Introduction

Dry cured hams or jamon have been produced using only pork, sea salt, fresh mountain air and time (Provence, 2002) in Southern Europe for 2000 years. USDA definition of a “ham” is the hind leg of a hog, which may be either fresh, cured, or cured-and smoked (FSIS, 1995). U.S. country (or dry-cured) hams are uncooked, cured, dried, smoked-or-unsmoked and produced from a single piece of meat from the hind leg of a hog (FSIS, 1995). Dry-cured hams and prosciutto are made by rubbing the fresh ham with dry salt and other ingredients which draws out the moisture and then drying for 6 months but most are cured 9-12 months and many over a year which reduces the ham weight by at least 18% (usually 20-35% which is the minimum in Spain) and consequently results in a concentrated ham flavor. Since this drying process also concentrates the salt and reduces the moisture level these hams are safe to store at room temperature. In the U.S. dry-cured hams cannot be injected with a curing solution or placed in a curing solutions, but they may be smoked (FSIS, 1995).

Types of hams

American country hams (dry-cured hams) – uncooked, cured, dried, smoked-or-unsmoked meat product from a single piece of meat from the hind leg of a hog (FSIS, 1995). These hams are salty due to longer curing times and sometimes contain pepper, sugar and nitrate and/or nitrite. Some are smoked with a variety of hardwoods. They are usually aged between 3 and 12 months.

Bayonne ham – dry-cured and dried, contains the hoof, and aged for 12 months. If boned, the ham is elaborated without the hoof.

Country ham – same as dry-cured ham in U. S.

Dalmatian ham – A dry-cured Italian ham.

D. O. Guijuelo hams – Spanish dry-cured hams made from Iberian pigs, which are fed acorns.

French jambon – French dry-cured ham.

Gammon – English term when leg is attached to the side and removed only after curing.
Iberico Bellota – hams produced in Jabugo, a small town in the mountains of SW Spain. These are black-footed (pata negra) Iberian pigs, which in the fall and early winter are fed on acorns (bellota). The hams are sometimes aged up to 5 years and are quite expensive (Provence, 2002).

**Jambon** is French for ham.

**Jambon de Bayonne** – French lightly salted ham consumed raw as hors’ d’oeuvres

**Jamón** is Spanish for ham. These hams usually contain the hoof and are aged longer than the French or Italian prosciutto of Parma dry cured hams and the flavor is bolder.

**Jamón Iberico (Iberian ham)** – These hams are made from black footed (pata negra) Iberian pigs and sometimes from Iberian/Duroc Jersey cross-bred animals. The minimum aging is 18 months (usually 24). There are three different categories of Iberian hams:
- **Pienso** – the pigs are fed intensively with grains.
- **Recibo** – the pigs are fed in the Mediterranean forest (Dehesa) for a couple of months with acorns and grass, complemented at the end of this period with grains.
- **Montanera or Bellota** – the hogs are exclusively fed in the dehesa with acorns and grass. Hams produced from these hogs are very appreciated by the Spanish consumers.

**Jamon Serrano (mountain cured ham)** – dry-curing similar to Iberico but is made from a white pig, typically a Landrace or Largewhite cross-breed which is fed a mixture of quality grains. The flavor is sweet with just a hint of saltiness (Provence, 2002) and the ham is not smoked. The minimum aging is 9 months (usually 12 months). It is never cooked before eating. (Tienda, 2002).

**Jinhua ham** – Chinese dry cured ham that has the hoof remaining.

**Mainz ham** – German ham that is eaten raw or cooked.

**Parma ham** – a prosciutto-type ham from the Parma locale in Italy, these hams are usually larger than the US hams since the hogs are larger at slaughter. The five-point ducal crown of Parma is branded into each dry-cured HSM-PROSCIUTTO CRUDO as a quality designation. If boned the ham is elaborated without the hoof. Salt is the only additive permitted. Pepper is sometimes added to the head of the femur or in the fat used to cover the ham.

**Prosciutto Cotto or cooked Prosciutto** – initial preparation is the same as Prosciutto but rather than aging, the hams are heated in ovens (Italian Specialty Producers of North America. 2002).

**Prosciutto ham** – Italian-style dry-cured hams which are not smoked but often coated with pepper. It can be eaten raw because of the way it is processed (FSIS, 1995). These hams are usually larger than the US hams since the hogs are larger at the time of slaughter. They have a delicate and soft texture and are light in taste (Italian Specialty Producers of North America. 2002).

**San Danielle** – Italian dry-cured ham that has the hoof remaining.

**Smithfield hams** – dry-cured country hams that are not fully cooked but are dry enough that they will keep at room temperature. They must be processed in the city of Smithfield, Virginia, U.S. (FSIS. 1995). However a Smithfield Style ham can be processed at any location.

