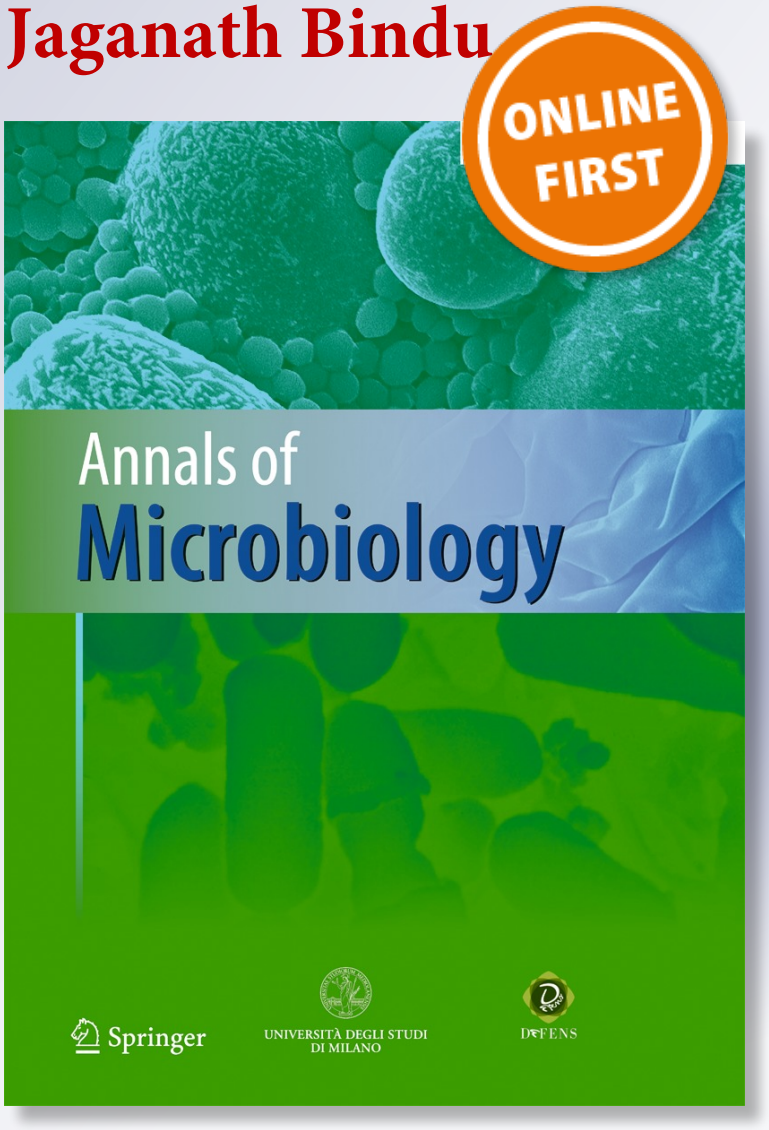
High pressure destruction kinetics along with combined effect of potassium sorbate and high pressure against Listeria monocytogenes *in Indian white prawn muscle*

Sanjoy Das, Kuttanappilly Velayudhanelayadom Lalitha, Ginson Joseph, Chandrasekharan Kamalakshi Kamalakanth & Jaganath Bindu

Annals of Microbiology

ISSN 1590-4261

Ann Microbiol
DOI 10.1007/s13213-015-1100-7



Springer

Ann Microbiol
DOI 10.1007/s13213-015-1100-7

ORIGINAL ARTICLE

High pressure destruction kinetics along with combined effect of potassium sorbate and high pressure against *Listeria monocytogenes* in Indian white prawn muscle

Sanjoy Das[1,2] · Kuttanappilly Velayudhanelayadom Lalitha[2] · Ginson Joseph[2,3] · Chandrasekharan Kamalakshi Kamalakanth[2] · Jaganath Bindu[2]

