GENERAL ASPECTS OF HAM PROCESSING

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Ham is produced from the primal cuts of porc. It is prepared by curing with salts and seasoning, followed by an aging period and finished by drying and in some cases smoking. The resulting end product can be stored at ambient temperature and is generally used as such, without further culinary processing. It is likely that air dried bone-in ham is amongst the earliest meat products, known already in prehistoric times; it was indeed a choise food greatly appreciated by the Greeks and the Romans. Today, some local productions have aquired world-wide fame and these products are protected sometimes by labels of origin. On the whole, all processing techniques are similar, the end products are characterized by their organoleptic properties. These improve with the extent of the processing time. Due to the fact that drying was performed originally by free circulation of air, the production centers developed in areas exposed to relatively strong winds and only small temperature fluctuations. Those conditions ensured even drying at an almost constant temperature. Hence, in some regions, ham production started only at the onset of the winter season and processing was further completed during spring time and the summer months; at that time the product would have already aquired microbiological stability.
Amongst the most popular hams one can list :
"Prosciutto di Parma" and "Prosciutto di San Daniele" (Italy), "Jambon de Savoie" and "Jambon de Bayonne"(France) "Jamón Serrano" (Spain), "Kraski Prcut" (Yougoslavia), "Schwarzwälder-, Westfälischer-, Niedersächsicher Rohschinken" (Germany), "Jambon d'Ardenne" (Belgium), "Virginia Ham" (USA), "Yunan Ho-Twe" or "Tschingwa Ho Twe" (China).

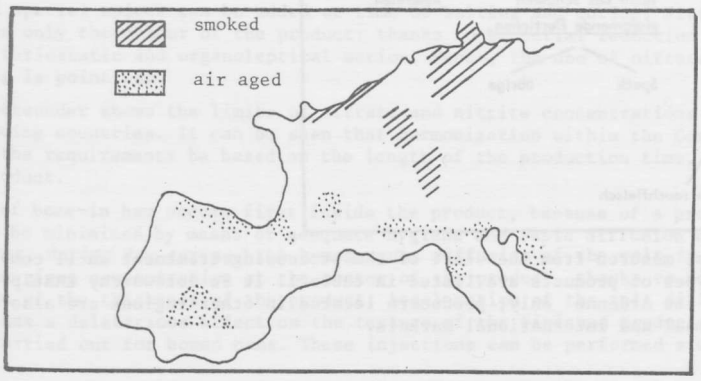

Figure 1 : Main European areas where ham manufacturing centers are sited (LINKE 1985)

I. PARAMETERS AFFECTING THE KEEPABILITY OF THE PRODUCT.

The three main parameters to be monitored are: temperature, pH and water activity (a_w) of the product. Raw meat has a high a_w (water activity) and its pH also is favourable to microbial developments. Hence, right from the beginning of the processing sequence one should operate at a sufficiently low temperature. In fact, in the old times, it was impossible to start any production except during the winter season. Today, thanks to cold storage, fast cooling rates, right after slaughtering, can be achieved. Such a treatment is of utmost importance to ensure the production guaranteeing good hygienic qualities. The temperature must be kept below 5°C at the center part of the ham and has to be maintained thus as long as the concentration of salt is insufficient, i.e. below 4,5%.
The microbial development in meat after slaughtering depends also on the glycolysis. If the pH is decreased after slaughtering from 7,2-7,0 to values of 5,5-5,8 (normal glycolysis) bacterial development is slowed down. On the other hand, if the product has a high pH (above 6) at time of curing, such as for DFD meat from animals which, prior to slaughtering, were stressed and exhausted, the curing salt diffuses too slowly inside the ham portion, maintaining thus a favourable environment for bacterial prolification. Thus, the decrease of pH to 5,8-5,5 and a temperature kept below 5°C represent two important barriers against microbial growth. However, in larger bone-in hams, such as Parma hams, the pH can increase during the curing period; such fluctuations represent 0,2 to 0,5 units. The pH zone, which prevails for most ham products, offers only a limited barrier against microbial development. It stands to reason that the decrease of the a_w of the product, resulting from the addition of salt and drying, are the main agents which ensure good keepability of ham. The role of a_w is more significant for hams than for sausages. Therefore, the saline concentration is higher in hams than in the latter. The inhibiting action of a_w towards altering agents (enterobacteriacea) and toxic germs (e.g. Cl.botulinum) occurs at a a_w below 0,96. In practice, this value corresponds to a mean saline concentration of 4,5%. Once this saline concentration is attained, the product may be aged, dried, and sometimes smoked at ambient temperature. Aging of ham, which takes place from curing onwards until the end of the drying period, allows the development of flavour, caused by ill-known enzymatic processes. This development is certainly initiated and furthered by the prevailing microbiological population, which normally attains its stability after the curing process. The specific flavour of each regional dried ham product depends on the temperature and ambience in which the ham is kept during the second part of the processing. A systematic study of the evolution of the microbial population and of the enzymatic reactions would certainly help to improve monitoring of the processing conditions for dried meat products.

