Acta Univ. Sapientiae, Alimentaria, **8** (2015) 86–94

DOI: 10.1515/ausal-2015-0008

High hydrostatic pressure: Can we trust published data?

Cs. Németh
e-mail: nemeth.csaba@capriovus.hu

Capriovus Ltd., Dunasor 073/72, 2317 Szigetcsép, Hungary

L. A. Castillo
e-mail: huto@uni-corvinus.hu

F. Horváth
e-mail: huto@uni-corvinus.hu

I. Zeke
e-mail: ildiko.zeke@uni-corvinus.hu

L. Friedrich
e-mail: laszlo.friedrich@uni-corvinus.hu

Cs. Balla
e-mail: csaba.balla@uni-corvinus.hu
Corvinus University of Budapest,
Department of Refrigeration and Livestock Products Technology,
Faculty of Food Science, Ménesi St. 45., 1118 Budapest, Hungary

Z. Németh
e-mail: nemeth.zoltan@capriovus.hu

Capriovus Ltd., Dunasor 073/72, 2317 Szigetcsép, Hungary

P. Póti
e-mail: poti.peter@ mkk.szie.hu

Szent István University, Institute of Animal Husbandry,
Páter Károly St. 1., 2100 Gödöllő, Hungary

Keywords and phrases: high hydrostatic pressure, data comparison.

Abstract. There are numerous new technologies whose implementation in food industry is hampered by the fact that people hesitate to invest in expensive systems which they cannot be sure will work or at least are questionable in terms of a given product. Until recently, preservation by HHP, high hydrostatic pressure, was such a technology, and still is today in some branches of the food industry. Investigations were conducted to answer the question of whether the literature, the laboratory, and the industrial (or at least pilot plant) measurements and results agree with one another. We compared the literature data with two HHP systems which were significantly different in terms of treatment capacity, but their efficiency in killing microbes was studied under the same treatment parameters. Our results show that in nearly all cases only minimal differences exist between the data in the literature and the measurements taken on the two appliances.

1 Introduction

HHP, or high hydrostatic pressure, is one of the "gentle" food preservation methods, as it does not use heat. In high hydrostatic pressure technology, food products are preserved by being subjected to between 100 and 1000 Mpa hydrostatic pressure. In HHP treatment, food products are vacuum-sealed in flexible packages and placed in liquid. Hydrostatic pressure is applied quickly and evenly (isostatically) according to the Pascal method (*Dalmadi & Farkas*, 2006); thus, neither the size nor the shape of the container play a role in the effects of the pressure treatment (*San Martin et al.*, 2002; *Farr*, 1990; *Lechowich*, 1993).

The advantage of this method, in contrast to traditional heat treatment, is killing microbes and inactivating enzymes without the undesirable effects of high temperature. This method does not change the product's taste, texture or colour and is less harmful to its nutritional value. Product freshness is better preserved as well. Additives may be reduced or eliminated completely. Moreover, with this method, new technological and functional properties may be developed (*Rico et al.*, 2007; *Oey et al.*, 2008).

Even in the area of liquid products, HHP technology is applied with increasing frequency (*Table 1*, *Knorr et al.*, 2011). Until now, rather small-capacity laboratory equipment has been used for testing the many advantageous properties of high hydrostatic pressure treatment of foods. The aim of our experiments was to determine the laboratory and pilot plant systems' degree of ability to kill microbes and, further, to discover how those results are comparable with the data in the literature.

