1.1. DRY CURED HAM MANUFACTURING PROCESS

1.1.1. Manufacturing process

Dry-cured ham is a whole muscle product. In the production of dry cured ham and similar cured products there is a number of drawbacks that make it difficult to obtain a uniform product of consistent quality.

The technologies used for raw ham production vary widely and have developed as a result of local practices that have evolved from experience and tradition.

The most important aspects for the processing are as follows:

- Selection of raw material:

Some important parameters related to the green hams are used:

- Temperature: It is required temperatures of 1-4 ºC. Improper pre-treatment of the meat and inadequate cooling could be the origin of microbiological problems.

- pH: When the pH of the meat is higher than 6.2, then the meat becomes dark firm and dry (DFD). The measurement of pH is done in *Semimembranosus* muscle. This meat is unsuitable to produce raw ham because of its dark colour and higher water binding capacity. The bacterial growth before the processing of the meat (curing) increases (Leistner, 1985). Low pH meat (PSE - Pale Soft Exudative) may also be a problem.

- Size: The hams are classified in order to obtain more homogeneous size. Big and small hams follow simillar processes, however big ones require longer time processing.

- Fat content: Hams with low fat content are rejected because they will not give the proper texture and flavour to the final product.

- Related to the curing process: the amount of curing salts added may influence the final quality of the product and the process parameters.

- Related to the drying process: the incorrect ripening parameters (temperature and relative humidity of air) may be the responsible for the spoilage of the ham. The air flux or air velocity is important for keeping the correct ripening parameters in each part of the drying chamber as well as to get the correct mass transfer between product and air.

An example of an industrial process used in raw ham production for 6 month is the following (Arnau *et al*., 1997):

1. Selection and pre-treatment of the meat: Green hams are selected by size and at temperatures of 1-3ºC and pH of 5.6 to 6.2 in *Semimembranosus* muscle.

2. Cutting and optional removal skin: the hams are cut removing the parts that are not necessary. Sometimes part of skin is removed. The blood in the ham is also removed to prevent microbiological growth.

3. Pre-salting and salting: salt, nitrate and nitrite is applied by a dry rub procedure. After this pre-salting, the hams are covered with dry salt for one day per kg of ham depending on the size. During this period ham may lose 7% of its water content (Gou, 1998).

4. Washing and scrubbing: hams are washed in cold water to remove the solid salt on the surface.

5. Post salting period: hams are hanged at 3-5ºC in a drying room with a relative humidity between 80 and 90% for 30 days. During this period the salt reaches the inner part of the ham and assures the microbiological stabilisation of the meat. At the end of the period, hams will have lost 14% of its initial water content.

6. Drying: the temperature into the drying room is kept at 12-14ºC and 60-80% relative humidity until the fifth month. The ham will have lost 20% of its initial water content at the end of this period.

7. Maturing and ageing: The temperature is increased to 20 ºC and the relative humidity is lowered below 70% for a period of 30 days. During this period the ham must improve in taste and aroma because of the enzymatic reactions mainly. At the end of the process the ham has lost 35% of its initial weight.

All this procedure aims to get a product as homogeneous as possible. Traditional hams can have ripening periods up to 24 months, depending on their size and fat content.

The water content, NaCl content and pH are changing during the drying process, and they have different evolution, depending mainly of the position into the ham (Section 1.2). Figure 1.1.1 shows an example of these different evolutions.