II. DEFINITION OF NON-COOKED CURED AND DRIED MEAT PRODUCTS.*

Non-cooked ham, comes from the rear carcass of porc and contains three bones - aitch (1), body (2) and shank (3). Long cut hams also contain part of the back bone, known in Germany as "Lachsschinken". Dried meat products are also obtained from animals other than porc, however, the present paper deals only with porcine meat and more specially with bone-in hams and other parts such as the cushion and knuckle sections.

* cooked products will be dealt with elsewhere

An example of a classification for cured meat has been outlined by LINKE (1985) for German products (see figure 2)
Part of the Belgian production is ruled by labels of origin and called "Jambon d'Ardenne". These labels specify the area of production and also the conditions for processing and the features of the premices.
The paper given by VANHEMMENS-SEGERS, LENGES, DE SPIEGELAIRE on "Correlations between drying rate and organoleptic properties of "Jambon d'Ardenne" lists these official specifications.
In view of a comparison between the Belgian products and similar productions from other European countries, copy is given hereunder of some paragraphs from the Belgian "Royal Decree" of 4/2/1974. This text describes the main characteristics of the product to be processed.
"Jambon d'Ardenne should be round shaped and should not have more than two finger-breadth of porc loin (at the aitch bone end). It should be hung by a string wound around the shank. The shank should not be pierced; the leg must be cut and not sawn-off. The aitch bone must be part of the ham portion. The ham should keep its natural shape and should not be netted or trimmed in any other fashion. The knee-cap must remain attached to the knuckle"

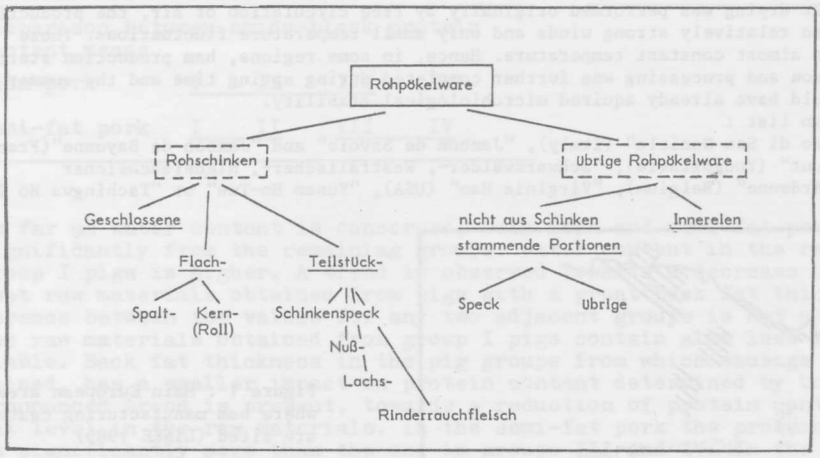

Figure 2: Classification of cured meat products in Germany (LINKE 1985)

The minimal and normal processing times, mesured from the start of the processing treatment until completion and the minimal weights of the different types of products are listed in table 1. It is noteworthy that production of ham in Belgium is not restricted to the Ardenne only; producers located in other regions are also able to offer first class products to the national and international markets.

Product	Months processing time		Weight (kg)	
	minimum	normal	minimum	average
Normal bone-in ham	4	6	4	5 - 6
Normal boned ham	4	6	3	4 - 5
"Coeur" d'Ardenne (cushion)	2	3	2,5	4 - 4,5
"Noix" d'Ardenne (knuckle)	0,75	1	0,8	1 - 1,5

Table 1:
Specification for "Jambon d'Ardenne" (label of origin)

The main Belgian products are: bone-in regular ham, regular ham, cushion ("coeur d'Ardenne"), knuckle ("noix de jambon"), flat ham.

