DRY-CURED AND FERMENTED MEAT PRODUCTS

INTRODUCTION

High Pressure Processing (HPP) is a non-thermal food processing technology used to increase safety and shelf-life of dry-cured and dry-fermented meat products; either they are sliced or whole pieces, preserving homemade taste. On this sector, the pressure range used it is between 500 MPa (72,500 psi) and 600 MPa (87,000 psi) applied at refrigerated temperature. HPP is a post-packaging preservation technology, thus recontamination after processing is avoided.

Regarding to physicochemical effect on food, the HPP technology is softer than a thermal treatment: it does not break or create covalent bonds, and does not create new compounds by molecule degradation, such as in a conventional thermal process. However, HPP is able to break, or create, weak bonds (hydrophobic and electrostatic interactions), only present on macromolecules such as proteins and polysaccharides (Cheftel, 1992). It allows microorganisms' inactivation without modifying the food nutritional and sensory quality. There are three main reasons that make the HPP technology beneficial for dry-cured and fermented meat products:

- Inactivating pathogens such as *Listeria monocytogenes, Salmonella*, allowing export to the most demanding countries.
- Increasing shelf-life, inactivating spoilage microorganisms, such as bacteria, yeasts and molds, allowing, in some cases, shelf stable storage.
- Keeping raw and dry-cured meat sensory and nutritional quality without heat treatment.
- Possibility of manufacturing meat products with preservative- and salt-reduced formulas.

FOOD SAFETY AND MICROBIAL SHELF-LIFE

Dry-cured and dry-fermented meat products are convenient and highly appreciated by consumers. However, the manufacture of this kind of food products increases the risk of microbial contamination, mainly during drying, slicing and packaging. HPP has demonstrated to be a suitable technology for controlling the spoilage microorganisms as well as pathogenic ones in this type of meat products.

Shelf-life increase

Tanzi *et al.* (2004) pressurized *Prosciutto di Parma* (Parma ham, 14 months of ripening, a_w 0.920) at 600 MPa (87,000 psi). Aerobic microbiota was immediately inactivated after HPP. Inactivation levels depended on holding time, reaching 4.5 log inactivation after 9 min at 600 MPa/87,000 psi (**Figure 1**).

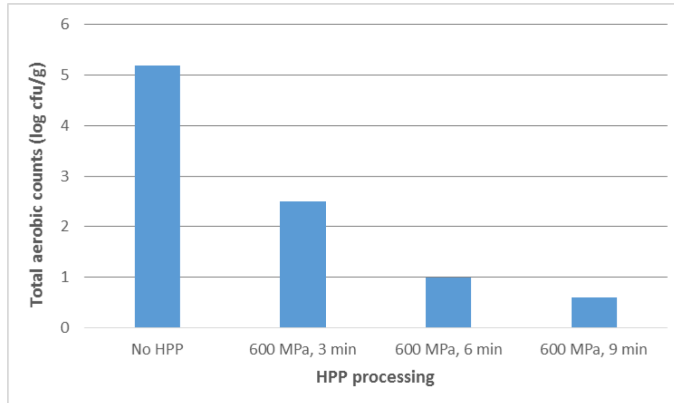

Figure 1. Immediate inactivation of aerobic bacteria after HPP in *Prosciutto di Parma* (Tanzi *et al.*, 2004).

In addition to an immediate inactivation of spoilage bacteria, HPP technology is able to delay the growth of microorganisms during storage. After 600 MPa (87,000 psi) for 6 min, counts of aerobic total, psychrotrophic and lactic acid bacteria (LAB) in dry-cured ham (pH 5.81 aw 0.890) were below 3 log cfu/g, during 120 days at 4 ºC/39 ºF (**Figure 2**, Garriga *et al.* 2004). The same authors did not detected yeast after HPP processing.

