THE WELFARE OF CRUSTACEANS AT HIGH PRESSURE PROCESSING

ABSTRACT

High Pressure Processing (HPP) is a non-thermal food processing technology that allows for food products with a longer shelf-life and safer, while preserving nutrients and their fresh taste and appearance. Industrial applications use high pressure to extract meat from crabs and lobsters.

Several studies have shown crustaceans have the capacity to suffer and to experience pain. European Food Safety Authority (EFSA) classified decapods in Category 1 status, animal who are able to experience pain and distress after concluding that largest of the decapods have a pain system.

Pressure induces different physiologic responses in crustaceans (low metabolic rate, reduced activity), depending the species and pressure level. Exposure above 7,348 psi (50.6 MPa) is lethal in many marine animals. At cellular (neuronal) level high pressure induces several changes, reducing influx of Ca^{2+}, inhibiting neurotransmitter release, which affects presynaptic response. These changes are related to. High pressure does affect N-type Ca^{2+} channels, key mediators of nociceptive signaling. Nociceptive (high intensity stimuli) mechanism is associated to pain experience. It is possible to suggest that HPP would not induce pain in crustaceans, since the inhibition of these channels would lead to an analgesic response.

Although there is no direct evidence of welfare of crustacean processed by HPP, available scientific literature suggests that meat extraction by HPP does not lead to suffering during processing.

COMMERCIAL APPLICATION OF HPP ON CRUSTACEANS

HPP technology

High Pressure Processing (HPP) is a non-thermal food processing technology that allows for food products with a longer shelf-life and safer, while preserving nutrients and their fresh taste and appearance.

Regarding to a physico-chemical 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, 1995).

HPP processing induces, mainly, changes in tertiary and quaternary structure of proteins (3D structure). Depending on the intensity of the processing, these changes can be reversible or not. For instance, the use of HPP as preservation technology is based on irreversible changes in cell membrane proteins of spoilage and pathogenic microorganisms due to high pressure levels (43,500 – 87,000 psi / 300 – 600 MPa), which leads to death.

HPP on seafood

On seafood sector, HPP technology provides a simple and efficient method for the removal of edible meat from shell and carapace of shellfish and crustaceans. The pressure range used for meat extraction is between 30,000 psi (200 MPa) and 43,500 psi (300 MPa) (Tonello, 2011). Process takes from 1 to 3 min to be completed, and at temperature between 41 to 59 ºF (5 to 15 ºC).

Industrial applications use high pressure to extract meat from crabs and lobsters. Differences in compressibility between meat and shell make that meat detach from the shell, facilitating extraction and increasing yields.

The process also enables operators to work on smaller parts such as the legs or antennae of the crustacean where meat is most difficult to obtain. Since there is no need for cooking, and the process never exceeds room temperature, HPP enables the meat to retain its natural flavors and provide customers with a fresh product for cooking prior to serving.

Figure 1. HPP facilitate meat extraction from crustaceans, even from smaller parts of the animal.

(Picture courtesy of Cinq Degrès Ouest http://www.5do.fr/)

EFFECT OF HPP ON CRUSTACEANS

From the end of 60's, it has been studied the effects of high pressures on cellular processes and organisms at laboratory controlled-conditions (Society for Experimental Biology, 1972; Zimmerman, 1970).

High pressure effect on marine invertebrates' physiology

Regarding invertebrates, research showed that smaller pressures, between 1,470 psi (10.1 MPa) and 2,939 psi (20.3 MPa), caused a temporary increase in the activity of many species. On the contrary, higher pressures (> 4,408 psi / 30.4 MPa) resulted in muscle contraction, decrease in respiration rate and, finally, in a rapid disintegration of the cellular gel structure (Schlieper, 1968). Fishes and invertebrates exposed for a short period to pressures of 7,348 psi (50.6 MPa) died.

High pressure effect on crustaceans' physiology

Pressure induces to three types of physiologic responses in crustaceans: Type I, hyperexcitability; Type II, readily reversed inhibition following exposure to minimal inhibitory pressure; type III, slowly reverse inhibition, following exposure to 7,348 psi (50.6 MPa). Exposure above this pressure is lethal in many marine animals (Schlieper, 1968). Crustaceans responded in a different way (presence and duration of responses types) to pressurization depending on their species, and their habitat. Pressure-tolerant crustaceans (living in deeper aquatic layers) recovered faster locomotion respiratory and metabolic rate (Macdonald & Teal, 1975). Metabolic rate was affected by interaction temperature-pressure, decreasing at low temperatures and high pressures. Behavior was mainly affected by pressure, with an increase from 735 to 1,470 psi (5 to 10.1 MPa) resulting in reduced activity of hermit crab (Thatje, Casburn, & Calcagno, 2010).

