High Hydrostatic Pressure Processing of Seafood

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Abstract

High Pressure Processing (HPP) technology is gaining remarkable presence in the seafood industry as a non-thermal technology for controlling microorganisms and improving the processing of shellfish and crustaceans. The conventional application of the technology was primarily for the inactivation of microorganisms for food safety and shelf-life extension benefits. However, more recently a number of the economic drivers have been important for the commercial adoption of HPP by seafood processors. The technology, particularly in the lobster and crab industries, provides the opportunity to market fresh, shucked lobster and crab meat without the use of heat. Additionally, this process increases meat recovery by as much as 50 % over traditional cooking methods, improves product weight by as much as 10% from the natural hydration of proteins, and improves product quality. Shellfish processors are using HPP to release the meat from shells allowing for huge reduction in the direct and indirect costs of manual labor by more than 50%. The use of HPP for shucking is generally done at pressures between 2500 and 4000 bars (250 to 400 MPa) for relatively short exposure times of 1 to 3 minutes which significantly increase product throughput of processing plants. In addition to the improved microbiological quality of HPP seafood, there is an improvement in a number of organoleptical properties that have resulted in an increased demand in the market for these products.

Introduction

High hydrostatic pressure processing (HPP) has become widely accepted as a viable and important process in the seafood industry both from an economic and food safety perspective. Several studies by universities and regulatory agencies have validated the technology in controlling pathogenic *Vibrio*, coliform bacteria, and viruses in oysters and other shellfish (Hermelstein, 1997; Cook, 2003; Murchie, *et al* 2005; Kingsley, *et al* 2007). This food safety intervention step in shellfish processing is an important public health development in the industry particularly in the segments which provide products that are consumed raw such as oysters. The recent high demand for HPP in the seafood industry, however, is for the processing of crustaceans, particularly for the separation of raw lobster meat and crab meat from the shell. This process allows for the recovery of 100 % meat from shells and inherent to the process, is the hydration of the raw protein resulting in a significant, natural increase in product yield and improvement in texture (mouth feel). Processors no longer need to skirt regulations by using chemicals such as phosphates (TTP) to facilitate the retention of moisture in protein for yield improvement and texture. HPP increased the gel strength of uncooked surimi by 2 to 3 fold by making protein substrates more accessible to transglutaminase which increases intermolecular cross-link formation and gel strength (Ashie and Lanier, 2007). These improvements in textural characteristics have created a high demand for HPP products from both the food service and retail sectors. HPP shucked oysters and lobsters have been given a number of national and international awards for innovation and quality. At the recently concluded European Seafood Exposition in Brussels (April, 2007), the top prize in the foodservice category was awarded to the United States company ImEx for its product, Shucked Fresh Raw Lobster Meat. Similar awards have been given companies using HPP to shuck oysters. Gold Band Oysters® shucked by HPP were chosen over all major oyster brands in a double-blind taste test. Award-winning chefs from across the US selected Gold Band Oysters® based on their freshness and taste.

Yield Improvement in Crustaceans

The improvement of yield in crustaceans shucked by HPP compared to traditional heat methods are achieved in the following ways. First, all meat is released from the shell including leg muscle (Figures 1, 2) after being subjected to pressures between 2,500 and 5,000 bars in an HPP vessel

(Figure 5). Second, with traditional cooking method, the protein dehydrates resulting in loss in weight, whereas with HPP, the opposite occurs, i.e. hydration of the raw protein. The average total weight percentage recovered in traditional cooked Maine lobster is 25 % of total body weight compared to an average of 43 % in HPP shucked lobster (Figure 3). A more significant increase in yield was seen in soft shelled (recent molts) animals with a 45 % recovery compared to 22 % from cooking (Figure 3). The HPP conditions were changed to improve the textural quality of the meat from the soft shelled lobster which is generally less desirable when processed by cooking. Similarly, for crabs (Blue, Dungeness, Alaskan King, and Golden) mean recovered weight is 19 % of total body by traditional cooking methods whereas, HPP increases the percentage to an average of 35 % (Figure 4).