**Spanish-style jamón** – salt-cured ham, which is aged longer and has a bolder flavor and is thin sliced and eaten uncooked (Provence, 2002). Spices are usually not used.

**Westphalian ham (Westfalischer Schinken)** – German-style dry-cured ham similar to Prosciutto which is smoked (sometimes with juniper berries).

**York ham** – lightly salted, lightly or heavily smoked, English ham, which is usually matured for 2 to 3 months, usually boiled before eating but sometimes consumed raw (i Chef’s recipe finder, 2002).
Type of hogs utilized Breeds

In the U.S. many breeds of hogs are utilized to produce hams used for dry-cured but it is preferable to use those that have a high degree of marbling. The Berkshire and Duroc are probably the most popular breeds used in the U.S. Pure breeds of Iberian, and Landrace are popular in Spain (See Figure 1). In Italy, Durocs have significantly higher intramuscular fat contents, water holding capacity, and cathepsin activities and also lower pH values which makes them more desirable for the dry curing purposes (Schivazappa et al., 2002). PSE (Pale, Soft and Exudative) pigs result in dry-cured hams that have a lower penetration force (80%), hardness, springiness, cohesiveness, and chewiness and therefore, are less desirable than RFN (Reddish pink, Firm, and Non-exudative) pigs (Tabilo, et al. 1999) for producing dry-cured hams.

This same paper suggested a preference for females hogs in order to obtain a more tender product. Mature pigs are more suitable because they have more pigmentation, larger quantities of fat and have less proteolytic potential (Monfort and Arnau, 2002). Genetics has also been reported to influence maturation, flavor and texture development in dry-cured hams (NSIF, 2000).

Feed utilized

In the U.S., the most popular hog diet is corn and soybean meal. However, Smithfield hams in the past were produced by hogs fed peanuts (no longer true today) that resulted in a softer fat which was more susceptible to oxidation and the more rapid development of the desirable country ham flavor.

In Europe (particularly Spain) hogs are fed on acorns as they graze in oak orchards or pastures. The mountaineer Iberian pig diet of acorns and fat produce a subcutaneous fat with relative high levels of monounsaturated and polyunsaturated fatty acids resulting in higher concentrations of volatile compounds in the cured hams (Timon et al., 1990).

Age at slaughter

In the U.S. pigs are usually slaughtered at 5 to 6 months of age and weigh 220 to 280 pounds. Top hogs usually weigh 260 pounds and yield 16-18 pound hams. If larger hams are desired, heavier pigs are slaughtered. Many producers prefer to cure 20 to 30 pound hams that would require hogs in the 300-pound weight range and they have discovered that large hams with adequate fat, age better and don’t dry out as much during the aging process (The Cure, 2002). In Europe, a variety of ages are used since hams of both small and large varieties are merchandized. The better quality is usually considered by the Europeans to be the larger hams.

Slaughter and cutting of carcass

Farm slaughter in the U.S. is normally conducted between Thanksgiving and Christmas when the weather is cold but not consistently below freezing. The season of processing is reported (Rastelli and Bellatti, 2000) to be responsible for appearance defects while composition of raw material affects product quality. The commercial slaughter methods are similar for both U.S. and European hogs but ham fabrication is different. The U.S. farm dry-cured ham is usually cut longer than the U.S. brine cured ham but for U.S. commercial production both hams are cut the same. The European ham not only is cut long but also the hoof often remains unless the ham is going to be boned and then the ham has the hoof removed. The presence/absence of the hoof does not significantly affect salt (NaCl) or moisture content of the ham after the salt equilibration procedure (Boadas et al., 2001). The presence of the hoof reduces the incidence of color fading in the joint caused by entrance of air; however, leaving hoofs attached seems to be mostly cultural (Monfort and Arnau, 2002). These authors also noted that it is often customary to cut the rind in the shape of a “V” so that the rind and part of the fat can be used for other purposes, to achieve more standardization of the thickness of subcutaneous fat and this also allows more lean to be exposed during the drying and slicing stages (See Figure 2). In Spain, the coxal (hip) bone is not removed and the morphology of the muscle remains intact but in France or Italy this bone is removed (which accelerates the drying process) with only a part (“anchetta”) remaining to avoid cavities (Monfort and Arnau, 2002). They also indicated that removal of the bone accelerates the entrance of salt and the loss of water especially in...
the Biceps femoris. During curing boneless hams will normally contain more mold and hot-boned hams will have a higher total aerobic plate count and a lower flavor score (Moore et al., 1992). An acceptable hot processed, boneless country-cured ham could be produced with one cure application and by enclosing the ham in a casing (Moore et al., 1992).