Table 1: Examples of high-pressure processed products commercially available in different countries

Country	Year	Product
Japan	1993	Rice wine
France	1994	Citrus juice
Mexico	2000	Citrus juice and concentrate
Lebanon	2001	Fruit juices
Portugal	2001	Apple and citrus flavour fruit juices
Czech Republic	2004	Broccoli, apple, beet and carrot juices
USA	2005	Fibre fruit juices
Northern Ireland	2006	Apple, wild strawberry and ginger juices
New Zealand	2009	Colostrum

2 Materials and methods

HHP treatment

Our experiments were carried out according to the parameters in published articles (matrix, treatment time, pressure during treatment and microbes). The Budapest Corvinus University Department of Refrigeration Technology and Animal Products owns two HHP systems: one laboratory type (Stansted Food Lab 900, plunger press system) and one pilot plant type (RESATO FPU 100-2000). Thus, it was possible to apply measurements derived from the literature, using similar parameters, on two separate machines.

Microbiological tests

We intended to examine each change in total viable cell count and the death of each important microbe specific to a given product. For our tests, we prepared inoculate with microbes grown on slant agar, after which we infected the samples with amounts which produced measurements similar to those found in the literature.

Preparation of *Salmonella Enteritidis*, inoculation of samples and colony counting

The *Salmonella enterica* subsp. enterica, serotype Enteritidis NCAIM B2052 species used in the experiments was obtained from the National Collection of Agricultural and Industrial Microorganisms (NCAIM). We prepared inoculate from microbes grown throughout 24 hours on meat broth slant agar, after which we added two streaks of preparation to each 10 ml of sterile peptone

water (the diluting liquid), and then this was administered in various amounts to the samples. Following HHP treatment, dilution plating was completed with selective XLD and Harlequin Salmonella agar. Plates were incubated for 48 hours at 37 °C, after which the growth of colonies was determined with a colony counter.

Preparation of *Listeria monocytogenes*, inoculation of samples and colony counting

The inoculation and colony counting of the samples with *L. monocytogenes* was carried out similarly to *Salmonella Enteritidis*, except that Brain Heart agar was used for the slant growth and plate pouring was done with PALCAM agar.

Preparation of *Escherichia coli*, inoculation of samples and colony counting

Inoculation and colony counting of samples with *E. coli* was similar to that of *Salmonella Enteritidis*, but plate pouring was carried out with ChromoCult Coliform agar.

Preparation of *Staphylococcus aureus*, inoculation of samples and colony counting

Inoculation and colony counting of samples with *S. aureus* was completed in a similar way to *Salmonella Enteritidis*, but here plate pouring was done with Baird Parker agar.

Preparation of *Pseudomonas aeruginosa*, inoculation of samples and colony counting

The inoculation and colony counting of *P. aeruginosa* samples happened in a similar way to that of Salmonella with the exception that Cetrimide agar was used for plate pouring.

Determination of aerobic viable cell count

A series was prepared from both the treated and untreated (uninfected) samples. They were diluted at a ratio of 10^{-1} with sterile water, after which we used Nutrient agar plate pouring to determine the microbe levels in the samples. Plates were incubated for 48 hours at 37 °C and a colony counter was used to determine how many colonies had appeared.

3 Results and discussion

It can be seen from our results that the levels of microbe death in certain foods varied only slightly between the laboratory and the (pilot) plant, while they agreed with the data in the literature (*Figure 1*). Slight variations in the total viable cell count test could be attributed to deviations in the microflora composition; variations in the test of given phyla may derive from differences of serotype; moreover, it can be said that the homogeneity of the food used as matrix was imperfect (water and fat content).

It is apparent from the data that results taken from the literature and laboratory systems allow us to make conclusions about how the material's microbiological condition will change during processing in a plant.

Figure 1 shows literature data (the measurements which we tried to reproduce) and correlation to results from pilot plant systems. It is clear that there is a close correlation, ($r^2 = 0.96$). The r^2 value was 0.99 for *Salmonella*, 0.92 for *Listeria*, 0.98 for *E. coli*, 0.77 for *S. aureus*, 0.96 for *Pseudomonas aeruginosa* and 0.87 for total viable cell count.