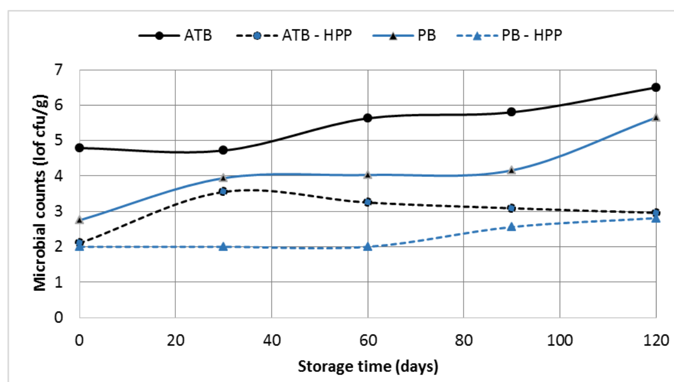

Figure 2. Evolution of microbiota (aerobic total bacteria, ATB; psychrotrophic bacteria, PB) on HPP dry-cured ham (600 MPa, 6 min) (Garriga *et al.*, 2004)

Rubio *et al.* (2007a) found microbial counts below 3 log/g in *Cecina de León* (pH 5.85, a_w 0.90) a typical Spanish dry-cured beef product. HPP at 500 MPa (72,500 psi) for 5 min avoided the growth of *Enterobacteriaceae*, *Enterococci, Pseudomonas* spp., and delay the growth of LAB, *Micrococcaceae* and yeast and molds during 210 days at 6 ºC (43 ºF).

Inactivation of pathogens

The presence of foodborne pathogens in dry-cured and fermented meats, as *ready-to-eat* (RTE) products, is being a concern for food safety authorities. HPP is a suitable technology for controlling them in this kind of products, reducing the risk of a foodborne illness.

<u>*Listeria monocytogenes*</u>

HPP at 600 MPa (87,000 psi) for 9 min totally inactivated (4.65 log-inactivation) 49 out of 50 inoculated *L. monocytogenes Prosciutto di Parma* (14 months of ripening, a_w 0.920) packages (Tanzi et al. 2004). Shorter holding times (3 and 6 min) led to lower inactivation levels, but always higher than 3 log cycles.

Bover-Cid *et al.,* (2011) developed and validated a model of the inactivation of *Listeria monocytogenes* in Spanish dry-cured ham (a_w 0.880; pH 5.84) as a function of pressure and time. Six hundred megapascals (87,000 psi) for 10 min of holding time were necessary to reach 3 log-inactivation of pressure-resistant *L. monocytogenes* strain (**Figure 3**). This inactivation level is relevant for fulfilling the requirements of USDA and Health Canada about controlling *L. monocytogenes* in RTE food products.

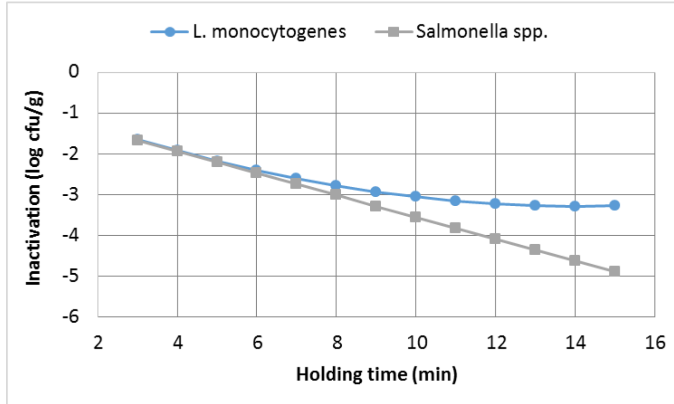

Figure 3. Inactivation of *L. monocytogenes* and *Salmonella* spp. in dry-cured ham at 600 MPa and different holding times (Bover-Cid *et al.*, 2011 and 2012).

Regarding dry-fermented meats, HPP demonstrated to be a suitable method for inactivating *L. monocytogenes* in *Genoa salami* (pH 4.60 a_w 0.94) according to Porto-Fett *et al.* (2010). HPP salami (600 MPa/87,000 for 5 min) inactivate around 5 log cycles of the pathogen, which was not able to recover during storage (28 days at 4 ºC/39 ºF).

<u>*Salmonella* spp.</u>

The effect of HPP on *Salmonella enteritidis* in dry-cured ham (pH 5.80, a_w 0.900) was evaluated by De Alba et al. (2012). Immediate inactivation of a three strains cocktail depended on HPP conditions, reaching 2.5 and 4.3 log-inactivation at 500 MPa (72,500 psi) and 600 MPa (87,000 psi) for 5 min, respectively (**Figure 4**). The pathogens was not able to recover during the storage (60 days, 8ºC/46 ºF), and at the most intensive conditions, *Salmonella* counts was below detection level.