Figure 2. Lobsters (Family *Nephropidae*); crayfish (Superfamily *Parastacoidea*), crabs (Infraorder *Brachyura*) are the main groups of crustaceans processed by HPP.

(Pictures from http://upload.wikimedia.org/wikipedia/commons/7/74/Lobster_NSRW.jpg, and http://www.seagrant.umn.edu/ais/img/rustycrayfish/rusty_crayfish_10_low.jpg)

IS HPP PROCEESING HARMFUL TO CRUSTACEANS?

Several studies have shown crustaceans have the capacity to suffer and to experience pain (Barr, Laming, Dick, & Elwood, 2008; Fernandez-Duque, Valeggia, & Maldonado, 1992). European Food Safety Authority (EFSA) classified decapods in Category 1 status, animal who are able to experience pain and distress after concluding that largest of the decapods have a pain system (EFSA, 2005).

Effects of HPP on crustacean nervous system

Effects on marine organisms can be attributed to the compressibility of the vital proteins and protein complexes (Schlieper, 1968). The function of neurons depends upon cellular polarization, and synapse is related to complex molecular machinery, which is based on a selective exchange of

ions (e.g. Na^{+}, Ca^{2+}) and neurotransmitters through neuron cell membrane. Membrane proteins could be altered by high pressure, affecting synaptic process.

The main effect of high pressure on crustacean synapsis is due to reducing calcium influx into nerve terminal and affecting neurotransmitter release (Grossman & Kendig, 1990). High pressure (1,470 psi / 10 MPa) affected significantly presynaptic mechanisms in crayfish abdominal muscles. (Golan & Grossman, 1992). According to the authors, high pressure induces several changes at neurological level:

- Reduction of entry of Ca^{2+} into the terminals.
- Synaptic delay was increased in a $[Ca^{2+}]$-dependent fashion.
- Extracellular nerve terminal potential amplitudes lowered.
- Inhibition of transmitter release.

Effect of HPP on synapsis and pain in crustaceans

Crustacean may possess an analgesic system like that found in vertebrates which "protect" them from nociceptive stimuli (high intensity stimuli) associated to pain experience (Barr et al., 2008). N-type Ca^{2+} channels are key mediators of nociceptive signaling (Altier & Zamponi, 2004) and are considered a validated pharmacological target for treating pain (Snutch, 2005). High pressure does affect N-type channels of the lobster neuromuscular junction (Grossman, Colton, & Gilman, 1991); therefore, it is possible to suggest that HPP would not induce pain in crustaceans, since the inhibition of these channels would lead to an analgesic response. Inhibition of N-type channels has been proved as a pain treatment in humans and in animals (Altier et al., 2007).

Industrial HPP machines are able to reach in short time (seconds) high pressures, avoiding animal suffering and pain (if it occurs) during the processing.

CONCLUSIONS

Although there is no direct evidence of welfare of crustacean processed by HPP, available scientific literature suggests that meat extraction by HPP does not lead to suffering during processing, since high pressure induces changes in neurological processes at cellular and physiological level which may inhibit pain and distress of animals. In addition, HPP cycles are done in short time and at low temperature, two relevant factors to minimize pain in crustaceans.

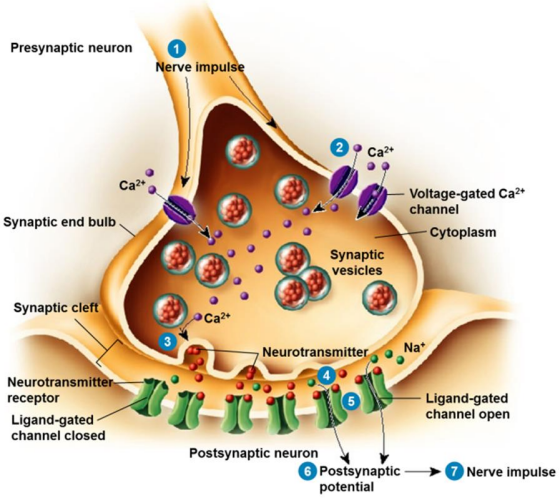

Figure 3. Scheme of synaptic ransmission at the neuromuscular junction

(Picture from http://antranik.org/synaptic-transmission-by-somatic-motorneurons/)

Effect on Crustaceans	Pressure Psi (MPa)	Estimated Time*, s
Low metabolic rate, reduced activity	735 – 1,470 (5 – 10.1)	7 – 10 s
Alteration of N-type Ca^{2+} channels (Pain inhibition)	Around 1,470 (10.1)	10 s
Death	7,348 (50.6)	24 s
Industrial meat extraction	30,000 – 43,500 (200 – 300)	74 – 104 s

*Time from the beginning of the HPP cycle

Table 1. Effect of high pressure on physiology of crustaceans and estimated time of industrial HPP processing.

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