One of the most famous ham products is the Parma ham. Its processing, which yields a first class product, involves a long aging period. Parma ham is taken from porc with a live weight above 140 kg. Dry curing takes place for a period of two months at low temperature (± 1°C), followed by diffusion of the salt inside the ham for one month at 3° to 4°C. Then the aging and drying process takes from 7 to 24 months, according to the size of the ham portion and ambient temperature.
Genuine Parma ham should weigh at least 7 kg after a treatment of 10 months. First quality grade hams should still weigh 9 kg after 12 months aging and drying. All other hams, which are produced in the same region and which do not satisfy entirely the set specifications are sold with the label - "Manufactured according to the Parma process".
Some regions of France and Italy are also well known for the preparation of crude hams (Savoie, Bayonne, Aoste). Ham from Aoste is produced from porc with a live weight of 100 to 130 kg and the hams weigh 8 to 10 kg before curing. Industrial production is performed in air-conditioned rooms, which are not influenced by the external atmospheric conditions. First class quality bone-in hams undergo aging periods taking up to 9 months and standard quality grade hams are stored for 6 months in aging cum drying chambers. Cottage industry productions require 9 to 12 months processing. The initial dry curing lasts one week and this is followed by a second curing period of 2 to 3 weeks at a temperature not exceeding 5°C inside the curing chambers. Diffusion of salts within the product proceeds for 4 to 6 weeks in chambers kept at 3 to 4°C and with 60 to 70% relative humidity. Aging itself is preceded by three to four hours steaming at 30°C. This is followed by the progressive decrease of temperature from 22° to 14°C for 6 to 7 days. During this period the relative humidity increases from 60 to 80%. This intermediate temperature increase helps to mobilize the enzymes, which are specific for meat and which

enhance the flavour development; it furthers also the reduction of nitrates into nitrites, thanks to the presence of micrococci and possibly allows detection of internal degradation, shown by an inflation of the ham. Drying and aging of hams take place at temperature between 10° to 15°C and relative humidities of about 80 to 85%.

III. PROCESSING TECHNOLOGY -GENERAL CHART AND POSSIBILITIES.

3.1. Salting - Curing.

Addition of salt helps to safeguard the microbiological stability and improves the organoleptical properties of the product. Generally, cheap non-cooked ham, processed within a short period of time, is not very dry and therefore more salt has to be added in view to reach an a_w which will ensure the keepability of the ham at room temperatures. Such a product has a neutral, quite salty taste. By contrast, for hams which have been processed for longer periods of time with the same amount of salt, the salty taste is less pronounced; in these productions the salt ions are more strongly bound to the proteins of the meat and therefore they dissolve less easily in the saliva. For microbiological stability, a minimum of 4,5% salt concentration is required, but this concentration should not exceed 6% in view to safeguard the nutritional and organoleptical properties of the ham. Parma ham is amongst the lowest in salt concentrations. 12 months after its production the salt content is not over 5%.

Curing can be performed with dry salt, by rubbing and slight massage, by submersion in brine, or by injection of the brine. The most common curing salts can be sub-divided into three groups:

- Sodium chloride or marine salt. This is used for bone-in hams with processing periods exceeding 9 months.
- Sodium chloride added with potassium nitrate : This mixture is used for products undergoing 3 to 9 months processing periods.This mixture sometimes contains some nitrite salt.
- Sodium chloride added with sodium nitrite. These salts are used for fast curing and limited processing times.

Herbs and special spices can be added at time of salting and curing. Nitrate displays a slow activity and influences only the colour of the product: thanks to bacterial reduction it changes slowly into nitrite, which has a bacteriostatic and organoleptical action. Hence, the use of nitrates for accelerated or short term processing is pointless.

Table 2 hereunder shows the limits of nitrate and nitrite concentrations for finished products, used in the main ham producing countries. It can be seen that harmonization within the Common Market should not be too difficult, provided the requirements be based on the length of the production time, which itself is linked to the dimensions of the product.

Spoilage of bone-in ham occurs first inside the product, because of a proliferation of anaerobical germs. Such risks can be minimized by means of adequate hygiene and rapid diffusion of the salt inside the mass.

