# Packaging and New Processed Meat Products

**Weber, Herbert**
University of Applied Sciences
Berlin, FB V, Department of Food Technology
E-mail: Dr.Web@t-online.de

## SUMMARY

The proportion of packaged meat products has increased steadily in recent years. Optimised packaging solutions are now being developed for hygienically sensitive products such as minced meat. Robot-controlled packaging machines are now able to replace sorting and placing of sausages by hand. Economic packaging is accompanied by minimal staff contact, optimal hygiene and high flexibility. In the meat product industry clean room technology is used during slicing and packaging of cooked ham. In future, protective cultures could become significant for improving the safety and shelf-life of "sensitive" meat products. For many years the Nacka and Sous-vide process has been used to produce refrigerated foods. High pressure processing (HPP) is intended to reduce the residual micro-biological risk for consumers. There are a range of pressure treated food products already on the market including meat products. The elimination of pathogens like EHEC from dry or semi dry sausages by high pressure is a potential preservation method in the meat industry. Gamma irradiation is completely effective for food decontamination yet its consumer acceptability is low in the EU and other countries. Whenever new technologies are used, it is important not only to examine their technical applicability, but also their consumer acceptance. Examples here are the lack of acceptance of irradiated and genetically modified foods in the EU and other countries.

### Keywords

Clean room technology, high pressure, irradiation, **Listeria monocytogenes**, meat products, modified atmosphere packaging, Nacka process, packaging hygiene, packaging, protective gas packaging, robot-controlled packaging, Sous-vide process, vacuum packaging.

## PACKAGING

In vacuum packaging the air and hence the available oxygen are withdrawn by evacuation. In inert gas packaging, air is used to substitute other gases. At reduced partial oxygen pressure aerobic microorganisms (Pseudomonas, Bacillus, moulds etc.) are crowed out and micro-aerophile and anaerobic (or optionally anaerobic) microorganisms are promoted. Micro-aerophilic bacteria include lactic acid bacteria, which thus find good development conditions and can suppress undesirable competing flora. The growth of lactobacilli in products packed under vacuum and inert gas is generally undesirable. At germ counts $>10^6$/g, the products, however, can develop an acid taste (Weber, 2002).

Apart from the spores and a few vegetative germs, boiled meat products no longer contain any significant flora of their own after heating. That is why these products usually do not have a normal spoiling flora, so bacteria (surviving germs or recontamination) that would usually not be able to thrive dominate. Depending on the initial flora, very different populations can develop. There is a danger that food toxins which are normally competitively inhibited by psychrotrophic spoiling agents can reproduce if this competition flora is missing. Particularly at risk are products stored at insufficient refrigeration. If listeria enters the low-germ product, they can reproduce in the absence of the competition flora even at refrigeration temperatures.

## Optimised packaging of heated meat products

The packaging hygiene is crucial for the shelf-life of packaged boiled meat products. The determining factor for the shelf-life is not so much the residual flora present, prior to packaging, but much more the contamination flora that finds its way onto the product during slicing, portioning and packaging. For this reason the packaging hygiene deserves special attention.

When the covering is removed and the product sliced, the surface increases to such an extent that the surface area available for microorganisms becomes extremely large. During the normal slicing and packaging process, the slicer knives, the personnel, surfaces in contact with the product and germ-contaminated ambient air re-contaminate the largely germ-free product. So in practice it is the secondary contamination with microorganisms that leads to a reduction in the shelf-life of packaged products. The temperature in the packaging room should be so low that water vapour does not condense on the surface of the product, thus creating ideal conditions for microorganisms.

Shelf-life can be extended and the composition of the micro-flora favourably influenced by vacuum or protective gas packaging. Lack of oxygen combined with a high nitrite and salt content inhibits above all the gram-negative spoiling flora (Pseudomonades, Enterobacteriacea).

Lactobacilli are best adapted to the microclimate in vacuum packs. These ubiquitous, facultatively anaerobic lactic acid bacteria are an unavoidable component of all vacuum-packed meat products and usually determine the limit of the shelf-life due to souring. They can reproduce up to final germ counts of $10^8$ to $10^9$ cfu/g in a relatively broad temperature range. At temperatures of between 4 and 6°C these germ counts are achieved in about 17 days, and at 20°C in just 3 days. That is why boiled cured goods should be stored at temperatures as low as possible, certainly below 4°C. Each degree colder down by 1°C means an extension of the shelf-life. **Brochothrix thermosphacta** can produce a cheesy, biting odour even at low germ counts and after a relatively short storage period (Weber, 2002).