Received: 9 September 2014 / Accepted: 19 May 2015

Abstract High hydrostatic pressure treatment not only inactivates the pathogenic and spoilage microorganisms present in the food but also preserves its sensory and organoleptic characters and nutrient value. In this study, the high-pressure destruction kinetics of an important food-borne pathogen *Listeria monocytogenes* ATCC 19115 was studied in Indian white prawn (*Fenneropenaeus indicus*) muscle. Headless muscle of prawn was artificially spiked with *L. monocytogenes* ATCC 19115 at the level of approximately 10^7 CFU/g. The spiked samples were vacuum-packed in an ethylene vinyl alcohol (EVOH) pouch and then subjected to high-pressure treatment at different pressure levels (250, 300, 350 and 400 MPa) for different durations of time. Pressure D values were estimated at different pressure levels. The pressure D values at 250, 300, 350 and 400 MPa were estimated as 34.521, 11.806, 5.92 and 5.099 min, respectively. It was observed that, even after 400 MPa pressure treatment for 12 min, the concentration of the *L. monocytogenes* population was found to be 3.387 Log_{10} CFU/g. The combination of high pressure and potassium sorbate dip treatment (in acidic pH) was found to be very useful in inactivating *L. monocytogenes*. Potassium sorbate (0.1 %) dip for 15 min coupled with 250 and 350 MPa pressure reduced the level of *L. monocytogenes* by 2.345 and 5.908 Log_{10} CFU/g, respectively. Thus, it can be concluded that pressure treatment alone is not sufficient enough to inactivate this pathogen in prawn muscle. The combination of potassium sorbate with high-pressure treatment is a promising approach to inactivate *L. monocytogenes* in Indian white prawn muscle.

Keywords *Listeria monocytogenes* · Prawn · Pressure destruction kinetics

Introduction

Listeria monocytogenes, a Gram-positive intracellular pathogen, is the causal agent for various serious illnesses, including abortion, encephalitis, arthritis, gastroenteritis, conjunctivitis, etc., in human beings with a high hospitalization and mortality rate (Va´zquez-Boland et al. 2001; Scallan et al. 2011). Contaminated food, water and beverages are known to be the major source of listeria infection. This pathogen is present in almost all types of environment and has been isolated from different varieties of food items including seafood. Being a psychrotrophic organism, *L. monocytogenes* can grow in food items stored at refrigerated temperature (Junttila et al. 1988). Hence, in the food industry, the control of this pathogen is a major challenge due to its ability to grow and survive in a wide range of environmental conditions within different types of food items including processed foods.

Among seafood, prawn is the most important commercially traded items because of its high market value and demand. On

✉ Sanjoy Das
sanjoy125@yahoo.co.in

Kuttanappilly Velayudhanelayadom Lalitha
kvlalithaa@gmail.com

Ginson Joseph
jinsonjosephif@gmail.com

Chandrasekharan Kamalakshi Kamalakanth
kamalakanthck@gmail.com

Jaganath Bindu
bindujaganath@gmail.com

[1] Present address: Kakdwip Research Centre of CIBA, P.O.- Kakdwip, Dist. South 24 Parganas, West Bengal 743347, India

[2] Fish Processing Division, Central Institute of Fisheries Technology, Matsyapuri P.O., Cochin 682029, India

[3] Present address: St Alberts College, Banerjee Road, Cochin 682018, Kerala, India

Published online: 16 June 2015

the value basis, frozen shrimp is a major export items among seafood from India and accounts for 64.12 % of the total revenue generated through the export of seafood from India during the 2013–14 financial year (MPEDA 2015). But, due to the presence of different pathogenic and spoilage bacteria, it is very often a great public health hazard. The occurrence of *Listeria* spp. and *L. monocytogenes* has also been reported in different types of seafood including prawn (Wang et al. 2011; Zarei et al. 2012; Das et al. 2013b).

