Korean J. Food Sci. An. Vol. 36, No. 2, pp. 283~288(2016)
© 2016 Korean Society for Food Science of Animal Resources
DOI http://dx.doi.org/10.5851/kosfa.2016.36.2.283
ISSN 1225-8563 eISSN 2234-246X

ARTICLE

Identification of Microorganisms in Duck Meat Products Available in Korea and the Effect of High Hydrostatic Pressure

Hyun-Joo Kim[1], Hae In Yong, Hyun Jung Lee, Samooel Jung[2], Joong-Ho Kwon[3], Kang Nyung Heo[4], and Cheorun Jo*

Department of Agricultural Biotechnology, Center for Food and Bioconvergence, and Research Institute of Agriculture and Life Science, Seoul National University, Seoul 08826, Korea
[1]Post-harvest Technology Division, National Institute of Crop Science, RDA, Suwon 16616, Korea
[2]Department of Animal Science and Technology, Chungnam National University, Daejeon 34134, Korea
[3]Department of Food Science and Technology, Kyungpook National University, Daegu 41566, Korea
[4]Department of Poultry Science, National Institute of Animal Science, RDA, Cheonan 31016, Korea

Abstract

The objective of this study was to investigate the microbial count of duck meat and duck meat products commercially available in Korea. High hydrostatic pressure (HHP) treatment was applied at 0.1, 300, 400, and 500 MPa for 5 min to enhance the microbiological safety of duck meats. The levels of total aerobic bacteria were in the ranges of 3.53-6.19 and 3.62-6.85 Log CFU/g in raw and smoked duck products, respectively. By DNA sequence analysis, we identified microorganisms responsible for spoilage, with the most common species in the raw and smoked duck products being *Aeromonas* spp. or *Pseudomonas* spp. and *Leuconostoc mesenteroides*, respectively. HHP treatment significantly reduced the levels of total aerobic bacteria in raw and smoked duck products. This study demonstrates that HHP treatment may be used to effectively improve the safety of raw and smoked duck meat products.

Keywords: duck meat products, microbial quality, identification, high hydrostatic pressure

Received March 9, 2015; Revised November 24, 2015; Accepted December 4, 2015

Introduction

Duck meat can be a good source of protein for humans (Adzitey *et al.*, 2012a) and is high in iron, selenium, and niacin, as well as containing fewer calories than many cuts of beef (Adzitey *et al.*, 2012b). Duck meat and duck meat products are relished and consumed by many people worldwide. The consumption of white meats, including duck meat, is gaining more attention owing to recommendations for a reduced intake of red meat due to its association with cardiovascular pathologies (Adzitey *et al.*, 2012b; Witak, 2008). The consumption of duck meat and duck meat products increased approximately 5-folds in Korea from 1997 to 2012 (Korea Duck Association, 2013).

The safety of food products has become a major issue of concern (Kim *et al.*, 2014). The consumption of contaminated duck meat or products, like other types of meat, poses the risk of foodborne diseases; however, it has received little attention in terms of epidemiological studies. For instance, the consumption of duck meat and duck meat products has been associated with outbreaks of salmonellosis (Adzitey *et al.*, 2012b). Contact with young birds, including ducklings in a nursery school, has also been linked to outbreaks of *Salmonella* infections (Merritt and Herlihy, 2003). The Korea Centers for Disease Control and Prevention announced that the prevalence of *Salmonella* spp. in food, especially in poultry meat, is high in the South Korea (Bae *et al.*, 2013). In addition, incidences of *Campylobacter* spp., *Escherichia coli*, *Listeria monocytogenes*, and enterococcus contamination in duck meat have been reported (Adzitey *et al.*, 2013; Hu *et al.*, 2011; Jamali *et al.*, 2015; Sánchez *et al.*, 2007).