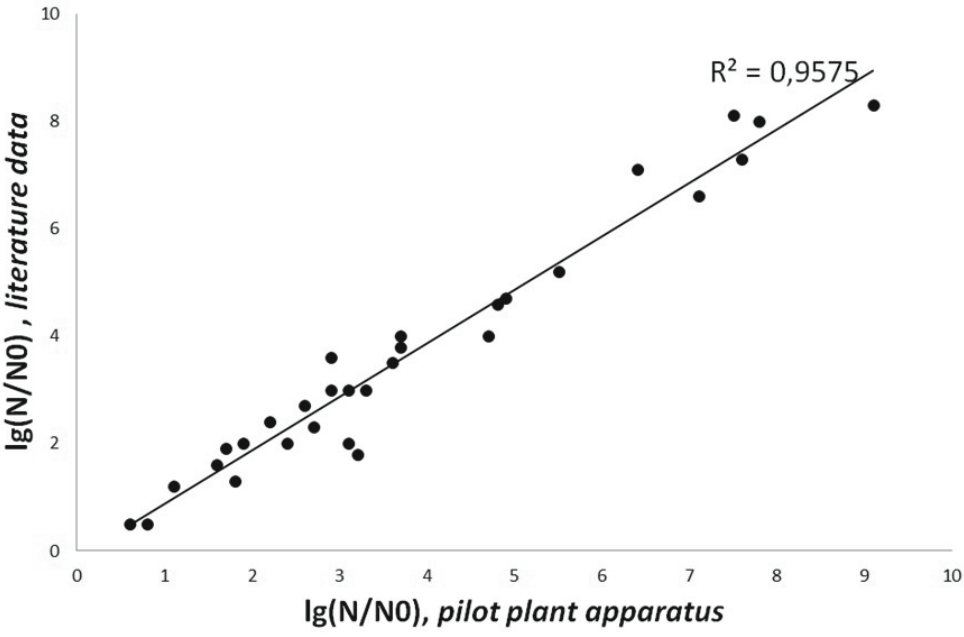

Figure 1: Correlation between the literature and the industrial results

Table 2: Comparison of literature data and our results

	p	t	LAB	PPA	LIT.	REF.
Salmonella						
(Enteritidis) meat broth	345	600	3.3	3.1	3.0	*Alpas et al., 2000*
phosphate buffer	350	600	0.9	1.1	1.2	*Tholosan et al., 2000*
boiled ham	400	600	2.0	1.7	1.9	*Aymerich et al., 2005*
(Enteritidis) ham	500	600	6.5	6.4	7.1	*Yuste et al., 2000*
broth	500	600	8.2	7.8	8.0	*Mackey et al., 1994*
Listeria monocytogenes						
phosphate buffer	375	900	2.2	2.4	2.0	*Patterson et al., 1995*
boiled ham	400	600	2.5	2.2	2.4	*Aymerich et al., 2005*
turkey breast	400	60	0.7	0.6	0.5	*Chen, 2007*
ham	450	600	3.0	2.9	3.6	*Morales et al., 2006*
turkey breast	500	60	4.1	3.7	3.8	*Chen, 2007*
Escherichia coli						
liquid whole egg	300	600	0.8	0.8	0.5	*Ponce et al., 1998*
(O157-H7) meat broth	345	600	7.7	7.5	8.1	*Alpas et al., 2000*
liquid whole egg	450	600	3.3	3.6	3.5	*Ponce et al., 1998*
phosphate buffer	500	300	7.5	7.6	7.3	*Hauben et al., 1997*
phosphate buffer	600	300	8.7	9.1	8.3	*Hauben et al., 1997*
Staphylococcus aureus						
sheep's milk	345	600	4.2	3.7	4	*Alpas et al., 2000*
water	400	1800	5.0	5.5	5.2	*Arroyo et al., 1999*
sheep's milk	450	1800	3.0	3.2	1.8	*Arroyo et al., 1999*
milk	600	900	2.2	1.9	2.0	*Mackey et al., 1994*
turkey meat	600	900	3.2	2.9	3.0	*Mackey et al., 1994*
Pseudomonas						
sheep's milk	250	1800	7.0	7.1	6.6	*Trujillo et al., 2002*
(aeruginosa) water	300	1800	5.1	4.8	4.6	*Arroyo et al., 1999*
(fluorescens) water	300	1800	4.5	4.9	4.7	*Arroyo et al., 1999*
broth	345	600	4.5	4.7	4.0	*Alpas et al., 2000*
corned beef	500	300	3.4	3.1	2.0	*Rubio et al., 2007*
Viable cell count						
chicken liver	200	1200	1.5	1.8	1.3	*Tuboly, 2009*
sliced pineapple	270	900	1.5	1.6	1.6	*Aleman et al., 1997*
liquid egg	300	600	2.4	2.7	2.3	*Németh et al., 2012*
sliced pineapple	340	900	2.9	3.3	3.0	*Aleman et al., 1997*
ham in brine	600	360	3.0	2.6	2.7	*Garriga et al., 2004*