High-pressure processing, which is also known as cold pasteurization, is considered to be one of the potential methods of preservation of food. The major advantage of high-pressure treatment is that it destroys to a great extent the pathogenic and commensal microorganisms present in food without compromising the sensory and organoleptic characteristics and nutrient value of the food (Smelt 1998; Wimalaratne and Farid 2008). The use of high pressure in food was first introduced in 1899 for the preservation of milk (Hite 1899) and, with the passage of time, its application has been extended in different parts of world to varieties of food items including seafood. At the present time, many high-pressure-treated commercial food products are available in markets, like fruit juices, jams, vegetables, herb products, seafood, etc. In order to assess the susceptibility of any organism to high hydrostatic pressure in any particular medium, it is very important to study the pressure destruction kinetics of the pathogen with time–pressure relationship. The pressure destruction kinetics of *Escherichia coli* was studied in apple juice by Ramaswamy et al. 2003. In the case of *L. monocytogenes*, the high-pressure destruction kinetics was studied in pork, milk and frankfurters (Mussa et al. 1998, 1999; Lucore et al. 2000). But so far no work has been carried out on the pressure destruction kinetics of this pathogen in prawn muscle. *Listeria monocytogenes* usually survives up to a high level of hydrostatic pressure treatment in food, particularly when pressure treatment alone is the only inhibiting factor. To reduce its population by 5 Log_{10} in frankfurters, pressure treatment at 700 MPa for 9 min is necessary (Lucore et al. 2000). As per past studies, this high level of pressure treatment is not suitable for the sensory characteristics of prawn muscle, as a cooked whitish appearance was observed at the pressure level of 435 MPa or above (Ginson et al. 2013). Consequently, in the past, many workers have focused, with varying success, on the synergistic effect of high-pressure treatment with other factors, like the application of mild heating, alternating current, use of nisin, lysozyme, etc., in different types of food (Shimada 1992; Heuben et al. 1996; Das et al. 2013a). Potassium sorbate is a commonly used class II preservative, which has been previously shown to be effective against different food-borne pathogenic bacteria including *L. monocytogenes* (Beuchat 1980; Hazarika et al. 2003), and application of this preservative is permitted in different food products in USA and Canada, with the permissible limit in most types of food being generally 0.1 % (USFDA 2013; Health Canada 2014). Previous studies in this aspect have also shown that potassium sorbate sensitizes the cells of *L. monocytogenes* to high hydrostatic pressure treatment (Mackey et al. 1995). But, until now, there has been no reported study of the combined effect of high pressure and potassium sorbate treatment for controlling *L. monocytogenes* in the muscle of Indian white prawn.

Keeping these facts in view, the current study has been undertaken with the objectives of determining the pressure destruction kinetics of *L. monocytogenes* in Indian white prawn muscle (*Fenneropenaeus indicus*) and of assessing the combined effect of potassium sorbate and high-pressure treatment against this pathogen in this seafood.

Materials and methods

Bacterial culture

Listeria monocytogenes ATCC 19115 was used in this current study. The strain was procured from the American type culture collection and was maintained on Tryptic soy agar (BD Difco) slants at 4 °C with intermittent subculture.

Preparation of culture for artificial spiking

Ten ml of tryptic soya broth (TSB) (BD Difco, USA) was inoculated with a loopful of culture of *L. monocytogenes* ATCC 19115 and was incubated at 37 °C for 18 h. The culture in the exponential phase was centrifuged at 7000 *g* for 10 min at 4 °C and the resultant pellet was dissolved in 10 ml sterile phosphate-buffered saline (PBS) (Na_2HPO_4 1.910 g, KH_2PO_4 0.38 g, NaCl 8.5 g, and distilled water upthe to 1 l, pH 7.2) . The bacterial population of the suspension was determined by plating different dilutions prepared in sterile normal saline on tryptic soya agar plates (TSA) (BD Difco). Based on the bacterial concentration, an appropriate amount of PBS was added to a suitable amount of bacterial suspension to make a stock bacterial suspension containing 10^9 CFU of *L. monocytogenes* per ml, and 100 μl (10^8 CFU) from the stock suspension was used for artificial spiking.

Prawn sample and artificial spiking

Fresh Indian white prawn (*Fenneropenaeus indicus*) samples were obtained from fish landing centre of Fort Kochi, Kerala. The samples were collected on ice in an insulated box and transported to the laboratory in chilled condition. After arriving at the laboratory, the prawns were beheaded and washed with potable water. Ten grams of prawn muscle were spiked with approximately 10^8 CFU of *L. monocytogenes* making the final concentration of bacteria 10^7 CFU/g. The spiking was

carried out following Das et al. (2011). The stock suspension was mixed thoroughly by vortexing and 100 μl was spread on 10 g of prawn muscle. The spreading was done on different parts of the piece of muscle. Following spiking, the samples were left at room temperature for 1 h for absorption of the inoculum. Before spiking, the samples were screened for the presence of *Listeria* spp. by the ISO 11290 Part 1 method as mentioned in previous studies (Scotter et al. 2001; Das et al. 2013b).