However, during dry curing, the homogeneous diffusion of the salt is slow. In this case, the time required to reach a given concentration at the center of the product, thanks to diffusion transfer, varies according to the square of the thickness of the product. Acceleration of the salt diffusion by tumbling is not advisable since it has a deleterious effect on the texture of the finished product. Homogeneous injection of brine can only be carried out for boned hams. These injections can be performed stepwise. The water, which is introduced in the ham by this action, can be removed quite easily by storing under pressure or during the drying sequence. LEISTNER (1985) describes a modern mixed curing process, which is rather ingenuous. It is used for "Prosciutto" ham in the States. Bone-in hams are injected with nitrite salts and surface salted and spiced by rubbing. They are then stored in superposed layers, separated by planks and pressed together by heavy weights. Thanks to the pressure, the injected water is removed during the storage taking place at 10°C, and lasting for 40 days. The product is washed and then smoked at 38°C for 7 days. The complete processing cycle takes 2 months. Pickling by submersion requires monitoring of the salt concentration in the brine to prevent the loss of flavour due to diffusion. Therefore the volume ratio of ham to brine has to be adjusted. This kind of curing allows the use of starter cultures, which ensure the reduction of nitrates into nitrites as well as the development of specific aromas, thanks to lysis of proteins into peptides.

Table 2: Use of nitrate and nitrite for the production of hams (LEISTNER,LUCKE, HECHELMANN - 1983)

Country	Additifs	Authorized residual levels
Soviet Union	forbidden	nil
Norway	forbidden	nil
Sweden	forbidden	nil
Democratic Republic of Germany	forbidden	nil
Italy	allowed	250 ppm ($NaNO_2$ + KNO_3)
Denmark	allowed	500 ppm KNO_3
Belgium	allowed	200 ppm ($NaNO_2$ + KNO_3)
Netherland	allowed	500 ppm KNO_3, 200 ppm $NaNO_2$
United Kingdom	allowed	500 ppm containing max 200 ppm $NaNO_2$
Federal Republic of Germany	allowed	600 ppm $NaNO_2$ + KNO_3 large pieces 100 ppm $NaNO_2$ small pieces
France	2000 ppm KNO_3 of 1000 ppm KNO_3 + 120 ppm $NaNO_2$	150 ppm $NaNO_2$
USA	2200 ppm KNO_3 of 624 ppm $NaNO_2$	200 ppm $NaNO_2$

Excessive bacterial proliferation can lead to "inversion" of the cure (settling out, flocculation, production of foam and jellies, and alteration of the organoleptic properties).
The predominant micro-organisms, which have been isolated from cures are Staphylococcus, Micrococcus, Gram negative rods and Lactobacillus.
The last part of this paper describes the analysis of germs, which have been isolated and quantified in finished products.

The main causes for alteration of the cures are :
- too high or fluctuating temperatures during processing;
- unsufficient salt concentrations;
- too high concentrations of proteins and of sugars;
- ham portions, which to start with are heavily contaminated;
- poor hygienic conditions in the curing chambers.

The germs, which produce deterioration in hams and cures are the same as those prevailing normally on the premices. Rotting is due to Gram negative bacteria (Vibrio), acidification to Staphylococcus, Micrococcus and Lactobacillus; production of jellies is caused by Leuconostococcus and the production of foam originates from intense enzymatic activity. Internal rotting of bone-in ham is furthered by poor cooling of the raw material, too high pH, unsufficient curing and too high curing temperatures. Primary infection is caused by psychrophile enterobacteriaceae, development of Clostridium botulinum is rare. Non-pathogenic Lactobacillus and Staphylococcus are not present, in general.

3.2. Aging- Smoking- Drying.

These processes start when the a_w of the product has reached 0,96 after homogeneous diffusion of the salt throughout the product. It is recalled that the minimum salt concentration to be attained is 4,5%. Starting from this moment, the product will be microbiologically stable and the temperature may be increased to 10 - 15°C.
Aging of ham follows a complex mechanism. The development of specific aromas results from a series of ill-known enzymatic and biochemical processes. It would be very useful to further research in this field in view to identify the organoleptic tracers, which are characteristic for high quality hams.
Investigations as to the nature of these tracers as well as to the technologies linked to aroma development would greatly facilitate monitoring the production of non-cooked hams.
One should aim to correlate the prevailing bacterial population to the flavour development during aging. Flavour evaluation by objective measures and appropriate sensory tests are some of the basic requirements for an efficient approach in this field.
Smoking is a process common for hams produced in various European countries and regions, such as Germany, Belgium, Alsace.
It serves four purposes:
- Formation of a brownish colour, resulting from reactions between the components of the smoke (carbonyls, aldehydes, phenolics and nitrogen oxides) and those present in the ham, which is to be smoked.
- Flavour development (smoke taste) due to reactions between the proteins of the meat and the phenolics, carbonyls and lactones in the smoke.
- Presence of antiseptics, such as aldehydes (formaldehyde), organic acids (acetic and formic) and phenols.
- Presence of anti-oxidants.