Curing procedures (addition of salt, often sugar and nitrate and/or nitrite to preserve, flavor and color)

When hogs are slaughtered in the U.S. on the farm, carcasses are usually chilled (take the animal heat out) overnight before curing and put in cure as soon as possible after chilling and trimming. Frozen meat, which assures cold temperature during transportation, can be thawed and utilized. Freezing and thawing also facilitates the dissolution of salt on the surface of the ham and its migration into the ham and also assist in the transport of water to the surface (Monfort and Arnau, 2002; Wang, 2001). These authors also indicate that if oscillation of temperature occurs during the defrosting process and/or the storage period and if the temperature fluctuations are prolonged this can cause superficial dehydration of the rind and lean tissue which causes freezer-type burns. This can hinder the salting process and spoil the final appearance. They also suggest that if there is a delay between obtaining the hams and salting it is better to freeze the hams than to refrigerate them while waiting for the curing process. Hams are sorted by weight and can vary from 12 to 31 pounds. This will determine the curing time with smaller hams taking less time to cure. During commercial production, hams are sorted into PSE (Pale Soft and Exudative), normal, and DFD (Dark Firm and Dry). DFD is more prone to produce a larger percentage of defective hams (Knight et al., 1997). The hams are deblooded (removal of blood from circulatory system and this will reduce microbiological problems along with improved appearance) and lightly to heavily salted by manual or mechanical methods (Knight et al., 1997).

Prosciutto uses fresh, long shank, bone in hams and they are gently (minimum amount of salt) salted and massaged, chilled, re-salted and re-massaged and then allowed to equalize for 3 months at slightly warmer temperatures (Italian Specialty Producers of North America. 2002). Tumbling will accelerate salt and nitrite penetration during the first 2 weeks of curing and will generally reduce microbial counts in the ham but does not seem to alter flavor of the finished product (Leak et al., 1984).

Reynolds et al., (2002) reported that dry-curing of inoculated hams limited proliferation of staphylococcal and resulted in a reduction of Salmonella spp., E. Coli O157:H7 and L. monocytogenes during curing for 69 and 120 days. Cordero and Zumalacarregui (2000) reported that the salt from dry-cured hams offered a suitable ecosystem for the survival of staphylocci and micrococci.

European hams are dry-salted by two procedures

1. The individual hams are covered with excess salt (e.g. San Danielle) under refrigeration (37°F) for 10 days (Arnau and Gou, 2001). They are often stacked to increase pressure particular on the lower hams (See Figure 3) or they may be placed in stainless steel containers for approximately 1 day per kilogram (2.2 pounds) for refrigerated and slightly less for frozen and defrosted hams (Monfort, and Arnau, 2002). During the salting period an equilibrium relative humidity of 75% is maintained (Leon Crespo et al., 1995). They also suggest that the relative humidity should be above 90% (never below 75%).
2. Limited salting by means of applying a given quantity of salt in proportion to the weight of the ham (e.g. Parma ham) can also be used and in this system the relative humidity should be between 70-75% (never above 85-90%) and the hams remain in a horizontal (thickness is reduced) position for 3-4 weeks (Monfort, and Arnau, 2002).
Under both salting techniques, hams are kept initially at low temperature. If temperature is below 34°F or frozen at 28°F, the fresh hams will not take cure properly and curing time must be extended. Also, if extended temperature above 50°F is encountered before the cure has penetrated the hams will spoil. Ideal temperature is 36-40°F. Salt is the only essential ingredient for dry-curing hams and often the only ingredient used in Europe. Salt is allowed to diffuse into the hams and water is pulled out by the salt (“taking salt”) and the purpose of salt is for its anti-microbial properties, flavor, and enhances salt penetration and water extraction (Texas A&M 2002).

U.S.

The USDA standard for country and dry-cured hams and shoulders can be found in Section 319.106 of the regulations. As the note at the end of that Section states, the times and temperature for salt equalization in Paragraphs (c)(5) and (6) are not being enforced. Requirements relating to product safety must be included in the HACCP plan.

In the U.S., sugar is sometimes added to the curing mix to enhance the action of salt, to counteract harshness, improve flavor, substrate for bacteria who convert nitrate to nitrite, and to keep the ham more moist and soft during aging (The Smokehouse, 2002; The Cure, 2002: Texas A&M 2002). Nitrates (preferred in long cures) and/or nitrites (often used with nitrate and in short cures) are often added to improve flavor, prevent warmed-over flavor, retard rancidity, to act as anti-bacterial agents, and to change the muscle color to cured-pink (Texas A&M 2002). Nitrate is present in very low levels in raw meat and in long cures can be transformed by bacteria to nitrite which alters the color of the ham (Monfort, and Arnau, 2002). Ascorbates although seldom used in dry-cured-ham would accelerate the transformation of nitrite to nitric oxide (necessary for cured color development) and retards the formation of nitrosamines (Monfort, and Arnau, 2002). Other seasoning such as black pepper, paprika and red pepper are sometimes added as flavoring agents (The Smokehouse. 2002).