## Packaging material

Packaging materials are of decisive importance for food quality and shelf life. Many packaging solutions have been developed to prevent rapid deterioration caused by oxygen, light and bacteria or by substances of foreign odour and taste that come into contact with the product. Packaging materials used for modified atmosphere packaging (MAP) or vacuum packaged foods should have high barrier characteristics. Polymers used include polyester, polypropylene, polystyrene, polyvinyl chloride, nylon, ethylene vinyl acetate and ethylene vinyl alcohol polymers. These are usually laminated or co-extruded with polyethylene, which comes in direct contact with the food and is the heat-sealing medium. One development is the use of re-closable packages, e.g. for sliced ham. The primary function of various basic materials is listed in table 1. Comparison of shelf-life for products in air and MAP respectively is listed in table 2.

Different plastic materials can therefore be chosen and combined to achieve:

- mechanical strength
- water vapour barriers to prevent weight loss and dehydration
- gas barrier
- gas permeability
- anti-fogging properties (the inside of the material should have a surface that does not allow the formation of water droplets, which reduce transparency)
- sealing properties, i.e. capable of sealing into a tight package while retaining material properties even along the welded seam.

## Clean room technology

Postprocess recontamination from the environment or personnel of appropriately processed product can lead to spoilage or food-borne infection or intoxication. One way of preventing contamination is slicing and packaging in "clean rooms". Here, clean room technology is used to screen off the area at risk. Constant checking of temperature, air humidity, air velocity as well as chemical and mechanical barriers (disinfection, protective clothing, goods and personnel "sluice gates" and hygienic training of personnel) can keep the critical slicing and packaging area as germ-free as possible. Clean room technology is currently used in Germany in boiled ham production (cleanliness category 100, air speed 0.45m/s). The users report positive experience with this method. The main aim of achieving microbiologically stable products has been attained. Application of clean room technology should be done in conjunction with full compliance to GMP (Sagner, 2001, Weber, 1996). Additionally, these manufacturers were able to reduce the rate of returned products. Today local clean room systems are also available that can be used as modular systems. They are screened off using transparent plastic curtains (Metz, 2001).

## Protective cultures

In future, protective cultures with the capability of producing bacteriocins could become significant for improving the safety and shelf-life of "sensitive" meat products. Bacteriocin forming lactic acid bacteria can prevent the growth of **Listeria monocytogenes**, if added at sufficiently high germ counts in the form of protective cultures during slicing. In practice, the slicer could for instance be retrofitted with an automatic spraying device for protective cultures (Kröckel, 1999, Weber, 1992). The search for further natural strains – possibly better than those now known – remains interesting.

The major hazards to the health of the consumer of fermented sausages are salmonellae and enterohaemorrhagic **Escherichia coli**. Probiotic and bioprotective **Lactobacillus rhamnosus** strains were able to produce technologically high quality dry sausage without increasing the risk from **Listeria monocytogenes** or **Escherichia coli** O157:H7 (Erkkila, 2001).

## Nacka process, Sous –Vide process

The brand shares of refrigerated ready dishes, both with and without meat, have increased in recent years. One of the crucial factors for keeping qualities is the pH-value. Storage times of up to 6 weeks are possible under refrigerating temperatures. Observance of the cooling chain is particularly important for these products, since killing of Clostridium botulinum spores is not ensured. For many years the Nacka process has been used to produce refrigerated

Table 1 Primary function of various basic materials

| Abbreviation | Basic materials | Primary function |
|---|---|---|
| Al | Aluminium | high barrier |
| APET | amourphous polyester | rigidity, gas barrier |
| CPET | cristallized polyethylene terephtalat | rigidity, high temperature resistance, gas barrier |
| EVA | ethylene-vinyl acetate | sealing layers |
| EVOH | ethylene-vinyl alcohol | gas barrier |
| HDPE | high density polyethylene | moisture barrier, rigidity, microwave capability, sealing layers |
| LDPE | low density polyethylene | sealing layers |
| OPA | oriented polyamide | gas barrier |
| OPET | oriented polyethylene-terephthalate | high temperature resistance, flexibility, puncture resistance |
| OPP | oriented polypropylene | moisture barrier, flexibility, puncture resistance |
| PA | polyamide (nylon) | high temperature resistance, flexibility, toughness, forming strength some gas barrier |
| PAN | acrylnitrile | gas barrier |
| PET | polyethylene terephthalate (polyester) | rigidity, some gas barrier |
| PP | polypropylene | moisture barrier, rigidity – microwave capability |
| PS | polystyrene | rigidity |
| PVC | polyvinyl chloride | rigidity, gas barrier |
| PVdC | polyvinylidene chloride | moisture, gas barrier |