Smoking of bone-in ham and ham portions is performed in a gas phase. The smoke is produced by burning sawdust or woodshavings leaves (oak, beech), to which juniper berries may be added. Occasionally broom, wild thyme and fir cones are added also.
In some countries the finished products are screened for polycyclic hydrocarbon contamination, by evaluating the level of 3,4 benzo-pyrene, which should not exceed levels of 1 ppb in the Federal Republic of Germany and in Belgium. This maximum value could be overstepped whenever the combustion temperature of the sawdust exceeds 600°C and when tar or soot gets deposited on the smoked goods.

Drying, as such, is a classical process, which consists in exposing the product to air circulation, chosing such temperature and relative humidity conditions as to allow normal aging and water diffusion to take place in the product without crusting. It stands to reason that the degree of drying influences the organoleptic properties of the hams and, more specially, their texture. This is mainly the case for products from short term production periods.

The paper by VANHEMMENS-SEGERS, LENGES, DE SPIEGELEIRE:" Correlation between drying rate and organoleptic properties of "Jambon d'Ardenne" reveals the existence of an optimum degree of drying, which has been identified by the water/protein ratio, offering highest acceptability for the product for consumption.
"Coeur d'Ardenne" (cushion) portions of final weight of 3,8 to 4,5 kg, taken from a same lot of production, have been dried for different periods of time, to reach a water/protein ratio comprised between 2,2 and 2,7.
At intervals, samples were taken from the drying chamber, and stored without wrappings. These samples were presented to a trained taste-panel and to an untrained consumer jury. The general appraisal of the two panels selected the same product, wich was characterized by a water/protein ratio of 2,55. A significant preference was given to this product. This study allowed to outline a optimum zone of appraisal and consequently, could serve as an over-all significant objective quality criterion.

IV. MICROBIOLOGICAL ASPECTS.

LEISTNER (1986), showed that molds of the Aspergillus glaucus family, which grow on the surface of non-smoked bone-in hams during the aging period, do not contribute to the production of any typical flavour for hams dried in free air. Presence of xero-tolerant molds, such as A. ruber and A.repens, which grow selectively in restricted amounts of air, is charcteristic for long aging periods in the case of Spanish hams, such as the "Jamon Serrano".
The development of molds on the surface of hams is not always desired, especially for Italien, German and Belgian hams. This mold production can be monitored thanks to adequate setting of the relative humidity of the air.
Sometimes, mold development is required for the production of typical flavours in the end product; such is the case for country bacon ("Bauernspeck") from the south of Tirol (Italy) or in smoked meat "Bündnerfleisch" produced in Switzerland. This mold development takes place spontaneously thanks to the micro-organism population of the premices and, hence, a risk exists also of toxic mold proliferation. It would seem advisable thus to make use of starter cultures.

RHEINBADEN and SELPP (1986) carried out an over-all study of the microbial population from one hundred samples of hams produced in the Federal Republic of Germany. They analysed more specially the family of Micrococcaceae. Altogether 25 strains of the Micrococcaceae family have been isolated and differenciated down to the species. The number of total germs varied from below one hundred to up 10^8 germs per gram of finished product. These were mainly gram positive non-spore forming rods (mainly Lactobacillaceae) and catalase-positive cocci of the Micrococcaceae family, which prevailed qualitatively and quantitatively. Other identified groups of micro-organisms belonged to the family of Streptococcaceae, gram negative rods, aerobic sporules, and yeasts. The differenciation of the Micrococcaceae family lead to 68% strains of the Staphylococcus genus and 32% strains belonging to the Micrococcus genus.
The results of these microbiological analyses have been correlated to the humidity of the finished product, to its salt content, pH and water activity. No correlation could be establishes between qualitative and quantitative composition of the microbial population and the technological parameters.

Starting from these microbiological data one should identify those strains which act favourably on the properties of ham during its processing. Monitoring of the microbial population and the study of the biochemical aging processes would result, as for the production of sausages, in improved mastering of the process and, therefore, in the production of a food product of high quality standard.

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