Massaging (Monfort and Arnau, 2002) will facilitate the penetration of curing salts (often a mixture of salt, nitrate, nitrite, ascorbate and sugar), eliminate the blood in veins, and arteries and make the ham easier to press and shape (moderate pressing as shown in (See Figure 4). Pressing will also reduce the thickness, which will facilitate penetration of salt. Also, pressing after curing and aging will shape the ham. Mixes used by some producers (most processors have their own sometimes secret mixture) in the U.S.

- One of the most common curing mixes would contain 8 pounds of salt, two to three pounds of sugar, one half to four ounces of salt peter (sodium nitrate) for each 100 pounds of fresh ham. This is equivalent to approximately one ounce (or one and a half ounces if the ham exceeds 20 pounds) per pound of ham. The curing mixture is divided into 3 portions and applied on the first, third (overhauled), and fifth day of curing. The cure is rubbed into all lean surfaces of the ham. The curing time is 7 days per inch of thickness or one and a half days per pound of ham and the temperature should be maintained at 36-40°F. (Graham and Marriott, 1999).
- Other combinations would include fifty pounds of non-iodized dairy salt, 2 pounds of blackstrap molasses, 1 pound of black pepper, 4 ounces of paprika, 2 ounces of red pepper or cayenne (The Cure, 2002) and the hams are covered with ½ inch of this cure.
- Some processors use two tablespoons of salt, 2 1/2 tablespoons of sugar, 1/4 tablespoon of tri-poly-phosphate, 1/2 ascorbic acid tablet or Vitamin C capsule (500mg), ground, per kilo of ham (How to make ham, 2002).
- Morton Tender Quick curing mix contains salt, sugar, sodium nitrate and sodium nitrite, propylene glycol, blend of natural spices, and dextrose (corn sugar). The smoke flavored variety (the curing reaction takes longer) also contains caramel color, natural hickory smoke flavor (Morton sugar cure, 2002). Dry cured hams require 1 to 1-1/4 ounces of Morton’s dry-cure per pound of meat, which is applied at the 0, 7 and 14 days of curing and the hams remain in cure 7 days per inch of thickness, and salt equilibrium is obtained at 20 days (Morton sugar cure, 2002).
- Cure that could be used for a 14-pound ham. Two pounds of salt, 1 pound of brown sugar, 1/2 ounce of salt peter (i Chef’s recipe finder, 2002).
- Dry cure mixture sometimes used– mix 10 pounds of salt and 1 ounce of nitrate, and this is spread 1/2 inch thick over the hams. The hams are cured for 5 weeks (Texas A&M 2002).
- In the U.S. salting if often done by spreading 1/2 inch layer of cure on a bench, place ham skin
side down, and cover all surfaces (cure will not stick to dry skin) with 1/2 inch of cure. Force cure into the cut shank ends of the hams. Pile up the hams and overhaul them several times (The Cure, 2002). Hams should stay in cure approximately 2 days per pound of ham.

**Importance of dry-curing in Europe**

Southern Europe production of dry-cured ham is quite large and important with Spain having 1,500 producers curing 125,000 tons per year, Italy with 250 producers producing 160,000 tons per year, France with 200 producers producing 40,000 tons per year and also significant production is found in Portugal and Germany (Knight et al., 1997).

**Washing**

Highly salted hams are often de-salted (See Figure 5) by scrubbing with a stiff brush and immersing in running water to eliminate excess salt before drying (Arnau and Gou, 2001) or smoking; however, if temperature can be maintained between 34 to 41°F during the stabilizing phase then it is possible to reduce the quantity of added salt and limited washing in tepid water is only done to remove the excess surface salt and impurities (Monfort, and Arnau, 2002). At this stage, it is also advisable to lightly press the hams in order to eliminate brine and any residual blood in the blood vessels. If the ham is dried too fast, water activity could be lowered which could cause crystallization of salt, drying of the lean meat and white stains on the rind (Monfort, and Arnau, 2002).

**Smoking and coatings used**

Hams are traditionally smoked in areas with a cool damp climate. In the U.S., most hams are often cold-smoked (temperature less than 90°F) by hanging in a smokehouse and allowing the ham to absorb smoke from a smoldering fire which gives the hams added flavor, color to a dark mahogany, adds antioxidants (particularly phenols), seals the surface of the ham, and slows the development of rancidity as well as having anti-bacterial properties (FSIS. 1995: The Smokehouse. 2002). Traditionally smoke houses were frame buildings with a dirt floor and vents or loosely fitted eves covered with fly screen. The hams are kept in the dark to discourage skippers (larvae of a small black fly); however, today smoke houses are often stainless steel with an external smoke generators (The Cure, 2002). If smoking temperure exceeds 120°F the ham starts to cook and cooked hams do not keep as well as cold smoked hams (The Smokehouse, 2002). Hams can only be labeled “hickory smoked” (or any other woods such as beech, birch or oak) unless hickory wood has been used (FSIS, 1995). Smoking 24 hours is usually sufficient. In the U.S. a honey or sugar (cane or beet) cured label can only be used if the sweetener is responsible for one half of the sweetening ingredients used and affect the flavor and/or color of the finished product (FSIS, 1995). In some areas the external surface is coated by rubbing with a mixture of a half pound of black pepper, one quart of molasses, one pound of brown sugar, one ounce of salt peter (sodium nitrate) and one ounce of Cayenne pepper per 100 pounds of ham.