Meat Separation (Shucking)

HPP is becoming well established as a processing technology for the shucking of shellfish and crustaceans. The commercial success of oyster shucking by HPP is well known with a number of companies in the US and elsewhere implementing the technology over the last 5 years. The same efficacy in shucking shellfish meat from their shells is seen in mussels, clams, scallops, crabs, and lobsters (Figures 1 & 2). In addition to the destruction of pathogenic microorganisms, HPP shucking of shellfish and crustaceans offers the processor a number of economical advantages including the following:

- Limited/or no need for shucking labor
- 100 % meat recovery
- No physical damage of meat from shucking knives
- Increased yield weight from hydration of raw protein
- Improvement of product quality
- New markets for raw lobster and crab meats, particularly the sushi industry.

These economical advantages have been the primary attraction for processors to HPP technology

Effects on Microorganisms

In the United States, the presence of *Vibrio vulnificus* in molluscan shellfish inflicts the highest fatality rate among foodborne pathogens (Cook, *et al* 2002). Several studies have demonstrated the reduction of *Vibrio* spp. and other pathogens in oysters and seafood products by HPP (Berlin *et al* 1999; Simpson, 1998). AVURE Technologies, in collaboration with oyster industry partners, and the FDA has conducted similar studies to evaluate the effects of HPP on pathogenic *Vibrio* bacteria in oysters and other shellfish. Similar studies were conducted at Oregon State University's Seafood laboratory.

The results of these studies clearly show that HPP is an effective method of reducing *Vibrio* spp. populations to non-detectable levels. Results from a study at AVURE on *V. parahaemolyticus* in Pacific Oysters (*Crassostrea gigas*) showed that pressures >35,000 psi reduced *V. parahaemolyticus* level from 6.7×10^4 CFU/g to <3.6 MPN/g (non-detectable). Another recently completed study conducted by the FDA's Gulf Coast Seafood laboratory in collaboration with AVURE Technologies, examined the effects of HPP on a newly isolated strain of *V. parahaemolyticus*, serotype O3K6 in the US. This strain is considered the most tolerant to HPP by regulatory and other shellfish researchers. Although the tolerance to pressure by the O3K6 strain was observed in our study, compared to other strains of *V. parahaemolyticus* and *V. vulnificus*, it nevertheless was susceptible to slightly higher pressures at longer hold times than that used for *V. vulnificus* inactivation (Cook, 2003). Other studies reported similar levels of inactivation of *V. parahaemolyticus* in oysters (Calik *et al* 2001). Recently, Kingsley *et al* (2002) reported in a study of the Hepatitis A virus and Calicivirus that HPP has the potential of making raw shellfish free of infectious viruses.

Recently, The State of California has issued regulations, which stated that oysters must be treated with a "Scientifically Validated Process to Reduce *V. vulnificus* to Non-Detectable Levels". High Pressure Processing is recognized as a validated process to reduce pathogenic *Vibrio* bacteria.

Conclusion

Although the preceding review addressed the remarkable success of adopting HPP technology in the seafood industry as a tool to increase food safety and enhance processing operations, the largest growth in the technology occurs in the animal meat industry. Several large corporations in North America and to a limited extent Europe are using the HPP as a active intervention step in the control of foodborne pathogens, particularly *Listeria monocytogenes*. However, companies are exploring the many non-microbiological advantages HPP offers in product development opportunities because of the unique behavior of raw proteins and other food components under pressure. The use of relatively low pressures can be used to tenderize and marinate meats providing higher margins for relatively lower value cuts of meats.

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Fig 1.