Modelling the effect of HPP parameters (pressure, time) on the inactivation of *Salmonella* spp. showed that the increase of pressure as well as holding time led to significant enhancement of lethal effect of HPP on a pressure-resistant strain of this pathogen (**Figure 3,** Bover-Cid *et al*., 2012).

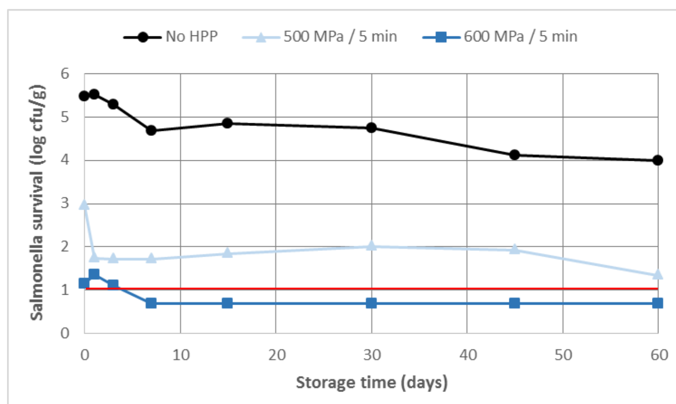

Figure 4. Survival of three strains cocktail of *Salmonella* spp. in HPP dry-cured ham during 60 days of cold storage (8 ºC). (De Alba *et al.*, 2012). Detection limit (red line).

HPP technology can be used before drying stage as an additional hurdle to control this pathogen during ripening, an important step of the manufacture of dry fermented meats. Pilot plant tests has showed good results in order to inactivate *Salmonella* in *Genoa salami* processed at 600 MPa (87,000 psi) for 5 min were reduced by up to by an additional 1.9 to 2.4 log cfu/g after ripening for 28 days compared to no HPP salami, reaching a cumulative inactivation above 6 log cycles after whole manufacture processing (Porto-Fett *et al.,* 2010). *Salmonella* in *Chorizo* (pH 5.7 a_w 0.83) and *Fuet* (pH 5.8 a_w 0.86), traditional Spanish dry-fermented sausages were controlled by HPP (300 MPa/ 43,500 psi for 10 min) during ripening at 12 ºC (54 ºF) and 80% relative humidity during 28 days (Marcos *et al*., 2005).

Escherichia coli O157:H7

HPP processing at 400 MPa (58,015 psi) and 500 MPa (72,500 psi) for 10 min was able to inactivate significantly inoculated *E. coli* O157:H7 in dry-cured ham (pH 5.68 a_w 0.88; De Alba *et al*., 2013). Although immediate inactivation is low (around 1 log cycle), inactivation levels increased during storage at abuse temperature (8 ºC/46 ºF), reaching around 4 log- inactivation after 60 days (**Figure 5**).

Challenges tests done in Norwegian (Omer *et al.*, 2010) and beef and Hungarian salami (Gill and Ramaswamy, 2008) and *Genoa salami* (Porto-Fett *et al.*, 2010) showed a maximum 4 - 5 log inactivation of verotoxigenic *E. coli* by HPP processing at 600 MPa (87,000 psi) with holding times of 3 -9 min.

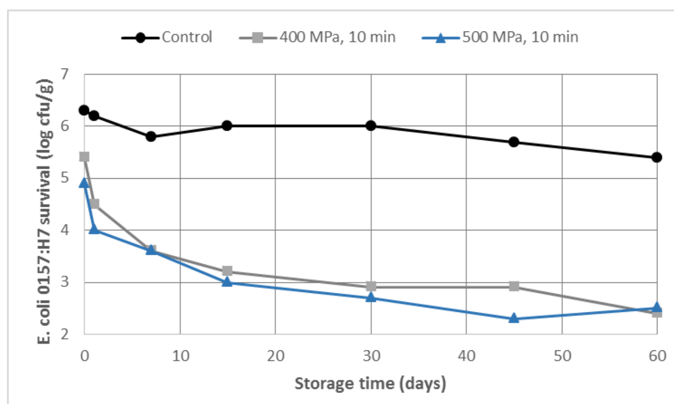

Figure 5. Evolution of *E. coli* O157:H7 at two HPP conditions in dry-cured ham stored at abuse temperature (8 ºC) during 60 days (De Alba *et al*., 2013).

