a maximum of between 28°C and 34°C and the RH is between 60% and 80%. However, in recent years, there has been a decrease in the length of time at high temperature to reduce the incidence of hams with soft texture and white film, both of which can cause a problem for the commercialization of sliced products. On increasing the temperature, the melting of the fat is produced, which then impregnates the muscle tissue and makes up one of the typical characteristics of Serrano hams.

A high-drying rate can produce crustiness, which reduces the capacity of the ham surface to retract (Olmos-Llorente 2006). This can produce cracking and hollows in the Adductor muscle and around the coxofemoral joint. The growth of aerobic bacteria, molds, and mites in this area may lead to the development of musty off-flavors in this region and the adjacent muscles (Fulladosa and others 2010a). This problem is more common in blocky and lean hams (Gou and others 1995; Guerrero and others 1996). The most effective measure to reduce these problems is the application of a layer of fat to this area during the drying stage (Hugas and Arnau 1987; Arnau 1998). The application of fat can be preceded by a washing and drying of the ham surface.

For lengthy processes, Serrano hams are submitted to a final phase named “cellar phase” at temperatures from 12°C to 20°C and RH from 50% to 80% to dry the ham until the desired texture is obtained. This phase begins after the drying period and continues until a minimum processing time of 7 months is reached. However, high-quality Serrano hams can attain a processing time of up to 16 months.

In Parma ham, the drying phase takes place at a temperature of about 15°C and RH around 65–80%. After 6–8 months, the drying rate is slowed down by means of several applications of a mixture of fat, flour (to make the paste more permeable), pepper, and salt. This paste is added several times as the ham becomes drier. Matured hams are fire stamped with the Parma ham brand after at least 10 months processing for pieces weighing between 7 and 9 kg, after at least 12 months for pieces over 9 kg while pieces of <7 kg cannot be branded.

With Iberian ham, after the post-salting period, hams are kept for approximately 90 days in a chamber where the temperature is slowly increased until it reaches 18–20°C. Following this, the temperature is increased slowly for a period of around 1–1.5 months until it reaches up to about 30°C and RH of 60–80%. Finally, the hams are kept in a cellar from 12 to 18 months with a temperature ranging from 10°C to 22°C and RH from 65% to 80%.
39.5 Commercial Presentation

The commercialization of dry-cured ham has traditionally been carried out in whole pieces. However, in recent years there has been an increase in the commercialization of vacuum-packed boned dry-cured hams and slices.

39.5.1 Boned Dry-Cured Hams

Hams are boned at the end of the process and then shaped and vacuum packed. Although no water losses occur during packaged storage, the diffusion characteristics are still very important for the product quality. Vacuum packaging of boned hams facilitates the slicing process, the homogenization of the ham texture, and prevents problems of mites or excessive drying. When the storage of vacuum packed ham is prolonged for a long period of time, it causes a moistening of the surface which can result in an unpleasant aroma. If the water activity is high, undesirable microorganisms can proliferate, and in this case, it is necessary to keep the product refrigerated and/or to apply additional treatments, for example, freezing or high-pressure processing (HPP).

39.5.1.1 Freezing

Although the storage of hams by freezing permits the conservation of flavor for long periods of time and slows down the formation of white film in sliced products (Arnau and Lloret 2007), it also facilitates the formation of white crystals. On the other hand, the freezing of unpacked pieces causes the loss of volatile substances, which decreases the aroma of the product.

39.5.1.2 High-Pressure Processing

This technology has also been applied to increase the microbiological stability of boned dry-cured hams vacuum packed without the modifications that a thermal treatment produces. The application of HPP (600 MPa) to boned dry-cured hams can provide additional microbiological benefits (Garriga and others 2004; Tanzi and others 2004). However, it modifies the sensory attributes of dry-cured hams. Tanzi and others (2004) and Fulladosa and others (2009) found that HPP treatment on boned dry-cured hams with high moisture content reduced softness and pastiness and increased saltiness, hardness, and fibrousness, which can be considered positive if NaCl content is reduced, but it also modified the color. However, the HPP effect on the sensory attributes is lower if the product has lower water content (Tanzi and others 2004).

39.5.2 Sliced Dry-Cured Ham

In products for slicing, hams are frozen to obtain a firm texture, thus facilitating a better cutting process and a neat cut. As the structure of the product has been broken and so the risk of microbiological contamination during slicing is higher than in non-sliced hams, slicing and packaging have to be done under especially hygienic conditions (e.g., clean room). Therefore, as in the case of boned hams with high \( a_w \), it is necessary to keep the product refrigerated and additional treatments can be applied to increase the product microbial stability, for example, packaging in modified atmosphere or HPP treatment on vacuum-packed slices.

39.5.2.1 Packaging in a Modified Atmosphere

Packaging in a modified atmosphere allows a more natural presentation of the slices, as this prevents adhesion and the waxy appearance of slices typically found in vacuum-packed hams. In order to prevent the deterioration of color and aroma, the gas mixture must not contain oxygen. The gas most frequently used is nitrogen, although CO\(_2\) can be useful to improve the conservation of hams with high water activity.
values. The type of plastic used must be a high barrier to prevent the gas mixture being affected. When using this type of packaging, abrupt changes of temperature must be avoided, as this could result in condensation on the internal surface of the packaging which in turn causes a local increase in water activity and, therefore, a reduction in the safety of the product (Arnau 2006).

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