High hydrostatic pressure (HHP) processing is a nondestructive and chemical-free food preservation technology that efficiently eliminates food spoilage microorganisms. In particular, HHP has good potential for application in

*Corresponding author: Cheorun Jo, Department of Agricultural Biotechnology, Center for Food and Bioconvergence, and Research Institute of Agriculture and Life Science, Seoul National University, Seoul 08826, Korea. Tel: +82-2-880-4804, Fax: +82-2-873-2211, E-mail: cheorun@snu.ac.kr

the meat industry (Garriga *et al.*, 2004). The ability of HHP to eradicate microorganisms regardless of product geometry and without preservatives/additives (Zhang and Mittal, 2008) make this technology safe and consumer-friendly (Kruk *et al.*, 2014). In the meat sector, its application is increasing continuously, particularly for enhancing the shelf life and safety of raw and sliced cooked products (Khan *et al.*, 2014).

Therefore, the current study was designed with the objectives of evaluating microbial contamination and identifying microorganisms in raw and smoked duck products that are commercially available in the Korea, and for determining the efficiency of HHP in microbial reduction in raw and smoked duck meat products.

Materials and Methods

Sample preparation

Refrigerated raw duck meat (sliced and bone-in whole type), frozen raw duck meat (sliced, deboned, and bone-in whole type), and smoked duck meat products (sliced and bone-in whole type) were purchased from local markets (Seoul, Korea). Each product was labeled randomly by alphabet letters. The samples (approximately 5 g) were transferred into a sterilized oxygen-impermeable nylon bags (2 mL O_2/m^2/24 h at 0°C, 0.09 mm thickness; Sunkyung Co. Ltd., Korea) with a sterilized knife and pincette on a clean bench. The packs were sealed and transferred to a refrigerated storage (4°C) before analysis. The frozen samples were thawed in a refrigerator at 4°C for 24 h before use.

Microbial analysis

Each sample was cut into small pieces (approximately 0.5 × 0.5 cm) and homogenized for 2 min in a sterile Stomacher bag containing 45 mL of sterile saline solution using the Stomacher BagMixer® 400 (Interscience Co., France). Then samples were serially diluted in sterile saline (0.85%) solution, and each diluents (0.1 mL) was spread on plate count agar (Difco Laboratories, USA). Plates were incubated at 37°C for 48 h, and microbial counts were expressed as colony forming units per gram (CFU/g).

Identification of microorganisms

Each strain was identified by using the 16S rDNA sequencing method. Briefly, each single colony from the purified isolates on the plate count agar plates were transferred to 10 mL tryptone soy broth (Difco Laboratories), and the cells were grown overnight at 37°C. The chromosomal DNA of isolated strain was separated by using the SolGent Genomic DNA prep kit (SolGent, Korea). The DNA extracts were used for the polymerase chain reaction (PCR) with the universal primers [27F (5'-AGA GTT TGA TCC TGG CTC AG-3') and 1492R (5'-GGT TAC CTT GTT ACG ACT T-3')] (Marchesi *et al*. 1998). PCR was carried out in a programmable therma cycler (SolGent EF-Taq, Korea), according to the following steps: one cycle of denaturation at 95°C for 15 min, followed by 30 cycles of 95°C for 20 s, 50°C for 40 s, and 72°C for 90 s. The final extension was carried out at 72°C for 5 min. The purified PCR product obtained by using a SolGent PCR purification kit (SolGent, Korea) was used for sequencing by Basic Local Alignment Search Tool (BLAST) search of the National Center for Biotechnology Information (NCBI) (Maidak *et al.*, 2001).

High hydrostatic pressure treatment

The vacuum-packed samples (-650 mmHg in 10 × 10 cm low-density polyethylene/nylon vacuum bags with oxygen permeability of 22.5 mL/m^2/24h atm at 60% RH/25°C and water vapor permeability of 4.7 g/m^2/ 24h at 100% RH/25°C) were transported to the Korea Food Research Institute (Korea) in a cooled container and were immediately subjected to HHP. Samples were placed in a pressure vessel submerged in hydrostatic fluid (Quintus food processor 6; ABB Autoclave Systems, Inc., USA) and pressurized at 300, 400 and 500 MPa for 5 min with the initial temperature of the pressure vessel set at 15± 3°C. The rate of pressurisation was 5-7 MPa/s and the pressure in the chamber was released within 10 s. Control samples were maintained under atmospheric pressure at 4°C while the other samples were treated. Immediately after treatment, all samples were transported on ice to the Laboratory, Seoul, Korea.