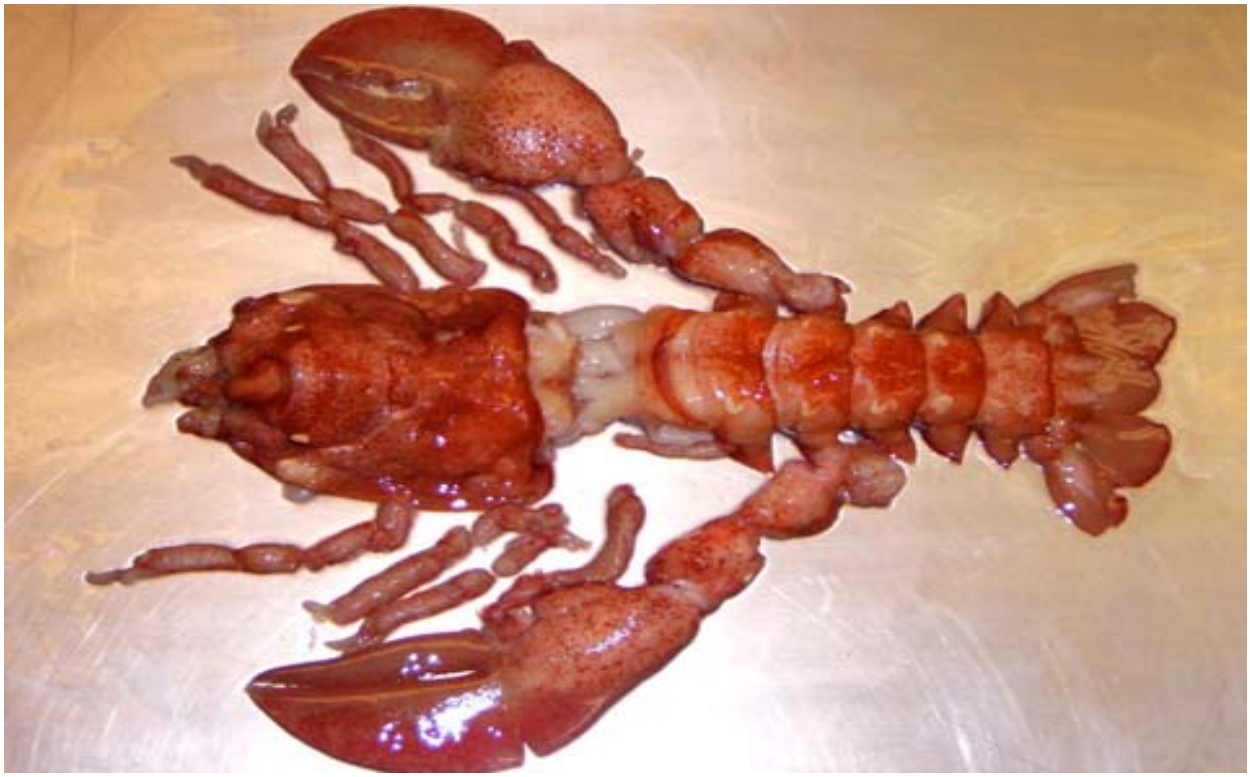


Figure 1. Complete removal of meat from Maine lobster using high pressure (HPP) technology in Avure's 215-L high pressure vessel in use at Shucks Maine Lobster, Mass. USA. Leg meat is easily removed with the use of rollers.

Fig 2.