Table 2 Comparison of shelf-life for products in air and MAP respectively

| Food | Typical shelf-life in air | Typical shelf-life with MAP |
|---|---|---|
| Row red meat | 2-4 days | 5-8 days |
| Raw light poultry | 4-7 days | 16-21 days |
| Raw dark poultry | 3-5 days | 7-14 days |
| Sausages | 2-4 days | 2-5 weeks |
| Sliced cooked meat | 2-4 days | 2-5 weeks |
| Fresh pasta | 1-2 weeks | 3-4 weeks |
| Pizza | 7-10 days | 2-4 weeks |
| Sandwiches | 2-3 days | 7-10 days |
| Ready meals | 2-5 days | 7-20 days |

foods. Here the meal is cooked with a core temperature of at least 80°C, filled hot into plastic tubes, evacuated in a water bath (core temperature at least 80°C, for 3 to 10 minutes). More recent processes include the Sous-Vide and the Nouvelle-Cart system. During sous vide cooking, raw materials are vacuum packages and subsequently cooked under controlled conditions as regards temperature and time. The temperature is usually below 100°C (Creed, 1995, De Baerdmaker et al. 1995, Weber, 2002).

## Robot-controlled packaging machines

Robot-controlled packaging machines are now able to replace sorting and placing of sausages by hand. Economic packaging is accompanied by minimal staff contact, optimal hygiene and high flexibility (Weber, 2002).

## High pressure processing (HPP)

As a consequence of market globalisation, the production of meat products is at a stage of innovative dynamics. Since the early eighties, high pressure processing is being thoroughly investigated as a processing method to replace, partially or totally, heat treatment of foods. Pressurization offers great possibilities for microbial inactivation and, therefore, enhances the safety and extends the shelf-life of most food products. Furthermore, pressure treatment does not considerably affect either the nutrient

content or some sensory properties, which allows fresh-like products to be obtained. Low pH or high water activity values generally reduce the resistance of microorganisms (Cheftel, 1995; Mackey et al., 1995; Roberts and Hoover, 1996; Cheftel and Culioli, 1997, Heinz and Knorr, 2002, Heinz, 2003). Ludwig et al. (1992) also stated that water in substrate is necessary for a suitable pressure-induced bacterial inactivation.

Combined treatments, physical (e.g., high pressure or heat) and/or chemical ones (e.g. acidifants, nisin or other preservatives), can increase lethality of micro-organisms (Patterson and Kilpatrick, 1998; Yuste et al., 1998 and 2000). Conditions applied in such combinations are less severe than those used for either treatment alone. Thus, minimally-processed foods with optimal microbiological quality can be manufactured.

High pressure treatment of foods was originally developed in Japan. In the meantime, research into the process has been conducted in different countries. High pressure processing uses an isostatic pressure at room temperature and between 100-600 MPa. The germ-reducing effect of pressure treatment declines in line with the water content in the product to be treated. Furthermore, bacteria spores are relatively insensitive to pressure (Inactivation see Figure 1).

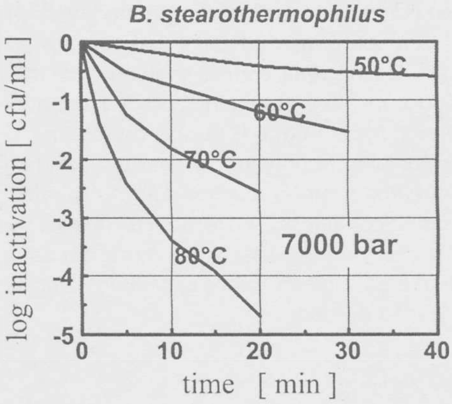


Fig.1. Inactivation of **B. stearothermophilus** Spores at 7000 bar. Ananta et al., 2001.

The rate and the inactivation kinetics of the microorganisms under high pressure processing depends on several parameters like: the type of microorganisms, the level of pressure, the time of treatment, the temperature, pH, the water activity and the food composition. In general, the inactivation increases with pressure.