Other pathogens

Two pathogenic bacteria, *Enterococcus faecalis* and *Serratia liquefaciens,* presented different resistance to HPP in dry-cured ham. High pressure at 600 MPa (87,000 psi) for 9 min reached 2.3 log-inactivation of *E. faecalis* (Belleti *et al.,* 2013a). For the same HPP conditions, around 6 log inactivation of *S. liquefaciens* was achieved (Belleti *et al*., 2013b).

Inactivation of *Trichinella spiralis*, a pork-borne nematode parasite, in *Genoa salami* by HPP technology was assessed by Port-Fett *et al*. (2010). Different HPP processing conditions of pressure (483 – 600 MPa/70,000 - 87,000 psi, 0.5 to 5 min) immediate inactivated *T. spiralis* larvae (3.4 log larvae/g) in this dry-fermented sausage.

Aspects to consider

In general, microbial inactivation by HPP technology depend on the pressure level and holding time as well as the physico-chemical characteristics such as water activity (a_w) or pH, of the pressurized food product.

As a 'rule of thumb', the lower pH the product has, the more effective microbial inactivation by HPP is reached. This is relevant in fermented meat products. On the other hand, aw of the product plays an important quality trait due to its synergetic/antagonist role. HPP technology is more effective in high-a_w products because water into the food acts as a pressure fluid transmission into cells, leading to death of microorganism. In low-a_w foods such as dry-cured or fermented meats, HPP is able to reach considerable inactivation levels. Although this preservation method achieve limited immediate inactivation levels, HPP injured survival microorganisms which are not able to recover or even die during storage because is defavorable conditions (high salt content, low water content, presence of bacteriocins and other preservatives) for cell repairing (**Figure 4** and **5**).

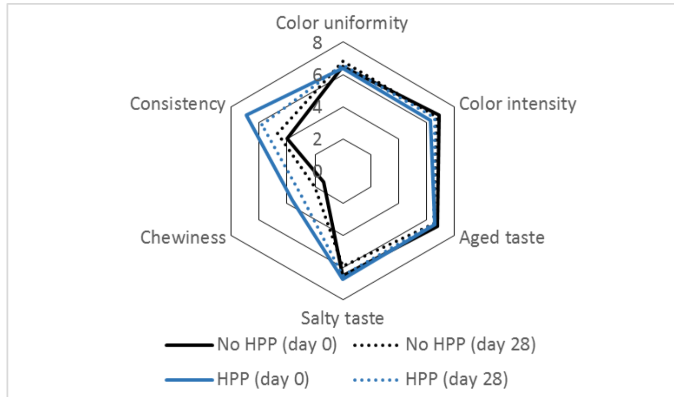

Figure 6. Sensory evaluation of HPP *Prosciutto di Parma* (600 MPa, 9 min) compared to non-processed ham at day 0 and 28 of storage at 4 ºC (Tanzi *et al*., 2004).

SENSORY QUALITY

Color and appearance

HPP (600 MPa/87,000 psi for 9 min) did not induce change in color and appearance of 18 months-ripened *Prosciutto di Parma* (Tanzi et al., 2004). Color uniformity and intensity of HPP ham was similar to non-processed *prosciutto* at day 0 and after 28 days at refrigeration when it was evaluated by a trained panel (**Figure 6**).

Pressure level determined changes in color in sliced dry-cured ham, when color was assessed by colorimetry according to de Alba *et al*., 2012. Color differences (ΔE) were detected in HPP sliced dry-cured ham 24h after HPP processing (**Figure 7**).