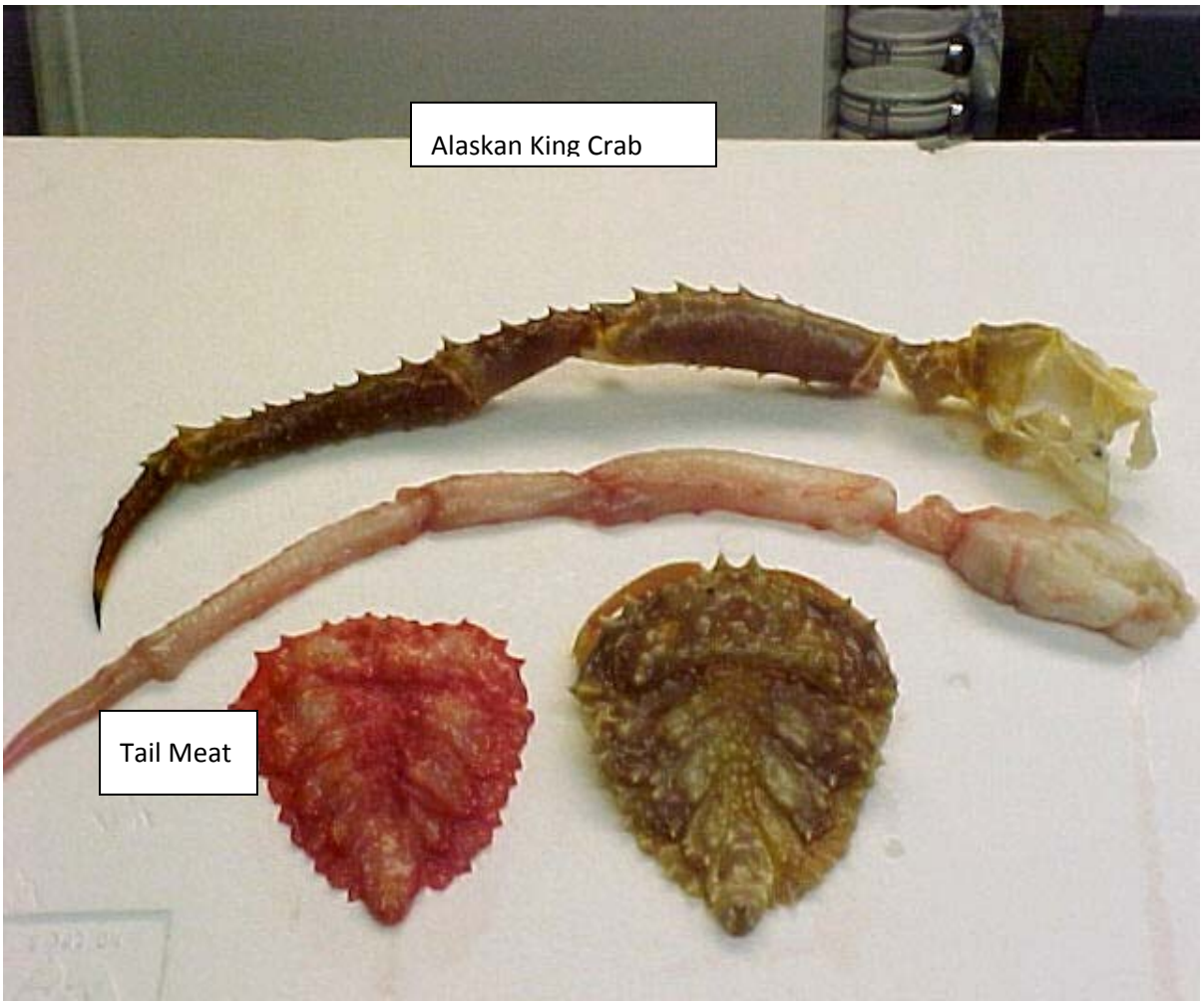


Figure 2. Shucking of raw Alaskan King Crab with High Pressure. The texture of the meat can be adjusted to desired firmness by using the correct HPP processing conditions.