p: Mpa treatment pressure, Mpa
t: treatment time
LAB: lg(N/N0) value in a laboratory apparatus
P.P.A.: lg(N/N0) value in a pilot plant apparatus
LIT.: lg(N/N0) value from literature data
REF.: literature which was used and which belongs to the LIT

4 Conclusions

In summary, we can say that the microbe-reducing effect of the HHP treatment – for the purposes of a processing plant – can well be calculated from literature data and from laboratory measurements. This very advantageous characteristic is due to the fact that with HHP technology the same pressure

bears on every point of the treated material simultaneously, regardless of the volume or size of the product.

Acknowledgements

Our research materials were produced with generous contributions from the KMR_12-1-2012-0181 research and development project titled "Support of market-oriented development ability in the central Hungary region". We are very grateful for this.

References

[1] I. Dalmadi, J. Farkas, Gyümölcskészítmények tartósítása nagy hidrosztatikus nyomással. *Élelmezési Ipar*, 60. (2006) 262–264.

[2] M. F. San Martin, G. V. Barbosa-Cánovas, B. G. Swanson, Food processing by high hydrostatic pressure. *Critical Reviews in Food Science and Nutrition*, 42. (2002) 627–645.

[3] D. Farr, High pressure technology in the food industry. *Trends Food Sci. Tech.*, 1. (1990) 14–16.

[4] R. V. Lechowich, Food safety implications of high hydrostatic pressure as a food processing method. *Food Technol.* Chicago, 47. (1993) 170–172.

[5] D. Rici, A. B. Martin-Diana, J. M. Barat, C. Barry-Ryana, Extending and measuring the quality of fresh-cut fruit and vegetables: a review. *Trends Food Sci. Tech.*, 18. (2007) 373–386.

[6] M. Oey, Lille, A. V. Loeya, M. Hendrickxa, Effect of high-pressure processing on colour, texture and flavour of fruit- and vegetable-based food products: a review. *Trends Food Sci. Tech.*, 19. (2008) 320–328.

[7] D. Knorr, A. Froehling, H. Jaeger, K. Reineke, O. Schlueter, K. Schoessler, Emerging technologies, in food processing. *Annual Reviews in Food Science and Technology*, 2. (2011) 203–235.

[8] H. Alpas, N. Kalchayanand, F. Bozoglu, B. Ray, Interactions of high hydrostatic pressure, pressurization temperature and pH on death and injury of pressure-resistant and pressure-sensitive strains of foodborne pathogens. *Int. J. Food Microbiol.*, 60. (2000) 33–42.

[9] J. L. Tholozan, M. Ritz, F. Jugiau, M. Federichi, J. P. Tissier, Physiological effects of high hydrostatic pressure treatments on Listeria monocytogenes and Salmonella Typhimurium. *J. Appl. Microbiol.*, 88. (2000) 202–212.