**Repose period (resting period)**

This step is to obtain a more even distribution of salt throughout the ham and to slightly dehydrate the ham. The dehydration should be faster in the first 1 to 2 weeks to discourage bacterial growth. Temperature should be less than 41°F and relative humidity should not be less than 75% until after most of the salt has penetrated the ham and then the humidity can be lowered below 75% to achieve the sweating process (Monfort, and Arnau, 2002). Arnau and Gou (2001) continued the resting period for 40 days. Some processors use a barrier between the ham and the atmosphere to reduce bacterial growth. Often two layers of heavy brown grocery bags are tightly folded and tied around the ham. This slows down the evaporation of moisture but some hams are simply hung without covering and exposed to the environment. During the repose period a spontaneous growth of fungi and Micrococcaceae microorganisms are produced on the surface of the ham (Monfort, and Arnau, 2002). Both of them are involved in the typical flavor of the Spanish ham (Ockerman et al., 2000). Monfort, and Arnau, (2002) also indicate that accumulated weight loss obtained at the end of this period should be between 10-15%. Monfort, and Arnau (2002) suggest that the
time required depends on the size of the ham, lean surface, type of polishing, inter- and intra-muscular fat and can be as short as one month for small hams or as long as 3 months with a low salt ham (e.g. Parma ham). Leon Crespo et al., (1995) indicated that in the response period the NaCl equilibrates throughout the ham and a period of 2.5 to 3 months are needed to obtain 6.3% of NaCl that inhibits the growth of *Clostridium* spp.

**Aging (drying or maturation or ripening) procedures including aging times**

During aging, hams continue to dehydrate and proteolysis and lipolysis of the protein and fat contribute to aroma (Monfort, and Arnau, 2002). Infiltrated fat prolongs the maturation time but it increases the mastication process due to the oily sensation and contributes to the appreciated (pleasant flavor of oxidized fat in dry-cured hams) mature flavor (Monford, and Arnau, 2002). These same authors reported that hams with little subcutaneous fat must be avoided since the rind area dries faster than the rest of the ham, results in a saltier taste, less yield and lower quality. They also reported that hams should be avoided if they have a pH of greater than 6.2 [sometimes found with DFD (dark firm and dry) hams] due to microbial safety, and therefore the high pH contributes to more deteriorated hams, poor salting characteristics, and poor appearance (shiny aspect or lesser curing), and softer texture. In this high pH meat the diffusion of water is less and areas inside of the ham could have a saltier taste. Drying or ageing rooms are used to further the curing process. Different drying rooms with controlled temperatures are maintained from 35°F to room temperature and relative humidity is controlled from 90% down to 60% (Knight et al., 1997). Some processors wrap the hams but most hang them with out wrapping.

In Spanish hams, the temperature is slowly increased from 10-12°C until it reaches a maximum of 82-86°F; however, in recent time there has been a decrease of time at the higher temperature (Monfort, and Arnau, 2002). These authors suggest that on increasing temperature there is a fusion of fat into the muscle tissue, which is reasonable for the typical ham flavor. They also suggest that during this stage a washing and drying and a fine layer of fat is frequently applied to prevent cracking, drying too fast, and the odor found in damp places. In the last 2 to 3 months, the ham may be covered (See Figure 6) with a layer of lard (Knight et al., 1997). Arnau and Gou (2001) utilized 53-81°F, 60-70% relative humidity for 8 months for an ageing period. In Parma hams, drying occurs at 59°F and after 6-8 months is stopped by application of a layer of fat, flour, pepper and salt (Monfort, and Arnau, 2002).