Statistical analysis

All experimental procedures were conducted in triplicate with 3 observations. In the results of microbial contamination, mean values and the standard deviation were calculated using a SAS Software and reported. The result of HHP treatment was performed using a one-way analysis of variance (ANOVA). When significant differences were detected, the differences among the mean values were determined by performing the Duncan's multiple comparison test at a confidence level of $p<0.05$.

Results and Discussion

Microbial quality of raw duck and smoked duck products

To evaluate microbiological contamination level of commercial duck meat products available in Korean market, total aerobic bacteria numbers were monitored. The total aerobic bacterial populations in commercial raw duck meats ranged from 3.53 to 6.19 Log CFU/g (Table 1). For refrigerated samples, bone-in whole raw duck meat showed significantly lower total aerobic bacterial counts than those in sliced raw duck meats. Samples stored frozen did not consistently show differences by distribution method. Levels of aerobic bacteria in smoked duck products ranged from 3.62 to 6.85 Log CFU/g (Table 2). Samples did not consistently show differences by distribution method.

Several studies have been carried out to assess the contamination levels of duck meat and duck meat products in Korea. Sung *et al.* (2013) reported numbers of total aerobic bacteria of 4.30, 3.43, and 3.84 Log CFU/g for fresh, fresh-torched, and freeze-thawed types of duck breast meats, respectively. Chae *et al.* (2006) showed that the numbers of total aerobic bacteria and *E. coli* were 3.26 and 0.43 Log CFU/g, respectively. The initial microbial load of meat depends on the physiological status of the duck at slaughter, contamination at slaughterhouses, and contamination during processing. The temperature and storage conditions during distribution also influence the rate of spoilage (Nychas *et al*., 2008). The different microbial groups that potentially contribute to meat spoilage depend on the storage conditions applied and their competition. Our results indicated that raw and smoked duck meat products were not safe enough for consumption. Therefore, an improvement in the safety of raw and smoked duck meat and duck meat products is needed.

Table 1. Microbial population (Log CFU/g) of the raw duck meats commercially available in Korea

Type		Products	Total aerobic bacteria
Refrigerated raw duck meats	Sliced	A[1)]	4.56±0.17[2)]
		B	5.33±0.25
		C	5.75±0.12
	Bone-in whole	D	4.40±0.26
		E	3.68±0.10
		F	3.53±0.24
Frozen raw duck meat	Sliced	G	4.12±0.09
		H	6.19±0.05
	Deboned	I	5.39±0.03
	Bone-in whole	J	4.97±0.04

[1)]Alphabet letters were randomly labeled for different commercial products.
[2)]Mean±standard deviation (n=9).

Table 2. Microbial population (Log CFU/g) of the smoked duck meat products commercially available in Korea

Type	Products	Total aerobic bacteria
Sliced	K[1)]	6.41±0.33[2)]
	L	6.85±0.01
	M	4.90±0.04
	N	6.50±0.34
	O	5.61±0.09
	P	4.55±0.18
Bone-in whole	Q	3.62±0.29
	R	6.84±0.03
	S	5.33±0.24

[1)]Alphabet letters were randomly labeled for different commercial products.
[2)]Mean±standard deviation (n=9).

Identification of microorganisms in raw duck and smoked duck products

The microorganisms that can colonize fresh meat depend highly on the characteristics of the meat and the way that it is processed and stored (Huisin't Veld, 1996). Sequence analysis identified spoilage microorganisms, such as *Aeromonas* spp., *Burkholderia* spp., *Pseudomonas* spp., and *Leuconostoc mesenteroides* in raw and smoked duck meat products (Tables 3-5).