High hydrostatic pressure treatment for estimation of pressure D value

High hydrostatic pressure treatment was carried out in high-pressure processing equipment (model no FPG 71009 / 2C; M/s Stansted Fluid Power, Harlow, Essex, UK) with a cylindrical type pressure chamber. The capacity of the pressure vessel was 2 l, with length and diameter being 570 and 70 mm, respectively. The pressure transmitting fluid used was 30 % monopropylene glycol. The temperature within the pressure chamber was monitored by a K-type thermocouple. The pressure treatment was carried out with four different pressure levels (250, 300, 350 and 400 MPa) for different periods of time at 600 MPa/min ramp rate with a set temperature of 30 °C. The temperature increased up to 32 °C while the pressure built up and decreased to 28 °C during decompression. The decompression time was 72 s. The reported pressure holding time in this study does not include the pressure build up and decompression time. The pressure treatment at 250 MPa was done for 0, 10, 20, 30 and 40 min, while the holding times of 0, 7, 14, 21 and 28 min were applied in the case of the 300 MPa pressure treatment. At 350 MPa, the pressure treatment was done for 0, 5, 10, 15 and 20 min whereas, at 400 MPa, the pressure treatment was carried out at 0, 3, 6, 9 and 12 min. In case of pressure treatment at 0 min, the vessel was allowed to attain the pressure, held for 2 s and then the pressure was released. All the experiments were carried out in duplicate and mean values were taken into consideration.

Enumeration of *L. monocytogenes*

Ten grams of pressure-treated spiked samples were added with 90 ml of sterile normal saline (0.85 % NaCl) into the EVOH pouch and blended in a stomacher blender (Seward, UK). The blending was carried out twice at the speed of 230 rpm for 30 s and then further 10-fold serial dilutions were prepared in sterile normal saline solution. The enumeration of *L. monocytogenes* was done by plating serially diluted sample on preset PALCAM agar plates (BD Difco) with 2.5 % egg yolk, which was added to the media for the revival of injured cells. The plates were incubated at 37 °C for 48 h. The counting was done and the result was expressed in Log_{10} values of CFU/g.

Determination of pressure D value

The pressure D value at a particular pressure level refers to the time required to reduce the bacterial population by 90 %. For calculation of pressure D values, the Log_{10} values of CFU/g at different pressures and times were plotted on MS Excel and the linear curve with the equation was deduced. The pressure D value was calculated using the equation obtained in MS Excel.

Study of combined effect of potassium sorbate and high hydrostatic pressure

Ten grams of prawn muscle was artificially spiked with approximately 10^8 CFU of *L. monocytogenes* ATCC 19115 (final concentration approximately 10^7 CFU/g). The preparation of the culture and the artificial spiking followed the same procedure as mentioned in the previous section. The spiked sample of prawn muscle was dipped in 30 ml of potassium sorbate solution (0.1 %) prepared in 0.02 (N) HCl for 15 min. Then, the sample was vacuum-packed in an EVOH pouch. This was followed by high-pressure treatment with 250 and 350 MPa at around 30 °C with 5 min holding time. The same equipment which was used for determination of D value was also used for this study. The pressure vessel, pressure transmitting fluid, ramp rate and pressure decompression time were the same as in the case of determining the pressure D value. One set of samples was not treated with high pressure after vacuum packing and one set was also used as control without pressure and potassium sorbate treatment. The samples of the control group were dipped in sterile normal saline solution for 15 min. The study was conducted in triplicate. The enumeration of the level of *L. monocytogenes* was done on PALCAM agar (BD Difco) containing 2.5 % egg yolk as mentioned previously.

Analysis of data

IBM SPSS v.22 was used for statistical analysis. One-way ANOVA was carried out to discover the difference between different treatment groups of the combined effects of potassium sorbate and high-pressure treatment (A = control group, B= treated only with 0.1 % potassium sorbate, C= treated with 0.1 % potassium sorbate and 250 MPa pressure, D = treated with 0.1 % potassium sorbate and 350 MPa pressure). Once the ANOVA was found to be significant at the 5 % level, Duncan's multiple range test was performed to compare the means of different treatment groups ($p<0.05$).

Results and discussion

The Indian white prawn (*Fenneropenaeus indicus*) samples used in this study were confirmed as free from *Listeria* spp. by the standard method as mentioned in the "Materials and methods".

Pressure destruction kinetics

A reduction of the population of *L. monocytogenes* was observed with the increasing duration of pressure treatment at each pressure level (250, 300, 350 and 400 MPa). Before applying the pressure treatment, the initial level of *L. monocytogenes* was around 10^7 CFU/g, as 10^8 CFU were inoculated for 10 g. At 0 min holding time, the concentration of the *Listeria* population was found to be 6.844, 6.782, 6.76 and 5.734 Log_{10} CFU/g at 250, 300, 350 ad 400 MPa pressure levels, respectively. A more rapid reduction was possible at higher pressure levels. The pressure decimal reduction time (pressure D value) was found to be 34.521, 11.806, 5.92 and 5.099 min at 250, 300, 350 and 400 MPa pressure levels, respectively. The results of pressure destruction trends have been depicted in Table 1 and Fig. 1a–d.