[10] M. T. Aymerich, A. Jofré, M. Garriga, M. Hugas, Inhibition of Listeria monocytogenes and Salmonella by natural antimicrobials and high hydrostatic pressure in sliced cooked ham. *J. Food Prot.*, 68. (2005) 173–177.

[11] J. Yuste, R. Pla, M. Mor-Mur, Salmonella Enteritidis and aerobic mesophiles in inoculated poultry sausages manufactured with high-pressure processing. *Lett. Appl. Microbiol.*, 31. (2000) 374–377.

[12] B. M. Mackey, K. Forestiere, N. Isaacs, R. Stenning, B. Brooker, The effect of high hydrostatic pressure on Salmonella Thompson and Listeria monocytogenes examined by electron microscopy. *Lett. Appl. Microbiol.*, 19. (1994) 429–432.

[13] M. F. Patterson, M. Quinn, R. K. Simpson, A. Gilmour, Sensitivity of vegetative pathogens to high hydrostatic pressure treatment in phosphate buffered saline and foods. *J. Food Protect.*, 58. (1995) 524–529.

[14] H. Chen, Temperature assisted pressure inactivation of Listeria monocytogenes in turkey breast meat. *Int. J. Food Microbiol.*, 117. (2007) 55–60.

[15] P. Morales, J. Calzada, M. Nunez, Effect of high pressure treatment on the survival of Listeria monocytogenes Scott A in sliced vacuum-packaged Iberian and serrano cured hams. *J. Food Prot.*, 69. (2006) 2539–2543.

[16] E. Ponce, R. Pla, E. Sendra, B. Guamis, M. Mor-Mur, Combined effect of nisin and high hydrostatic pressure on destruction of Listeria inocua and Escherichia coli in liquid whole egg. *Int. J. Food Microbiol.*, 43. (1998) 15–19.

[17] K. J. Hauben, D. H. Bartlett, C. C. Soontjens, K. Cornelis, E. Y. Weytack, C. W. Michiels, Escherichia coli mutants resistant to inactivation by high hydrostatic pressure. *Lett. Appl. Microbiol.*, 63. (1997) 945–950.

[18] G. Arroyo, P. D. Sanz, G. Préstamo, Response to high-pressure, low-temperature treatment in vegetables: determination of survival rates of microbial populations using flow cytometry and detection of peroxidase activity using confocal microscopy. *J. Appl. Microbiol.*, 86. (1999) 544–556.

[19] J. Trujillo, M. Cappelas, J. Saldo, R. Gervilla, B. Guamis, Applications of high-hydrostatic pressure on milk and dairy products: a review. *Innovative Food Science and Emerging Technologies*, 3. (2002) 295–307.

[20] B. Rubio, B. Martinez, M. D. Garcia-Gachán, J. Rovira, I. Jaime, Effect of high pressure preservation on the quality of dry cured beef "Cecina de Leon". *Innovative. Food Sci Emerg Technol.*, 8. (2007) 102–110.

[21] E. Tuboly, Nagy hidrosztatikus nyomású technológiai alkalmazásának hatásai néhány élelmiszer mikrobiológiai állapotára és más minőségjellemzőjére. *Doktori értekezés.* (2009)

[22] G. D. Aleman, D. F. Farkas, J. A. Torrws, E. Wilhelmsen, S. Mcintyre, Ultra-high pressure pasteurization of fresh cut pineapple. *J. Food Prot.*, 57. (1994) 931–934.

[23] Cs. Németh, I. Dalmadi, B. Mráz, L. Friedrich, I. Zeke, R. Juhász, Á. Suhajda, Cs. Balla, Effect of high pressure treatment on liquid whole egg. *High Pressure Res.*, 32. (2012) 330–336.

[24] M. Garriga, N. Grébol, M. T. Aymerich, J. M. Monfort, M. Hugas, Microbial inactivation after high-pressure processing at 600 MPa in commercial meat products over its shelf-life. *Innovative Food Science and Emerging Technologies*, 5. (2004) 451–457.