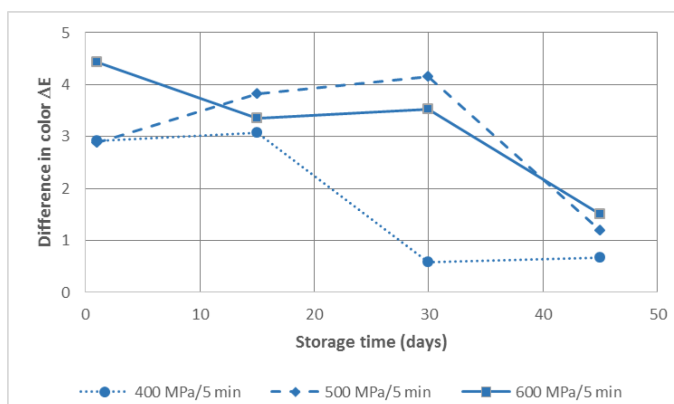

Figure 7. Differences in color (ΔE) of HPP sliced cured-ham at 400, 500 and 600 MPa for 5 min compared to non-processed ham (ΔE=0) during cold storage at 8 ºC (De Alba *et al.,* 2012).

The differences in color were higher at 600 MPa (87,000 psi). As storage time (at 8ºC/46ºF) goes by, the differences in color got closer to zero, meaning no differences compared to non-HPP-processed ham. De Alba *et al.* (2012) stated that the impact of HPP on dry-cured meat color was lower than the changes produced during storage period in agreement with Campus *et al.,* (2008) and Cava *et al.,* (2009). Sensory evaluation by trained panelists showed slight differences in color and appearance of dry-cured ham processed at 600 MPa (87,000 psi) for 5 min (**Figure 8**, Fuentes *et al*., 2010).

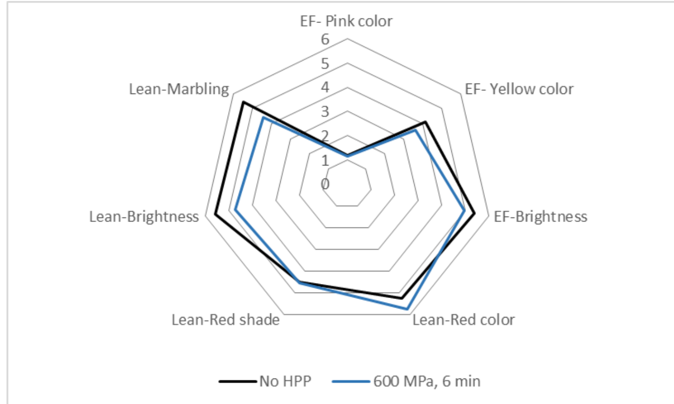

Figure 8. Color and appearance of external fat (EF) and lean in HPP dry-cured ham at 600 MPa for 6 min after 30 days at cold storage (8 ºC) compared to non-processed ham evaluated by sensory analysis (Fuentes *et al*., 2010).

Texture

HPP (600 MPa/87,000 psi for 9 min) *Prosciutto di Parma* presented slight but no significant differences in chewiness and consistency compared to non-processed ham (**Figure6**; Tanzi et al., 2004). In a similar way to color, the changes in texture of dry-cured ham induced by HPP were noticeable at the early stages of cold storage (De Alba *et al*., 2012). During the cold storage (8 ºC/46 ºF), the differences in texture were minimizing (**Figure 9**). The researchers did not found differences in hardness of HPP dry-cured ham.

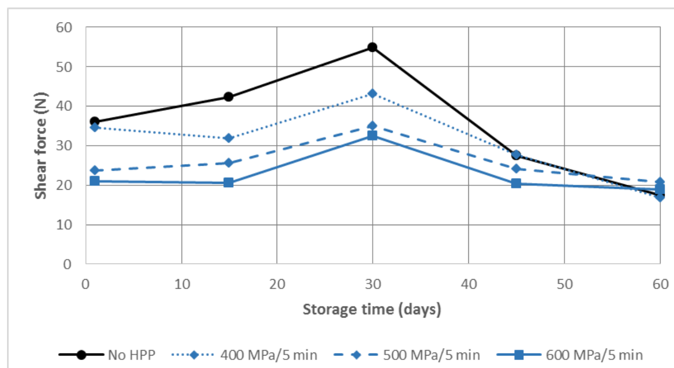

Figure 9. Shear force of HPP dry-cured ham at 400, 500 and 600 MPa for 5 min compared to non-processed ham during cold storage at 8 ºC (de Alba *et al*., 2012).