So, it is evident that there was a rapid reduction of the pressure D value when the pressure was increased from 250 to 300 MPa. But a further increase of pressure beyond 300 MPa showed a slow decrease of the pressure D value. After applying a pressure treatment of 400 MPa for 12 min, the level of surviving cells of *L. monocytogenes* was observed as 3.387 Log_{10} CFU/g.

Table 1 Effect of different pressure levels for different durations on *L. monocytogenes* ATCC 19115 in Indian white prawn muscle

Pressure (MPa)	Holding time (min)	Concentration of *L. monocytogenes* (Log_{10} CFU/g) (mean value)
250	0	6.844
250	10	6.464
250	20	6.384
250	30	5.865
250	40	5.695
300	0	6.782
300	7	6.108
300	14	4.920
300	21	4.809
300	28	4.466
350	0	6.760
350	5	5.204
350	10	3.951
350	15	3.803
350	20	3.239
400	0	5.734
400	3	4.919
400	6	4.342
400	9	3.731
400	12	3.387

The effect of combined treatment of high pressure and potassium sorbate

The 250 and 350 MPa pressure treatments coupled with potassium sorbate dip treatment reduced the level of *L. monocytogenes* by 2.345 and 5.908 Log_{10} CFU/g, respectively. However, the reduction of the level of this pathogen by just the potassium sorbate treatment was found to be 0.986 Log_{10} CFU/g when compared to the control (Fig. 2). Statistical analysis showed that potassium sorbate treatment alone did not significantly reduce the population of *L. monocytogenes* in prawn muscle whereas, a significant reduction was observed with potassium sorbate treatment in combination with both 250 and 350 MPa pressure treatments ($p<0.5$) (Fig. 2).

Listeria monocytogenes can resist high hydrostatic pressure. Recently, it has been found that the proline synthesis gene (proAB) plays a role in the barotolerance of *L. monocytogenes* (Considine et al. 2011). In this organism, high pressure induces the increased expression of genes involved in the DNA repair mechanism, transcription and translation protein complexes, the septal ring, the general protein translocase system, flagella assemblage, chemotaxis and lipid and peptidoglycan biosynthetic pathways (Bowman et al. 2008). In this study, it is interesting to note that even 400 MPa pressure treatment for 12 min could reduce the population only to 3.387 Log_{10} CFU/g. In comparison to this study, in the case of *E. coli*, 350 MPa pressure treatment for 3 min reduced the population from 8.0 to 2.22 Log_{10} CFU/ml in apple juice (Ramaswamy et al. 2003). Another study showed that 700 MPa pressure treatment for 9 min was required to reduce the population of *L. monocytogenes* by 5 log_{10} in frankfurters (Lucore et al. 2000). Myers et al. (2013) observed that 600 MPa pressure treatment for 3 min could reduce the population of this organism by only 3.85–4.35 log_{10} CFU/g in ready-to-eat sliced ham and turkey meat. Thus, the current study reiterated the fact that *L. monocytogenes* is a highly high-pressure-resistant organism and very high pressure is required to inactivate it. But this much high pressure is not suitable for the sensory attributes of prawn (Ginson et al. 2013). So, it can be stated that pressure treatment alone may not be sufficient to inactivate this pathogen in prawn muscle and a combination of other inhibitory factors with high-pressure treatment is required to inactivate it in prawn muscle to a greater extent.

Potassium sorbate is a safe preservative, the use of which is generally allowed in different kinds of food including fish (USFDA 2013; Health Canada 2014). According to USFDA,