The flavor development of Spanish Serrano is during the ripening-drying state and involves time (7 to 12 months) and temperature interactions, which are the most important factors (Flores et al., 1998; Roiz et al., 2001). Prosciutto hams are dried and aged for a minimum of 7 months, they are then trimmed and the bone removed. Other varieties (“Americanized” style) accelerate the aging process with heat (Italian Specialty Producers of North America. 2002). Extensive lipolysis which is of importance to dry-cured ham flavor occurs during the ageing period and this oxidation is induced by aging time, degree of drying, salt level, proximate composition, intramuscular fat composition, the degree of lipolytic activity of fat and the high iron level. Timon et al., (2001) found that lipolytic and oxidative processes were more intensive in subcutaneous than in intramuscular fat. This oxidation can be followed by TBA analysis, peroxide number and cholesterol oxides (Vestergaard, 1998). The current method of determination of ham quality relies on insertion of a probe into the ham and then analyzing the odor exuded from the probe at an average of 2 to 3 pre-defined locations on the ham (Knight et al., 1997). Spanish hams after ripening show a significant difference in lightness, redness, yellowness, chroma and a/b ratio with the highest values found in the biceps femoris, and the lowest values in the semimembranosus (Rodriguez et al., 1990). The dominant species of microorganisms found (Ruiz et al., 2001) in dry-cured hams was *Staphylococcus xylosus* and *S. Aureus* (coagulase-negative) but these did not exhibit proteolytic activity and microorganisms role in aroma characteristics of dry-cured hams remains unclear. Mites are sometimes a problem in dry-cured hams and Ranchez and Castanera (2001) reported that *Tyrophagus putrescentiae* (astigmatid mite) can affect dry-cured hams and suggested that monoterpenes can be used to control the mobile stages of these mites. Deep putrefaction is sometimes a problem in dry-cured hams and Losantos et al., (2000) reported that *Enterbacteriaceae, Serratia liquefaciens* and *E. Proteus vulgaris* strains were believed to be responsible even with the hams that had similar pH’s and water activity values. Country or dry-cured hams will keep almost indefinitely but achieve excellent flavor at about 1 year when “white flecks” (tyrosine crystallization precipitation) appear on the muscle.

**Figure 6. Applying lard to ham surface.**
(The Cure, 2002) in the area of cell lyses (Stella, 2000). Some 40-pound hams have been reported to be aged 5 years and were wonderful (The Cure, 2002). Important factors for sensory quality include barriers for microbial growth, selection of raw material (genetics of pig, level and type of fat), influence of cut, use of appropriate temperatures and relative humidity for drying and ripening (Arboix, 2002). Volatile markers obtained by solid phase microextraction include products of oxidative deterioration of lipids, products of the Strecker degradation of amino acids, and trepans (Ruiz, et al., 2002). Piazzani et al., (2001) reported that high cathepsin B activity and high aging temperature increased total free fatty acids but Alanine, Leucine, Lysine, Phenylalanine and Threonine levels did not change during aging. The total amino acids content, the total amount of peptides also did not differ among the different treatment groups during aging. Sentandrue and Toldra (2001) found that dipeptidases, a group of enzymes important for flavor development, remain active during the total (9-12 months) processing of dry-cured hams except DPP II whose activity disappeared after 240 days.

Mold Growth and its influence

Mold is often found on dry-cured hams and most of these are harmless but some mold growth on more moist hams can produce mycotoxins. Molds growing during the long dry-curing and drying process is due to high salt and low temperature and this can be washed off along with the pepper if present with hot water and a stiff vegetable brush (FSIS. 1995). Most dry-cured ham fungal flora is primarily composed of strains of the genus Penicillium and many of these strains have a positive influence on flavor and in fact some are inoculated for that purpose (Ockerman et al., 1999).

Storage after purchase

U.S. country, uncooked, uncut ham can be stored 2 to 3 months under refrigeration (remove from refrigerator 12 hours before cooking) or can be frozen for 1 month. This ham can be hung (do not lay it flat on a hard surface) and stored at room temperature, preferably in a cool, dry place, for up to 1 year and after one year is still safe to eat but quality may suffer (FSIS, 1995; House of hams, 2002b). U.S. country ham that has been cooked can be refrigerated for 7 days or frozen for 1 month before consumption (FSIS, 1995). Prosciutto, Parma or Serrano or dry Italian or Spanish type that have been cut can be stored 2 to 3 months under refrigeration or frozen for one month (FSIS, 1995).

Cooked or eaten raw (How to protect against foodborne organisms if hams are consumed uncooked)

Trichinella spiralis (trichina) parasites are sometimes present in hogs and all U.S. hams that are specifically processed to USDA guidelines should be trichinae free (FSIS. 1995). Staphylococcus aureus (staph) can also be associated with hams but is destroyed by cooking and processing but can be re-inoculated by mishandling. The staph can produce a toxin that is not destroyed by further cooking. Dry-curing may not destroy the S. aureus but the salt content on the surface inhibits their growth. Upon slicing the S. aureus may be moved to the interior of the ham and therefore U.S. sliced dry-cured hams must be refrigerated (FSIS. 1995). Challenge studies have indicated that with a water activity below 0.91, pH less than 5.5, temperature less than 68°F and a 5-6% salt content the enterotoxin was not produced by S. aureus (Rose-Morrow et. al 2000). This same study also indicated that S. aureus, L. monocytogenes, E. coli O157:H7 and Salmonella spp. were controlled by the dry curing and aging process (Rose-Morrow et., al 2000). In the absence of other scientific documentation in connection with HACC, the USDA would expect a brine concentration of at least 10% or a water activity of not more than 0.92 in the finished product. Microbes can also cause the meat to “sour” by a putrefaction process and this can cause approximately a 2% loss (Knight et al. 1997). Clostridium botulinum have on rare occasions been the cause of illness when dry cured hams were contaminated with this organism (Pavic, et al., 2001). In the U.S. ready-to-eat hams including Prosciutto and fully cooked hams can be eaten with out further cooking. Fresh U.S. and dry-cured hams that are only trichina treated must be cooked before eating and these hams will bear a safe handling label (FSIS. 1995). With the European ham the salt curing process preserves and stabilizes the meat and makes it safe to eat the ham uncooked (Provence, 2002). In Spain dry cured ham is available in every restaurant, delicatessen and bar and is eaten uncooked.