Fig 3

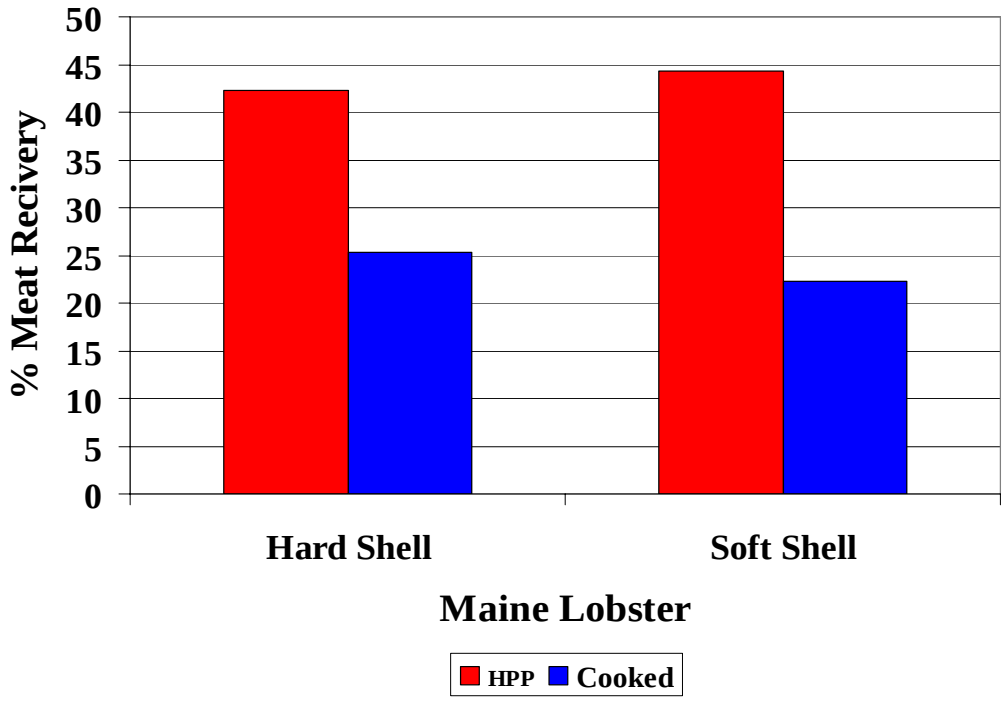

50
45
40
35
30
25
20
15
10
5
0
% Meat Recivery
Hard Shell
Soft Shell
Maine Lobster
HPP
Cooked

Figure 3. Percent meat recovery to total body weight in hard shell and soft shell Maine Lobster by traditional cook method and high pressure processing technology. Weights were recorded prior to processing method and meat was recovered following HPP and cooking using commercial conditions.