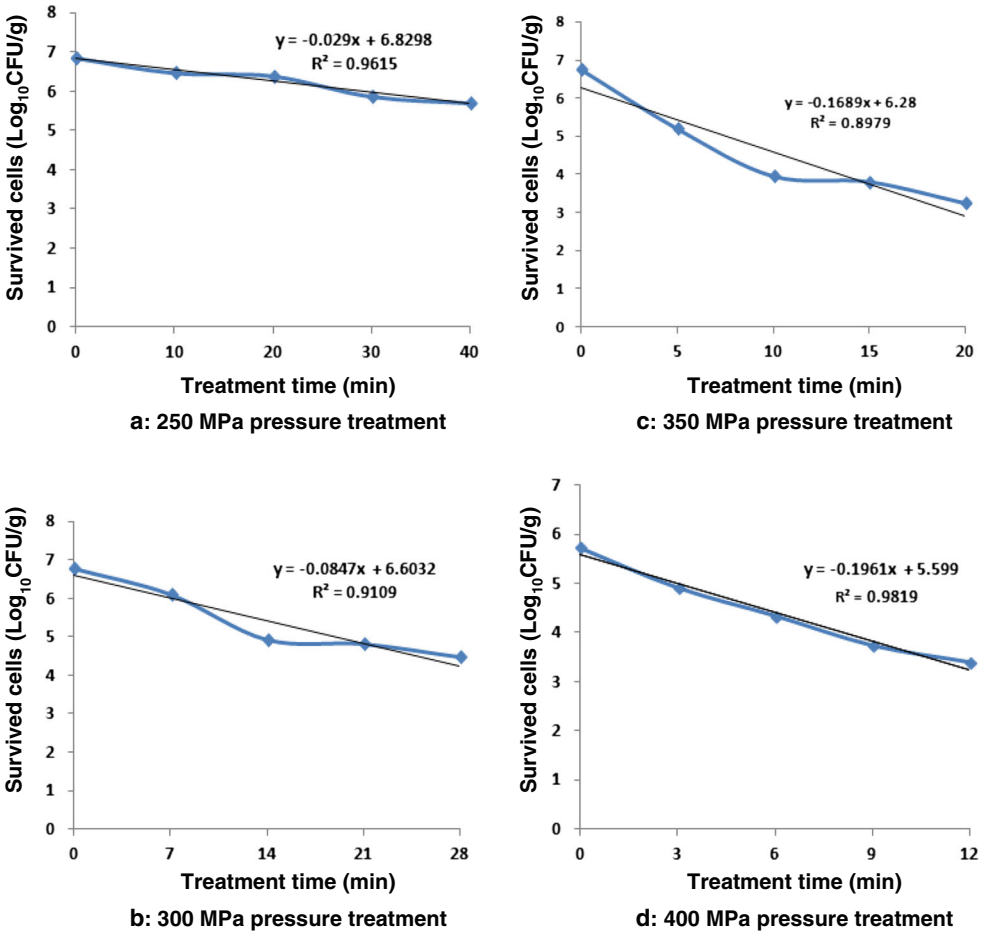
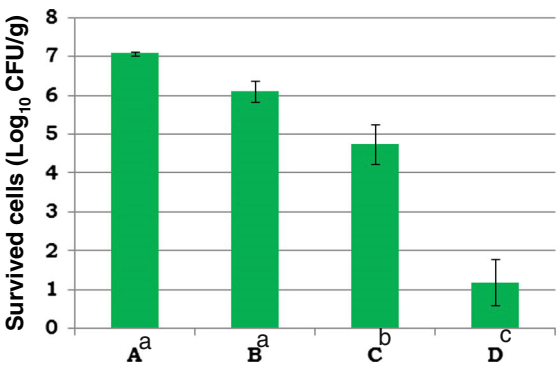


Fig. 1 Pressure destruction kinetics of *Listeria monocytogenes* ATCC 19115 at different pressure levels in Indian white prawn muscle. **a** 250 MPa pressure treatment. **b** 300 MPa pressure treatment. **c** 350 MPa pressure treatment. **d** 400 MPa pressure treatment

this preservative is generally recognized as safe when used in accordance with good manufacturing practices (CFR 2013).



A = Control (7.089[a] ± 0.050)
B = Only Potassium sorbate (6.103[a] ± 0.271)
C = Potassium sorbate + 250 MPa pressure (4.744[b] ± 0.515)
D = Potassium sorbate + 350 MPa pressure (1.181[c] ± 0.592)
(p< 0.05)

Fig. 2 Effect of high pressure and potassium sorbate on *Listeria monocytogenes* in Indian white prawn (*Fenneropenaeus indicus*). **a** Control (7.089a±0.050). **b** Only potassium sorbate (6.103a±0.271). **c** Potassium sorbate+250 MPa pressure (4.744b±0.515). **d** Potassium sorbate+350 MPa pressure (1.181c±0.592) ($p<0.05$)