Cooking procedure for U.S. hams.

Hams should be washed with hot water and a vegetable brush to remove mold growth and pepper be-
fore soaking. Cut off a slice from both the butt and shank ends (not often done) and then soak for at least 12 hours or longer (up to 3 days for hams aged more than a year) under refrigeration to reduce the salt content before cooking. Often this is repeated twice with fresh water for up to 72 hours (House of hams, 2002b). Drain ham and scrub again. They are then covered with water in a lard can or turkey roaster (skin side down), brought to a boil and immediately reduced to cook by simmering (preferred) and/or baking (preferred for finish cooking). Hams should be simmered 18 to 25 minutes per pound or until the center of the ham reaches 155°F. The last hour of simmering some of the water can be removed and root beer, sliced red and green apples, orange slices, cracked pepper, ground cloves can be added to the water. If these ingredients were added, then further simmered after ham removal, until the liquid is thickened, makes a good glaze or can be used to season greens, rice or soup (House of hams, 2002b; Cook's 2002). Water can be changed during cooking to further reduce the salt level but then the internal temperature must be used to indicate when the ham is cooked instead of time. A good indicator of when the ham is done is when the meat separates from the bone or when the big bones or flat pelvic bone move freely (House of hams, 2002b). After cooking take the ham out of pot, place skin side up and remove skin and all but 1/8 to 1/4 inch of the fat. Score the fat side and apply brown sugar or breadcrumbs or your favorite glaze. Place on a flat rack in a large roasting pan, add 2 cups of water, and add glaze. Brown at 375 to 450°F for 10 to 30 minutes depending on glaze used (FSIS, 1995: House of hams, 2002b). Glazes can burn or blacken if baked too long. If you are baking the ham do not apply the glaze until the last 30 minutes (House of hams, 2002b). An example of a glaze that might be used is an orange glaze containing 1/2 cup of brown sugar, two tablespoons of prepared mustard and the juice and grated rind of one orange and after baking it can be garnished with orange slices. A mustard glaze may contain 1/2 cup of brown sugar, 2 tablespoons of prepared mustard, 2 tablespoons of vinegar and 1 tablespoon of water. A spice glaze would contain 1/2 cup of brown sugar, 1 cup of juice (spiced peaches or pineapple) and after baking garnished with whole pickled fruit (VPI, 1978). Another glaze might include 2 cups of brown sugar, 1/2 cup pineapple juice, 2 to 3 pieces of laurel, 1 to 2 clavo de carambolo, a few dried oregano leaves, and 1 bottle of 7-UP or 1/2 cup anise seed wine. If a caramel glaze is desired you might utilize 2 cups brown sugar, _ cup pineapple juice and 1-cup soup ham juice (How to make a ham, 2002). Another caramel glaze would use 2 cups brown sugar, 1/2 cup pineapple juice, and 1 cup of soup ham juice (How to make a ham 2002).

Baking of a dry cured ham is a little more difficult but also a popular cooking method. Scrub, soak and then place ham in a roaster, fat side up on a rack with 2 inches of water (some add Dr. Pepper or other soft drinks and pickle juice to the water). Bake (some tent with aluminum foil) for 15 to 25 minutes per pound at 325°F. Baste frequently until internal temperature reaches 155°F and the bones move easily (House of hams, 2002b). Remove from kettle, remove skin and most of the fat, place fat side up, add glaze and return to a 375 to 450°F oven for 10 to 30 minutes or until browned, depending on glaze (House of hams, 2002b). Coke or Pepsi can also be added to water and concentrated and used as a brown gravy (House of hams, 2002b).

Glazes for baked hams (1 cup of glaze/ 14 to 15 pound ham):
1. Brown sugar, flour, syrup, water or stock, and mustard -- mix to a paste and spread over ham, diamond score (1 inch on side) on fat side and place whole cloves in diamond. Bake with glaze at 375°F for 30 to 40 minutes.
2. Three tablespoons of orange juice and 1-1/4 cup brown sugar, 1 teaspoon of ground cloves – glaze and bake (Cook’s 2002)
3. One-fourth cup of mustard and 1-1/4 cup brown sugar, 1/2 teaspoon ground cloves glaze and bake.