Fig 4

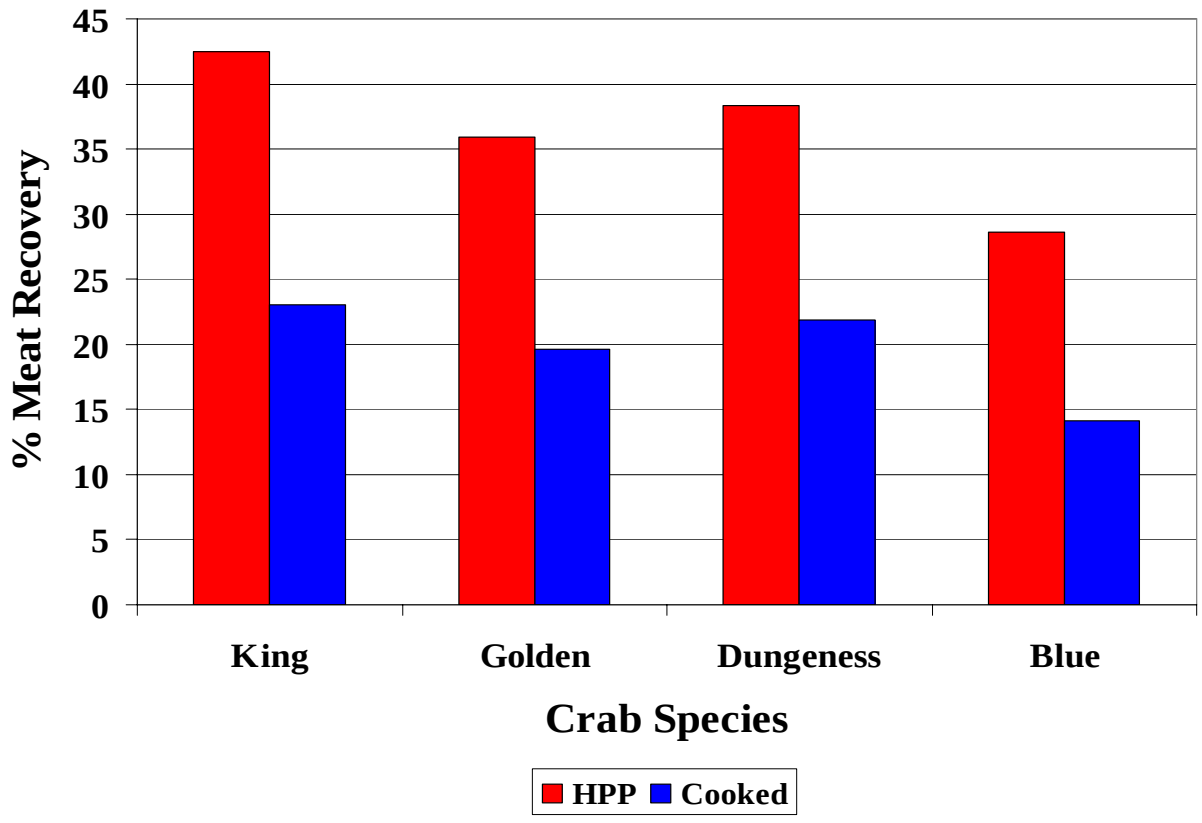
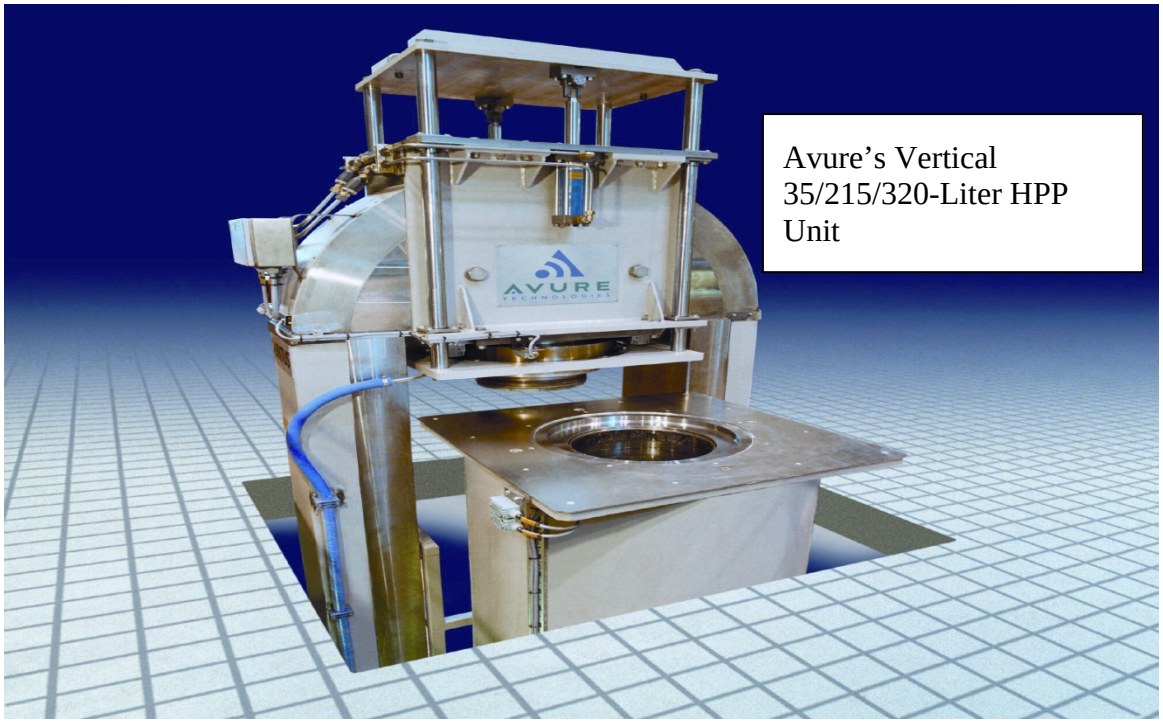