Potassium sorbate and other related class 2 preservatives (e.g. sodium benzoate) work well at low pH (Hazarika et al. 2003), and it has also been reported that microorganisms are more pressure-sensitive when the pH is low (Alpas et al. 2000). To reduce the pH, the potassium sorbate solution for dip treatment was prepared in 0.02(N) HCl. The present study revealed that the combination of potassium sorbate and high pressure was very effective in reducing *L. monocytogenes* in Indian white prawn muscle as compared to potassium sorbate treatment alone (Fig. 2). The level of reduction of *L. monocytogenes* ATCC 19115 was 2.345 and 5.908 Log_{10} CFU/g, when potassium sorbate treatment was combined with pressure treatments of 250 and 350 MPa, respectively. As compared to potassium sorbate treatment alone, an additional 1.359 and 4.922 Log_{10} CFU/g more reduction was observed when combined with 250 and 350 MPa pressure treatment, respectively (Fig. 2). On the other hand, when only high-pressure treatment was used, 250 and 350 MPa pressure treatment reduced the level of the same organism by only 0.496 and 2.532 Log_{10} CFU/g, respectively, in Indian white prawn muscle (Das et al. 2013a).

So, this study indicates that just high-pressure treatment is not enough to inactivate *L. monocytogenes* in prawn muscle, and a combination of other inhibitory factors is required to

achieve greater reduction in the level of this pathogen. Among the inhibitory factors, potassium sorbate is a good candidate, and a high level of decline in the level of *L. monocytogenes* can be achieved by applying potassium sorbate dip treatment before proceeding to high-pressure processing. However, this present study can be extended to involve a large number of isolates of this food-borne pathogen and by preparing potassium sorbate solution in different organic acids like lactic acid, acetic acid, etc. It is also required to conduct a monitoring study of organoleptic characteristics during the storage of seafood with added potassium sorbate as a preservative.

Conclusion

The pressure destruction kinetics of *L. monocytogenes* ATCC 19115 in the muscle of Indian white prawn (*Fenneropenaeus indicus*) was estimated as 34.521, 11.806, 5.92 and 5.099 min at 250, 300, 350 and 400 MPa pressure level, respectively. So, this study reiterated the fact that *L. monocytogenes* is pressure-resistant organism and a very high hydrostatic pressure is required for its inactivation in food stuffs. But one has to compromise with the sensory characteristics of food including prawn for the application of very high pressure. To overcome this problem, the combination of high pressure with other inhibitory factors is a good approach. The present study showed that a combined treatment of potassium sorbate dip followed by high pressure is very effective in reducing the viable load of *L. monocytogenes* in the muscle of Indian white prawn.

Acknowledgments The authors are very grateful to the Director, CIFT, for providing the necessary facilities for carrying out this work. The financial assistance obtained from National Agricultural Innovation Project (NAIP) is also greatly acknowledged.

References

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

Beuchat LR (1980) Comparison of anti-*Vibrio* activities of potassium sorbate, sodium benzoate, and glycerol and sucrose esters of fatty acids. Appl Environ Microbiol 39:1178–1182

Bowman JP, Bittencourt CR, Ross T (2008) Differential gene expression of *Listeria monocytogenes* during high hydrostatic pressure processing. Microbiology 154:462–475

CFR (2013) CFR- Code of Federal Regulations Title 21 dated April 1, 2013. United States Food and Drug Administration. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=582.3640&SearchTerm=potassium%20sorbate Accessed 16 Feb 2015

Considine KM, Sleator RD, Kelly AL, Fitzgerald GF, Hill C (2011) A role of proline synthesis and transport in *Listeria monocytogenes* barotolerance. J Appl Microbiol 110:1187–1194

Das S, Singh VP, Ltu K, Kathiresan S, Sharma B, Bhilegaonkar KN (2011) Detection of *Listeria monocytogenes* from freshwater fish, prawn and chicken meat by direct nested PCR. Asian Fish Sci 24: 432–442

Das S, Lalitha KV, Ginson J, Bindu J (2013a) Combination of nisin and high pressure processing: an effective method of inactivating *Listeria monocytogenes* in white shrimp. Presented at 3rd International Conference on Food Technology (INCOFTECH) held at Indian Institute of Crop Processing Technology (IICPT), Thanjavur, India, during January 4–5, 2013

Das S, Lalitha KV, Thampuran N, Surendran PK (2013b) Isolation and characterization of *Listeria monocytogenes* from tropical seafood of Kerala, India. Ann Microbiol 63:1093–1098

Ginson J, Kamalakanth CK, Bindu J, Venkateswarelu R, Das S, Chauhan OP, Gopal TSK (2013) Changes in K value, microbiological and sensory acceptability of high-pressure proessed Indian white prawn (*Fenneropenaeus indicus*). Food Bioprocess Technol 6:1175–1180