Frying of ham is also popular – cut outer edges to prevent cuping, fry 1/4 (some use 1/2 inch) thick or less ham slices over medium heat, turn often, for 5 to 6 minutes on each side and place on a hot plate for serving. Ham slices can also be placed in a covered casserole and baked in a 375°F oven and are uncovered for the last 15 minutes for browning. Broiling may also be used to cook ham slices.

Redeye gravy – after frying ham slice, add 1/4 cup of black coffee or water (and sometimes a little whiskey, flour, salt, pepper, onions) to 3 tablespoons of ham drippings with scrapings (these are the redeyes) and bring to a boil. Serve over ham or biscuits (House of Hams, 2002a) or add to casseroles, eggs benedict, stews or soups to enhance the flavor (House of hams, 2002b).

Many other dishes use dry-cured ham as one of the ingredients due to its unique flavor. A few examples would be ham salad (grinding ham, and mixing with chopped celery, onions and/or pickles and moisten-
ing with mayonnaise), ham and oysters, ham roulades, creamed cheese and ham, ham loaf, creamed ham, ham and dumplings, ham and cheese, greens, pasta, rice, ham soufflé, and omelet.

An average dry-cured ham will yield about 20-30 portions (varies with size of the ham).

**Slicing methods**

U.S. hams should be cooled, after simmering and baking or baking, before trying to slice the ham very thin. Most American hams are sliced vertically or diagonally across the grain, cutting down to the bone, the Europeans place the ham on a specially designed rack and hand slice jamon very thin, parallel to the bone (See Figure 7) and therefore the fiber (Provence, 2002; Italian Specialty Producers of North America. 2002). This is becoming a lost art and electric slicers are often used today particularly on boneless hams (Italian Specialty Producers of North America. 2002). The American philology is that cutting across the grain makes the ham more tender and the European reasoning is that cutting in the direction of the fiber reveals more flavorful bands of sweet fat and more flavor (Provence, 2002). A good European ham slicer can cover a plate with 100g of non overlapping slices.

**Packaging**

Some dry-cured ham products are ripened in various modified atmospheres (Wang, 2001). One hundred percent nitrogen or 75% nitrogen and 25% carbon dioxide are sometimes used and the author noted increased lipolytic and proteolytic compounds with out significant effects on microbiological quality or sensory acceptability. Some sliced dry cured ham slices are packaged in atmosphere-protected packages (Citterio, 2002) and others are vacuum packaged (Wool et al., 1998). Vacuum packaging prevents problems of acapus or excessive drying (Monfort and Arnau, 2002). If the slices are stored for a prolonged period of time this can cause re-moistening of the surface which will result in unpleasant marks on the surface (Monfort and Arnau, 2002). If the water activity is high in some areas of the package, microorganisms may proliferate and it may be necessary to refrigerate the product or keep it frozen. Frozen storage permits maintaining the desirable flavor for long periods of time and retards the formation of white velum but also facilitates the formation of marks on the surface (Monfort and Arnau, 2002). Freezing of unpackaged pieces causes loss of volatile substances and a decrease in aroma (Monfort and Arnau, 2002). If inoculated prior to packing a few *Staphylococcus aureus*, *Salmonella* and *Listeria monocytogenes* will survive storage (Wool et al., 1998) but no *Escherichia coli* were detected in any control samples. Alcala et al., (2000) also found that if hams were spiked with *Yersinia enterocolitica* and vacuum packaged for up to 200 days that these microorganisms declined rapidly during storage.

**How products are utilized and consumed**

Slice paper-thin and serve with biscuits or soft yeast rolls (Brown Alton, 2002). The hams are often used as appetizers at parties or special occasions or at fancy banquets. This product is often used for special family gatherings such as holidays and anniversaries.

**Conclusion**

The major differences in U.S. and European dry-cured hams are the type of feed used (U.S. – corn and soybeans; Spain – acorns), fabrication (U.S. – usually short cut with hoof removed; Europe – hoof often remaining), salt curing (U.S. – heavy and often with other additives; Europe – light to heavy and often with only salt), smoking (U.S. often done; Southern Europe – seldom done), aging (U.S. – shorter to one year; Europe – shorter to often longer), slicing (U.S. – perpendicular to bone; Europe – often parallel to bone), and preparation for consumption (often simmered and baked; Europe – often eaten raw). Both techniques produce an excellent, favorable product.

**References**


NSIF. 2000. Influence of pig genetics on the technological and sensory quality of Bayonne ham http://mark.acsu.edu/nsif/00proc/garnieposter.htm


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