Aroma

No changes in volatile compounds of *Serrano* ham, and in two fermented meats *Espetec* and *Salchichón* (Rivas-Cañedo *et al.,* 2009a, 2009b and 2012) by HPP (400 MPa/58,015 psi, 10 min). Aroma profile did not change in dry-cured ham at 600 MPa (87,000 psi) for 6 min compared to a control ham (**Figure 10**, Fuentes *et al.,* 2010).

Some studies have shown an increase in lipid oxidation after HPP in dry-cured meat (Fuentes *et al.,* 2010; De Alba *et al.*, 2012). However, other studies found the opposite effect on lipid oxidation at different HPP conditions (Campus *et al.,* 2008; Clariana *et al.,* 2011). Cava *et al.* (2009) stated the conflicting results are a manifestation of the complexity of the oxidative processes in dry-cured meats. Factors such as HPP conditions, storage time and temperature and raw meat composition affect oxidative stability. No differences in rancid aroma in HPP dry-cured ham were detected by trained panelists (**Figure 10**; Fuentes *et al*., 2010).

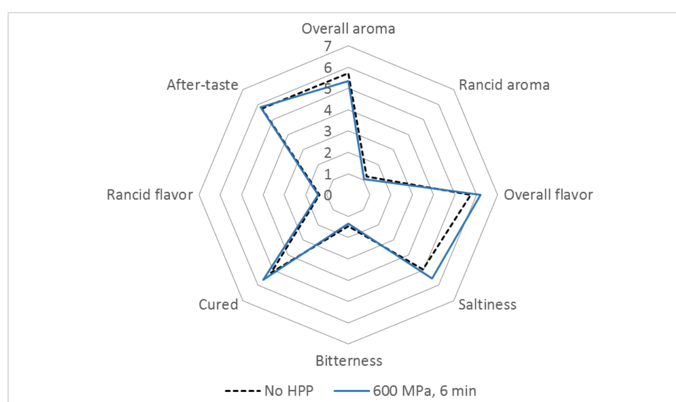

Figure 10. Aroma and flavor profile of HPP dry-cured ham (600 MPa, 6 min) after 30 days of cold storage (8 ºC) compared to non-processed ham evaluated by a sensory panel (Fuentes *et al*., 2010).

HPP processing has other beneficial effect on preserving aroma in dry-cured and fermented meats. HPP (350 MPa/50,760 psi, 15 min) reduced significantly the production tyramine, putrescine and cadaverine, biogenic amines related to off-odors in this kind of meat products (Ruiz-Capillas *et al*., 2007).

Flavor

HPP technology is softer than a thermal treatment: it does not break or create covalent bonds, and does not create new compounds by molecule degradation, such as in a conventional thermal process. Fuentes *et al.* (2010) found HPP dry-cured ham (600 MPa/87,000 psi, 6 min) after 30 days at refrigeration presented a similar flavor profile compared to non-processed ham. The authors found a slight increase in saltiness and flavor intensity in HPP ham (**Figure 10**).

High pressure promotes tighter binding of sodium to proteins, and at the same time, a protein denaturation, which would explain the increase in saltiness perception (Picouet *et al.,* 2012). The phenomena would allow manufacturing low-sodium dry-cured meat products by using HPP technology.

NUTRITIONAL QUALITY

Overall nutritional quality

HPP processing (400 MPa/58,000 psi for 10 min) did not lead changes in nutritional composition of sliced dry-cured ham (Clariana *et al.,* 2012). The content of fat, protein, collagen and moisture in HPP dry-cured meat was similar to non-processed ham (**Figure 11**).

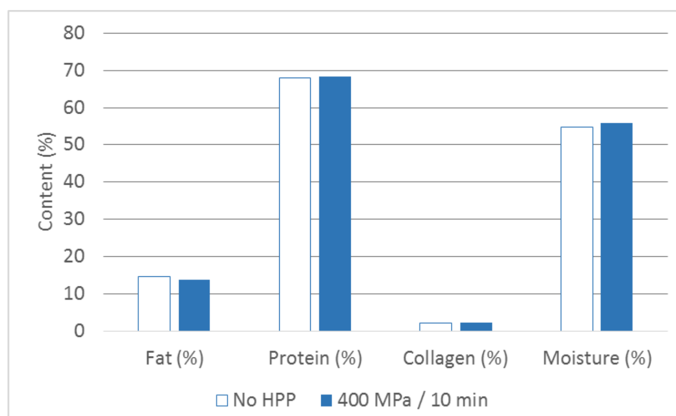

Figure 11. Fat, protein, collagen and moisture composition of sliced dry-cured ham after HPP (400 MPa, 10 min) (Clariana *et al.,* 2012).