This process is intended to reduce the residual microbiological risk for consumers. There are a range of pressure treated food products already on the market. Concerning meat products, so far there are two Spanish meat companies using high pressure processing. In the USA, several meat companies have made this method available. In Germany the suitability of pressure treatment was tested for semi dry sausages and scaled sausage. A new plant is presently being built in Italy.

## HPP and semi dry sausages

The elimination of pathogens like EHEC from dry or semi dry sausages by high pressure is a potential preservation method in the meat industry. In Figure 2, the inactivation of **Escherichia coli** in semi dry sausages ("Zwiebelmettwurst") is shown (Heinz and Knorr 2002). High pressure treatment can achieve the required 5 log reduction even in the case of EHEC 103:H2. It is known that fermentative organisms like Lactobacillus are comparably resistant against pressure (Smelt et al., 1994, Smelt et al., 1998)). In this study the reduction was found to be in the range of only one log cycle. It was surprising that in spite of this poor inactivation the fermentative activity was completely inhibited.

## HPP and marinated beef loin

Marinated beef loin, which is a raw uncooked meat product with high water activity, al low level of salt and without nitrite, harbours a mixed flora of spoilage and pathogenic microorganisms. Sliced, skin vacuum-packaged marinated beef loin was treated by high pressure at 600 MPa for 6 min at 31°C. Aerobic, psychrophylic and lactic acid bacteria counts showed at least a 4 $\log_{10}$ cycle reduction after treatment and remained below the detection limit ($<10^2$ cfu $g^{-1}$) during the chilling storage of 120 days, helping to prevent the sour taste and off-flavours while untreated samples reached $10^8$ cfu $g^{-1}$ after 30 days under same conditions. **Enterobacteriaceae** were kept below 10 cfu/g during the whole storage period in high pressure treated samples, while untreated samples reached $10^5$ cfu/g after 30 days.

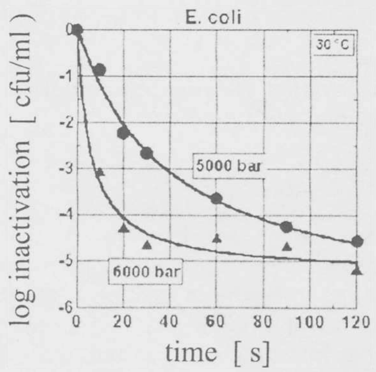


Fig.2. Inactivation of **E. coli** in „Zwiebelmettwurst". Process temperature 30°C. Heinz und Knorr, 2002.

High pressure technology is a powerful tool to control risks associated with **Salmonella** spp. and **Listeria monocytogenes** in raw or marinated meats (Table 3). Most of the untreated samples showed presence in 25 g from one or both of the pathogens, whereas all pressurized samples showed absence in 25 g (Garriga et al. 2002). The high pressure treatment could extend the shelf life of the marinated beef loin by controlling the growth of both spoilage and pathogenic bacteria.

Table 3 Investigations of **Listeria monocytogenes** and **Salmonella spp.** in HPP treated marinated beef loin (600 MPa, 31°C, 6 min) compared to untreated (NT) during storage of samples at 4°C.

| | **L. monocytogenes / 25 g** | | **Salmonella spp. / 25 g** | |
|---|---|---|---|---|
| **Days** | **NT** | **HPP** | **NT** | **HPP** |
| 0 | 2/3[a] | 0/3 | 3/3 | 0/3 |
| 30 | 2/3 | 0/3 | 2/3 | 0/3 |
| 60 | 3/3 | 0/3 | 2/3 | 0/3 |
| 90 | 1/3 | 0/3 | 0/3 | 0/3 |
| 120 | 1/3 | 0/3 | 2/3 | 0/3 |

[a]number of positive samples / investigated samples (Garriga et al. 2002)

## HPP and vacuum-packed cooked ham

Sliced vacuum-packed cooked ham is a highly perishable product due to its composition, pH and water activity and the lack of a background flora competing with spoilage or pathogenic microorganisms. The physico-chemical and microbiological characteristics of cooked ham do not present any hurdles to bacterial growth. Its shelf life depends on the hygienic characteristics of the final product after post-processing as well as to the packaging methods where cross-contamination is more likely to occur. The techniques used to reduce cross-contamination include good manufacturing practices, post-pasteurisation after packaging or even the use of clean room at the slicing and packing stage.