Previous studies examined the levels of foodborne pathogens, i.e., *Salmonella* spp. and *Campylobacter* spp., in duck meats. However, very few detected spoilage microorganisms in duck meats (Adzitey *et al.*, 2012b; Jamali *et al.*, 2015). Bacteria developing in meat at cool temperatures are regarded as psychrotrophic and include *Acinetobacter*, *Pseudomonas*, *Brochothrix*, *Flavobacterium*, *Psychrobacter*, *Moraxella*, *Staphylococcus*, *Micrococcus*, *Clostridium*, lactic acid bacteria (such as *Leuconostoc mesenteroides*), *Aeromonas*, and different genera of the family *Enterobacteriaceae* (Doulgeraki *et al.*, 2012; Labadie, 1999). Despite the large number of microorganisms detected, few species dominate to cause spoilage because of the storage temperature, time, and packaging atmosphere during storage of fresh meat (Casaburi *et al.*, 2015). *Pseudomonas fragi* can occur in meat stored in vacuum packaging and modified atmosphere packaging (Ercolini *et al.*, 2011; Pennacchia *et al*., 2011), producing volatile organic compounds, recognized as active odor molecules, which are possibly responsible for off-odor release during meat storage at cool temperatures (Casaburi *et al*., 2015).

Table 3. Identification of microorganisms in refrigerated raw duck meats using 16S rDNA sequencing

Type	Products	Microorganisms
Sliced	A[1)]	*Acinetobacter* spp., *Burkholderia* spp., *Enterobacter* spp., *Kocuria rhizophila*
	B	*Aeromonas* spp., *Raoultella terrigena*, *Pantoea ananatis*, *Streptococcus parauberis*
	C	*Enterobacter* spp., *Pseudomonas* spp., *Serrita* spp., *Serrita liquefaciens*
Bone-in whole	D	*Chryseobacterium* spp., *Chryseobacterium piscium*, *Kocuria rhizophila*, *Soonwooa buanensis*, *Staphylococcus pesudinterimedius*, *Streptococcus parauberis*
	E	*Acinetobacter* spp., *Aeromonas* spp., *Burkholderia* spp., *Chryseobacterium indologenes*, *Soonwooa buanensis*
	F	*Dysgonomonass* spp., *Flavobacterium indicum*, *Kocuria rhizophila*, *Raoultella planticola*

[1)]Alphabet letters were randomly labeled for different commercial products.

Table 4. Identification of microorganisms in frozen raw duck meats using 16S rDNA sequencing

Type	Products	Microorganisms
Sliced	G[1)]	*Acinetobacter* spp., *Arthrobacter globiformis*, *Burkholderia* spp., *Chryseobacterium* spp., *Deinococcus aquaticus*, *Enterobacter* spp., *Kocuria rhizophila*, *Lactococcus* spp., *Pseudomonas* spp.
	H	*Burkholderia* spp., *Escherichia hermannii*, *Lactococcus lactis*, *Ralstonia pikettii*
Deboned	I	*Chryseobacterium* spp., *Chryseobacterium indologenes*, *Deinococcus* spp., *Kocuria rhizophila*, *Lactococcus garvieae*, *Moraxella* spp., *Pantoea ananatis*
Bone-in whole	J	*Enterobacter* spp., *Kocuria* spp., *Kocuria rhizophila*, *Pseudomonas* spp., *Spingobacterium* spp.

[1)]Alphabet letters were randomly labeled for different commercial products.

Table 5. Identification of microorganisms in smoked duck meat products using 16S rDNA sequencing

Type	Products	Microorganisms
Sliced	K[1)]	*Burkholderia cepacia*, *Leuconostoc mesenteroides*, *Ralstonia* spp., *Pseudomonas* spp.
	L	*Enterobacter* spp., *Lactococcus lactis*, *Leuconostoc mesenteroides*, *Klebsiella* spp.
	M	*Burkholderia cepacia*, *Leuconostoc mesenteroides*, *Ralstonia pikettii*, *Pseudomonas brenneri*
	N	*Leuconostoc mesenteroides*, *Pseudomonas* spp.
	O	*Acinetobacter* spp., *Kocuria rhizophila*, *Leuconostoc mesenteroides*, *Stenotrophomonas maltophilia*
	P	*Bacillus* spp., *Bacillus subtilis*, *Bacillus pumilus*, *Microbacterium laevaniformans*
Bone-in whole	Q	*Burkholderia* spp., *Klebsiella* spp., *Pseudomonas* spp.
	R	*Burkholderia* spp., *Lactococcus lactis*
	S	*Burkholderia* spp., *Klebsiella pneumoniae*, *Leuconostoc mesenteroides*

[1)]Alphabet letters were randomly labeled for different commercial products.