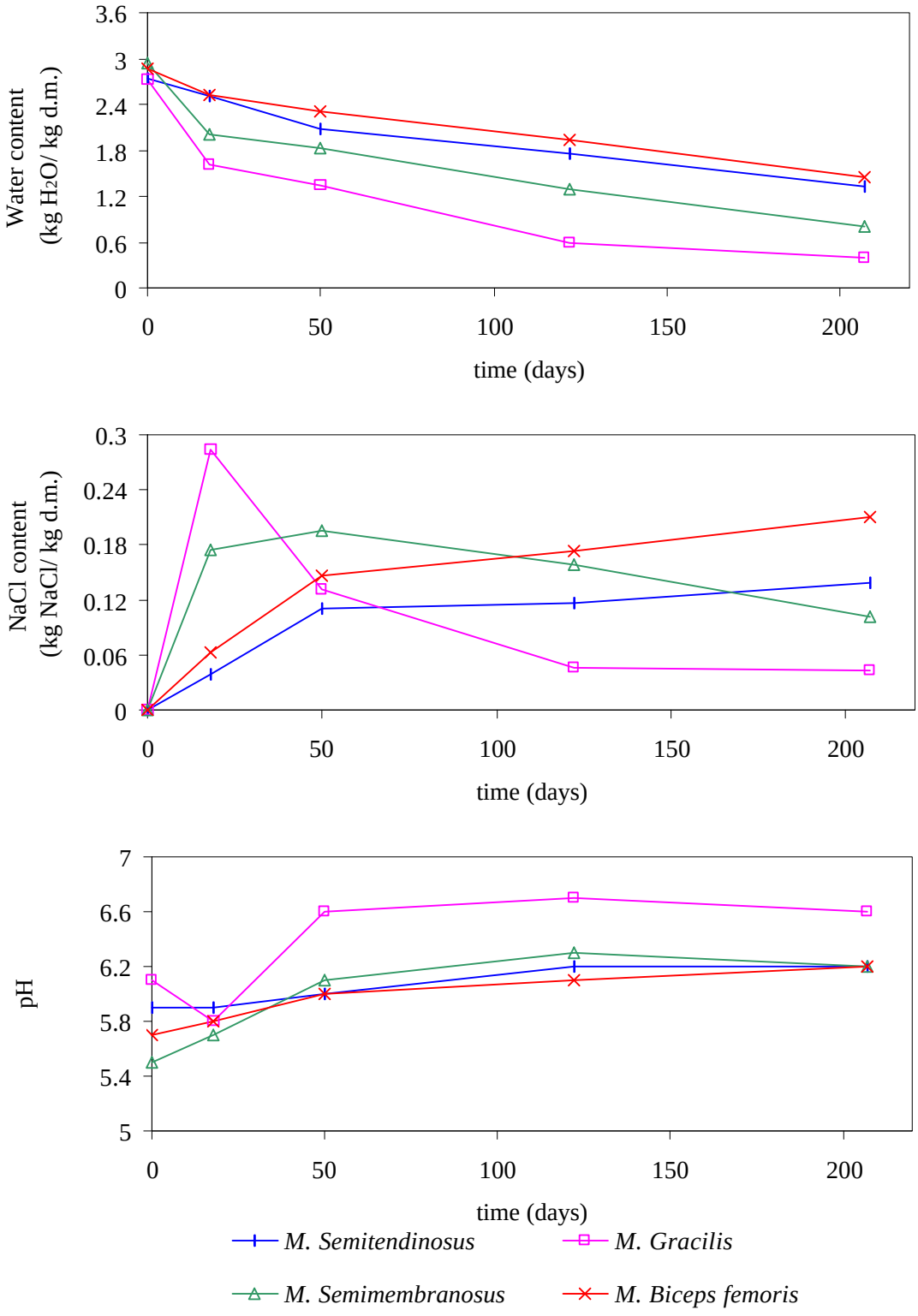

Figure 1.1.1 Evolution of water content, NaCl content and pH in different ham muscles during drying process (Arnau *et al*. 1995).

1.1.2. Drying equipment

The stage of drying and curing in the process of raw cured products needs an accurate control of temperature, relative humidity and air velocity. For this step of the process a chamber, where the hams are hung, is required (Figure 1.1.2). The temperature and relative humidity are regulated by a heat pump dehumidifier, which is an air-to-air heat pump that functions in a manner similar to a domestic refrigerator (Perera and Rahman, 1997). It consists of a condenser (hot heat exchanger), a compressor, an evaporator (cold heat exchanger) and a fan to provide air movement. The heat pump is located along with the product in an enclosed chamber that has insulated walls. Dry, heated air is supplied to the product to pick up moisture and it is recirculated. Some of this humid air passes through the evaporator of the heat pump where it condenses, giving up its latent heat of condensation, which is taken up by the refrigerant in the evaporator. This heat is used to reheat the cool dry air passing over the hot condenser of the heat pump. A schematic diagram of the operation of a typical heat pump dehumidifier is shown in Figure 1.1.2.

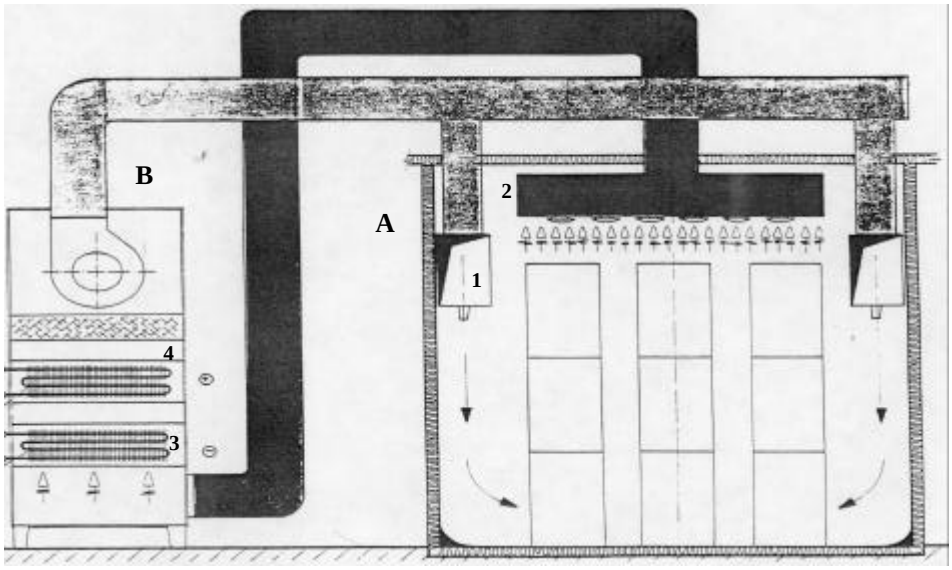

Figure 1.1.2 Drying equipment A. Drying chamber: 1. dry air pipe line; 2. humid air pipe line. B. Drying device: 3. cold heat echanger (evaporator); 4. hot heat exchanger (condenser).

In a heat pump dehumidifier dryer, the source of the heat that is absorbed at the evaporator is the humid air that is drawn from a product during the drying process. As this moist air passes through the evaporator, it is rapidly cooled to a temperature below its dew point, resulting in water condensing out. The latent heat recovered in the process is released at the condenser of the refrigeration circuit and used to reheat the air within the dryer. The system is entirely recirculatory. In practice, design modifications such as partial evaporator by-pass systems and additional heat exchangers are used to maximize efficiency (Nacenta and Cánovas, 1998). Although most of the heat pump dehumidifier dryers currently available recirculate all the air.

The air blown into the chamber during the drying process is intermitent. The air is blown when the drying equipment is working, and sometimes, it is also blown to recirculate the air into the chamber and avoid the air stratification.