Sliced, skin vacuum-packed cooked ham treated by high pressure processing at 600 MPa for 6 min showed a significant delay in the growth of spoilage associated micro-organisms compared to untreated samples, thus contributing to the maintenance of organoleptic freshness for at least 60 days after treatment (Garriga et al. 2002). The high pressure process helped to prevent any sour taste, off-flavours, ropiness and colour changes. Thus, high pressure processing of cooked ham under the conditions mentioned above was an effective process to avoid the growth of yeasts and **Enterobacteriaceae**, with the potential to produce off-flavours and accordingly, it contributed to the shelf life extension in this highly perishable meat product.

## Irradiation

In the last century, several alternative complementary preservation technologies to classical processing were developed. A good example is gamma irradiation, which is completely effective for food decontamination, yet its consumer acceptability is low in the EU and other countries.

In 1981, the FAO/IAEA/WHO Joint Expert Committee on Food Irradiation stated that "irradiation of food up to an overall average dose of 10 kGy presents no toxicological hazard and introduces no special nutritional or microbiological changes" (World Health Organisation, 1981). More recently the WHO convened a Study Group to review all data on products irradiated above the 10 kGy ceiling and found the products to be safe and wholesome. As a result, WHO has recommended removing any dosage limit so that it would be possible to achieve commercial sterility, as in canning (Anon., 1999).

In 1997, because of the **E. coli** 0157:H7 problems in the USA the use of food irradiation brought the debate into the public domain. Changes were made in the legislation to permit the irradiation of red meat. In 1997 the Food and Drug Administration (FDA) approved the irradiation of red meat and by February 2000, the Food Safety and Inspection Service within the USDA permitted the use of ionizing radiation for refrigerated or frozen uncooked meat to reduce the levels of food-borne pathogens. There are now at least ten categories of food products approved for irradiation in the USA, including uncooked poultry, beef, lamb, goat and pork.

In the EU, the situation is far different from that in the USA with legislation only permitting the irradiation of dried aromatic herbs, spices and vegetable seasonings to an overall maximum dose of 10 kGy. Some individual countries have additional irradiation authorizations such as the UK, where a range of fruit, vegetables, cereals, bulbs and tubers, spices and condiments, fish, shellfish and poultry have been approved for irradiation to different specified doses.

The majority of European consumers are not strongly in favour of the use of irradiation. Whenever new technologies are used it is important not only to examine their technical applicability, but also consumer acceptance. Examples for this are the lack of acceptance of irradiated and genetically modified foods. The consumer, being the last link in the chain, has demonstrated in the case of gen-food that he is also the strongest link in the chain. Consumer decisions to buy or refuse are critical for the market success of a product (Weber, 2002).

## "Transparent Production"

Consumer confidence in safe and healthy foods of animal origin has been shaken by recent crisis. All incidents have been caused at the producer stage, in other words in the run-up to meat product production. In future, information technology will become even more important. The path taken by the meat from animal rearing right through to the sausage product must be disclosed. The term applied here is "transparent production". Traceability of the final production can only be achieved, if all participants in the production process are networked in a data chain. The product flow must be accompanied by a dataflow. Traceability comprises inter-organisational information management accompanying any process. There are now many traceability systems available for meat and meat products, for example: IFS – International Food Standard, BRC – Global Standard Food (British Retail Consortium), QS – Qualität und Sicherheit GmbH (Weber, 2002).

## REFERENCES

Ananta A., V. Heinz, O. Schlüter, D. Knorr (2001). Kinetic studies on high pressure inactivation of **Bacillus stearothermophilus** spores suspended in food matrices. Innovative Food Science and Emerging Technologies 2, 261-272.

Anonimous (1999): High-dose irradiation. Wholesomeness of food irradiated with doses above 10 kGy. Report of a Joint FAO/IAEA/WHO Study Group. Geneva: World Health Organisation (1999).

Cheftel, J.C. and J. Culioli. Effects of high pressure on meat: a review. Meat Sci. 46, 211-236 (1997).

Cheftel, J.C.: Review: High-pressure, microbial inactivation and food preservation. Food Sci. Technol. Int. 1, 75-90 (1995).

Creed, P.G. (1995). The sensory and nutritional quality of "sous vide" foods. Food Control 6, 45-52.

Erkkila, Susanna (2001). Bioprotective and probiotic meat starter cultures for fermentation of dry sausages. Academic Dissertation, University of Helsinki, Department of Food Technology.