High hydrostatic pressure treatment

HHP treatment was evaluated for the ability to control microbial populations in duck meats by treatment of three products that have the largest microbial populations according to previous experiments. HHP treatment reduced the numbers of total aerobic bacteria in raw duck meats and duck meat products (Fig. 1). Compared to the control, the numbers of total aerobic bacteria in all samples at 300 MPa were reduced by about 2 Log CFU/g. The HHP treatment at 500 MPa inactivated the growth of aerobic bacteria in duck meats to undetectable levels (<1 Log CFU/g), except for in raw sample H.

The effect of HHP on the inactivation of microorganism was confirmed by previous studies. Pressures between 100 and 400 MPa efficiently reduced the numbers of bacteria of strains of *Salmonella* spp. (Malicki *et al.*, 2005).

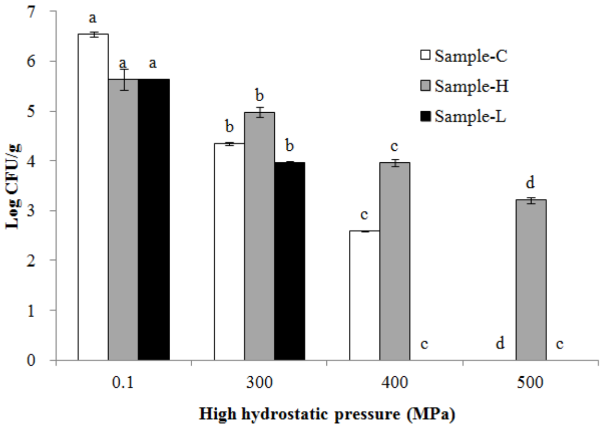

Fig. 1. Effects of high hydrostatic pressure processing on the number of total aerobic bacteria (Log CFU/g) of duck meat. [a-d]Values with different letters differ significantly (p<0.05).

Pietrzek *et al.* (2011) reported that the proliferation of aerobic bacteria in chicken patties was suppressed by HHP treatment at 500 MPa, with decreases of 3 Log CFU/g and 6 Log CFU/g after storage at 4-6°C for 14 and 21 d, respectively. Khan *et al.* (2014) showed that a combination treatment at 200 MPa and 70°C for 10 or 20 min was sufficient to produce microbiologically safe duck breast products. Additionally, Kruk *et al.* (2011) and Jung *et al.* (2012) indicated that pressures of 450 to 600 MPa almost completely eliminated three major pathogens, i.e., *Salmonella* Typhimurium, *E. coli*, and *L. monocytogenes*. Microbial cellular membranes are affected by HHP, resulting in osmotic changes, lysis, alterations of nuclear material, and other modifications, which can result in cell death (Mackey *et al.*, 1994).

Conclusion

The total numbers of aerobic bacteria in raw and smoked duck meat products were high in Korean commercial products and most of these bacteria were spoilage microorganisms. Even though there were no identified pathogens found in commercial duck meat products in the present study, it is necessary to implement sanitary step to minimize the growth of pathogenic and spoilage microorganisms. HHP treatment significantly reduced the levels of total aerobic bacteria in raw and smoked duck products. The results of the present study indicate that HHP treatment (300-500 MPa) is effective for ensuring the safety of duck meats and duck meat products.

Acknowledgements

This research was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ01011402)", Rural Development Administration, Republic of Korea and Institute of Green Bio Science and Technology, Seoul National University, Republic of Korea.