Proteins

Dry-cured and fermented meat are source of protein in human diet and any processing technology should maintain the protein quality post-processing. HPP did not alter free amino acids in dry-cured meat (Campus *et al.,* 2008; De Alba *et al.,* 2012), reducing protein oxidation in HPP dry-cured ham and loin (Cava *et al.,* 2009) and did not change in purine and pyrimidines nucleosides after HPP processing (Clariana *et al.,* 2011b).

Lipids

Clariana *et al.* (2011a, 2011b) studied the impact of HPP (600 MPa/87,000 psi, 10 min) on lipid quality of dry-cured meat products. The authors found no change in fatty acid profile as well as HPP did not induce oxidation of cholesterol.

Antioxidants

Although, meat and meat products are not considered a relevant source of antioxidants in human diet such as fruit and vegetables, the content of antioxidants in these food products is important to keep antioxidants/free-radicals balance.

HPP (400 MPa/58,000 psi for 10 min) did not change the activity of catalase in dry-cured ham (**Figure 12**). However, the activity of glutathione peroxidase and superoxide dismutase increased compared to control ham (Clariana *et al.,* 2011c and 2012). The extractability of vitamin E increased in HPP dry-cured ham (Clariana *et al*., 2012), which could entail an increase in vitamin E bioavailability, as well.

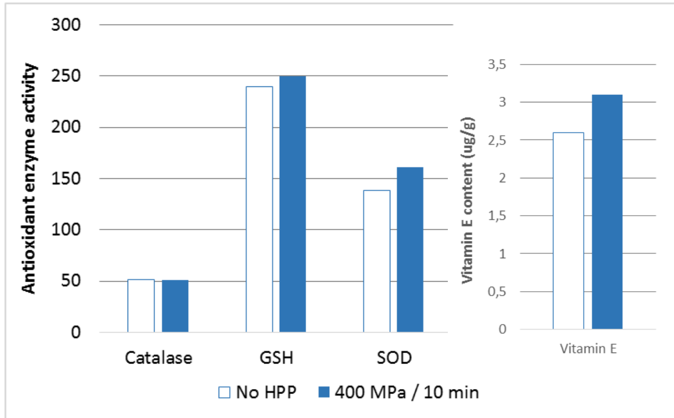

Figure 12. The effects of HPP processing (400 MPa, 10 min) on antioxidant enzymes (catalase; glutathione peroxidase, GSH; superoxide dismutase, SOD) and vitamin E in dry-cured ham (Clariana *et al.,* 2012)

CONCLUSIONS

Dry-cured and fermented meat products have successfully been processed by high hydrostatic pressure since their first processing of Spanish dry-cured ham in 2000. HPP technology increases the shelf-life and reduce food safety risks of dry-cured and fermented meats, maintaining their sensory and nutritional quality.

The positive effects of high hydrostatic pressure on dry-cured and fermented meat products quality has made the number and volume of this kind of meat products grows quickly in few years.

A reflection of this is the growth of the number of our customers as such as this link shows: http://www.hiperbaric.com/en/customers

You can get more information about Hiperbaric and high pressure processing of foods on the next links:

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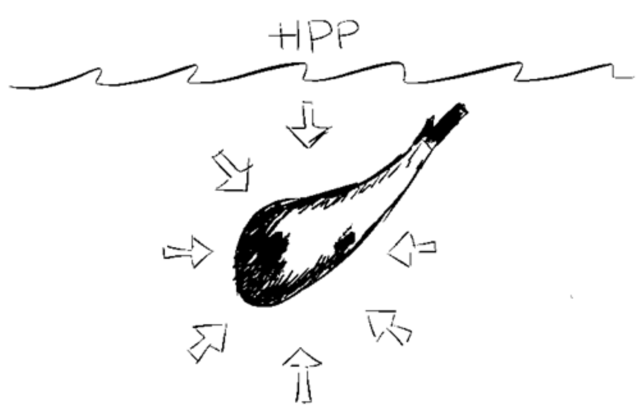

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