De Baerdmaker, J., Nicolai, B.M. (1995). Equipment consideration for sous-vide cooking. Food Control 4, 229-236.

Garriga, M.; M.T. Aymerich and M. Hugas. Effect of high pressure processing on the microbiology of skin-vacuum packed sliced meat products: cooked pork ham, dry cured pork ham and marinated beef loin. Profit Final Project Report. FIT060000200066 (2002).

Heinz, V., Knorr, D. (2002). Verringerung pathogener Mikroorganismen durch Hochdruck und gepulste elektrische Felder: theoretische und praktische Betrachtungen. Ernährung/Nutrition 26/3, 102-106.

Heinz, V. (2003). Hochdruckbehandlung von Lebensmitteln. Fleischwirtschaft 4/2003, 106-110.

Kröckel, L. (1999). Natürliche Barrieren für die Biokonservierung. Fleischwirtschaft 1/99, 67.

Libbey Eurotext/Les Editions INSERM, vol 224, Montrouge, 25-32 (1992).

Ludwig, H.; C. Bieler; K. Hallbauer and W. Scigalla. Inactivation of microorganisms by hydrostatic pressure. In high pressure and biotechnology. Balny, C., R. Hayashi, K. Heremans and P. Masson, John

Mackey, B. M.; K Forestiere and N. Isaacs (1995). Factors affecting the resistance of **Listeria monocytogenes** to high hydrostatic pressure. Food Biotechnology 9, 1-11.

Metz, M. (2001). Einsatz von lokalen Reinraumzonen in hygienisch sensiblen Prozessen der Lebensmittelherstellung. Vortrag TFH Berlin.

Patterson, M. F. and D. J. Kilpatrick (1988). The combined effect of high hydrostatic pressure and mild heat on inactivation of pathogens in milk and poultry. J. Food Protect. 61, 432-436.

Roberts, C.M. and D.G. Hoover (1996): Sensitivity of **Bacillus coagulans** spores to combinations of high hydrostatic pressure, heat, acidity and nisin. J. Appl. Bacteriol. 81, 363-368.

Sagner, H.(2001). Mikrobiologische und physikalische Anforderungen der Reinräume an Lebensmittelbetriebe und im pharmazeutischen Bereich. Diplomarbeit TFH Berlin.

Smelt, J.P.P.M.; N. Dutreux; J.C. Hellemons (1998). Inactivation kinetics of microorganisms by high pressure. In (ed. N.S. Isaacs) High pressure food science, bioscience and chemistry, p. 403-407. The Royal Society of Chemistry, Cambridge.

Smelt, J.P.P.M.; A.G.F. Rijke; A. Hayhurst (1994). Possible mechanisms of high pressure inactivation of microorganisms. High Press. Res. 12: 199-203.

Weber, H. (Hrsg.). Mikrobiologie der Lebensmittel. Fleisch und Fleischerzeugnisse. Behr's Verlag, Hamburg (1996).

Weber, H. (1996). Mikrobiologie der Lebensmittel. Grundlagen. Behr's Verlag, Hamburg.

Weber, H. (1992). Die biologische Konservierung von Lebensmitteln. Spezielle Anwendungen am Beispiel Rohwurst. SozEp Heft 4/1992 (Hrsg. Dehne, L., K. W. Bögl, Bundesgesundheitsamt Berlin.

Weber, H. (2002). Kochpökelwaren – Mikrobiologische Aspekte und deren Auswirkungen auf Haltbarkeit und Sensorik. Fleischwirtschaft 4/02, 55 – 58.

Weber, H.(2002). Technologie – Mehr Sicherheit und Stabilität. Fleischwirtschaft 5/02, 57 – 62.

World Health Organization )1981). Wholesomeness of irradiated food. Report of a joint FAO/IAEA/WHO Expert Committee in food irradiation. WHO Technical Report Series 659.

Yuste, J.; M. Mor-Mur; M. Capellas; B. Guamis and R. Pla (1998). Microbiological quality of mechanically recovered poultry meat treated with high hydrostatic pressure and nisin. Food Microbiol. 15, 407-414.

Yuste, J.; R. Pla; M. Capellas; E. Ponce and M. Mor-Mur (2000). High-pressure processing applied to cooked sausages: bacterial populations during chilled storage. J. Food Protect. 63, 1093-1099.