45
40
35
30
25
20
15
10
5
0
% Meat Recovery
King
Golden
Dungeness
Blue
Crab Species
HPP
Cooked

Figure 4. Percent meat recovery to total body weight in four species of crab by traditional cook method and high pressure processing (HPP) technology. Weights were recorded prior to processing method and meat was recovered following HPP and cooking using commercial conditions.

Fig 5.


Avure's Vertical
35/215/320-Liter HPP
Unit
AVURE

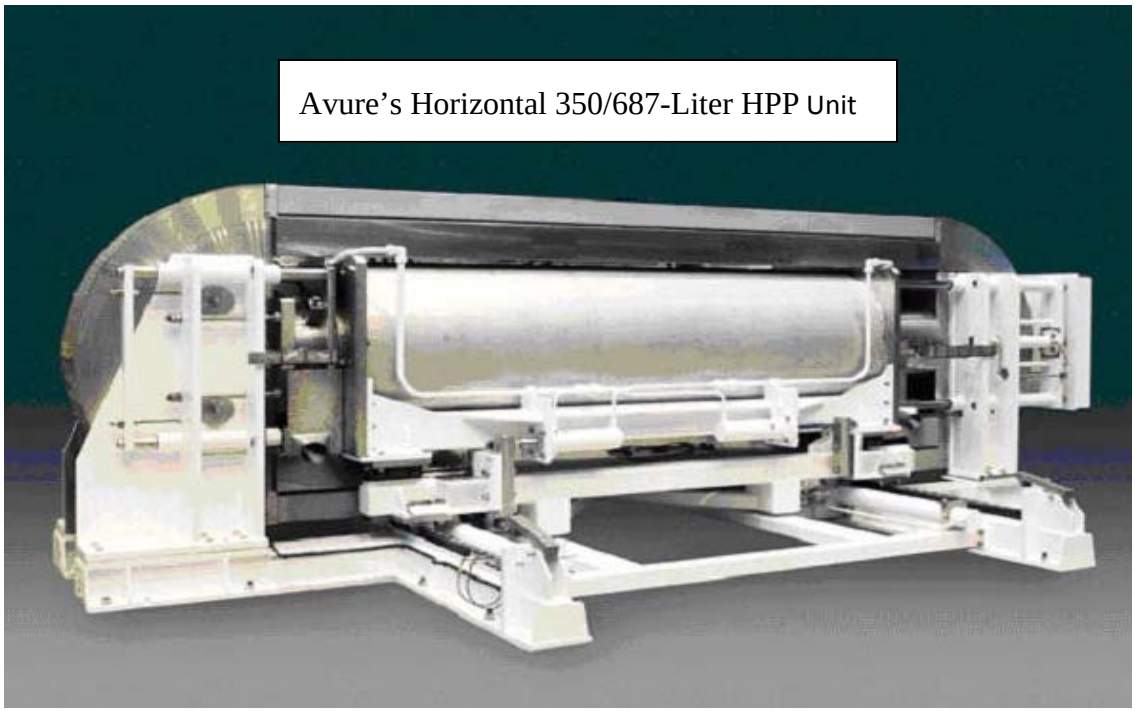

Avure's Horizontal 350/687-Liter HPP Unit

Figure 5. High Pressure processing equipment from Avure Technologies, Kent WA. USA. Above: The vertical HPP system available in 35, 215, and 320-Liter sizes. Below: The 350 and 687-Liter horizontal high pressure processing (HPP) systems.