Hazarika RA, Singh DK, Kapoor KN, Bhilegaonkar KN, Agarwal RK, Malik SV (2003) Survivality of vero toxic *E. coli* O111 against sodium benzoate and potassium sorbate added to simulating media for beef gravy. J Vet Publ Health 1:103–112

Health Canada (2014) List of permitted preservatives (List of permitted food additives). http://www.hc-sc.gc.ca/fn-an/securit/addit/list/11-preserv-conserv-eng.php#a1. Accessed 16 May 2014

Heuben KJA, Wuytack EY, Soontjes CCF, Michiels CW (1996) High-pressure transient sensitization of *Eschericia coli* to lysozyme and nisin by disruption of outer-membrane permeability. J Food Prot 59: 350–355

Hite BH (1899) The effect of pressure in the preservation of milk. West Virginia Univ Agric Exp Station Bull 146:1–67

Junttila JR, Niemala SI, Hirn J (1988) Minimum growth temperature of *Listeria monocytogenes* and non-hemolytic listeria. J Appl Bacteriol 65:321–327

Lucore LA, Shellhammer TH, Yousef AE (2000) Inactivation of *Listeria monocytogenes* Scott A on artificially contaminated frankfurters by high-pressure processing. J Food Prot 63:662–664

Mackey BM, Forestiere K, Issac N (1995) Factors affecting the resistance of *Listeria monocytogenes* to high hydrostatic pressure. Food Biotechnol 9:1–11

MPEDA (2015) Marine product export crosses US $ 5 billion during 2013–14. http://www.mpeda.com/inner_home.asp?pg=trends. Accessed 9 Feb 2015

Mussa DM, Ramaswamy HS, Smith JP (1998) High pressure (HP) destruction kinetics of *Listeria monocytogenes* Scott A in raw milk. Food Res Int 31:343–350

Mussa DM, Ramaswamy HS, Smith JP (1999) High pressure destruction kinetics of *Listeria monocytogenes* on pork. J Food Prot 62:40–45

Myers K, Montoya D, Cannon J, Dickson J, Sebranek J (2013) The effect of high hydrostatic pressure, sodium nitrite and salt concentration on the growth of *Listeria monocytogenes* on RTE ham and turkey. Meat Sci 93:263–268

Ramaswamy HS, Riahi E, Idziak E (2003) High pressure destruction kinetics of *E. coli* (29055) in apple juice. J Food Sci 68:1750–1756

Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowso M-A, Roy SL, Jones JL, Griffin PM (2011) Food-borne illnesses acquired in the United States-Major pathogens. Emerg Infect Dis 17:7–15

Scotter SL, Langton S, Lombard B, Schulten S, Nagelkere N, Int Veld PH, Rollier P, Lahellec C (2001) Validation of ISO method 11290 Part 1- Detection of *Listeria monocytogenes* in foods. Int J Food Microbiol 64:295–306

Shimada K (1992) Effect of combination treatment with high pressure and alternating current on the total damage of *Escherichia coli* cells and *Bacillus subtilis* spores. In: Balny C, Hayashi R, Heremans K, Masson P (eds) High pressure and Biotechnology. Libbey, London, pp 49–51

Smelt JPPM (1998) Recent advances in microbiology of high pressure processing. Trends Food Sci Technol 9:152–158

USFDA (2013). Food additive status list. http://www.fda.gov/food/ingredientspackaginglabeling/foodadditivesingredients/ucm091048.htm. Accessed 16 May 2014

Va´zquez-Boland JA, Kuhn M, Berche P, Chakraborty T, Domi´nguez-Bernal G, Goebel W, Gonza´Lez-Zorn B, Wehland J, Kreft J (2001) *Listeria* pathogenesis and molecular virulence determinants. Clin Microbiol Rev 14:584–640

Wang F, Jiang L, Yang Q, Han F, Chen S, Pu S, Vance A, Ge B (2011) Prevalence and antimicrobial susceptibility of major food-borne pathogens in imported seafood. J Food Prot 74:1451–1461

Wimalaratne SK, Farid MM (2008) Pressure assisted thermal sterilization. Food Bioprod Process 86:312–316

Zarei M, Maktabi S, Ghorbanpour M (2012) Prevalence of *Listeria monocytogenes*, *Vibrio parahaemolyticus*, *Staphylococcus aureus*, and *Salmonella* spp. in seafood products using multiplex polymerase chain reaction. Foodborne Pathog Dis 9:108–112