References

1. Adzitey, F., Ali, G. R. R., Huda, N., Cogen, T., and Corry, J. (2013) Prevalence, antibiotic resistance and genetic diversity of *Listeria monocytogenes* isolated from ducks, their rearing and processing environments in Penang, Malaysia. *Food Control* **32**, 607-614.
2. Adzitey, F., Huda, N., and Rusul, G. (2012b) Prevalence and antibiotic resistance of *Campylobacter*, *Salmonella*, and *L. monocytogenes* in ducks: A Review. *Foodborne Pathog. Dis.* **9**, 498-505.
3. Adzitey, F., Rusul, G., and Huda, N. (2012a) Prevalence and antibiotic resistance of Salmonella serovars in ducks, duck rearing and processing environments in Penang, Malaysia. *Food Res. Int.* **45**, 947-952.
4. Bae, D. H., Dessie, H. L., Baek, H. J., Kim, S. G., Lee, H. S., and Lee, Y. J. (2013) Prevalence and characteristics of *Salmonella* spp. isolated from poultry slaughterhouses in Korea. *J. Vet. Med. Sci.* **75,** 1193-1200.
5. Casaburi, A., Piombino, P., Nychas, G. J., Villani, F., and Ercolini, D. (2015) Bacterial populations and the volatilome associated to meat spoilage. *Food Microbiol.* **45**, 83-102.
6. Chae, H. S., Yoo, Y. M., Ahn, C. N., Jeong, S. G., Ham, J. S., Lee, J. M., and Singh, N. K. (2006) Effect of singeing time on physico-chemical characteristics of duck meat. *Korean J. Poult. Sci.* **33**, 273-281.
7. Doulgeraki, A. I., Ercolini, D., Villani, F., Nychas, G. J. E. (2012) Spoilage microbiota associated to the storage of raw meat in different conditions. *Int. J. Food Microbiol.* **157**, 130-141.
8. Ercolini, D., Ferrocino, I., Nasi, A., Ndagijimana, M., Vernocchi, P., La Storia, A., Laghi, L., Mauriello, G., Guerzoni, M. E., and Villani, F. (2011) Monitoring of microbial metabolites and bacterial diversity in beef stored in different packaging conditions. *Appl. Environ. Microbiol.* **77,** 7372-7381.
9. Garriga, M., Grèbol, N., Aymerich, M. T., Monfort, J. M., and Hugas, M. (2004). Microbial inactivation after high-pressure processing at 600 MPa in commercial meat products over its shelf life. *Innov. Food Sci. Emerg. Technol.* **5**, 451-457.
10. Hu, Q., Tu, J., Han, X., Zhu, Y., Ding, C., and Yu, S. (2011) Development of multiplex PCR assay for rapid detection of *Riemerella anatipestifer*, *Escherichia coli*, and *Salmonella enterica* simultaneously from ducks. *J. Microbiol. Methods* **87**, 64-69.
11. Huisin't Veld, J. H. J. (1996). Microbial and biochemical spoilage of foods: an overview. *Int. J. Food Microbiol.* **33**, 1-18.
12. Jamali, H., Ghaderpour, A., Radmehr, B., Wei, K. S. C., Chai, L. C., and Ismail, S. (2015) Prevalence and antimicrobial resistance of *Campylobacter* species isolates in ducks and geese. *Food Control* **50**, 328-330.
13. Jung, S., Yun, H., Kim, H. J., Ham, J. S., Kim, I. S., Lee, M., and Jo, C. (2012) Inactivation efficiency of *Escherichia coli* and *Listeria monocytogenes* in ground pork by combination of natural food ingredients and high pressure processing. *Korean J. Food Sci. An.* **32**, 1-5.
14. Khan, M. A., Ali, S., Abid, M., Ahmad, H., Zhang, L., Tume, R. K., and Zhou, G. (2014) Enhanced texture, yield and safety of a ready-to-eat salted duck meat product using a high pressure-heat process. *Innov. Food Sci. Emerg. Technol.* **21**, 50-57.
15. Kim, J. H., Nam, K. C., Jo, C., and Lim, D. G. (2014) Perception of the HACCP system operators on livestock product manufacturers. *J. Anim. Sci. Technol.* **56**, 19.
16. Korea Duck Association. (2014) General Statistics: Per capita duck meat consumption. Available from: http://www.koreaduck.org/. Accessed at October 20, 2014.
17. Kruk, Z. A., Kim, H. J., Kim, Y. J., Rutely, D. L., Jung, S.,

Lee, S. K., and Jo, C. (2014) Combined effects of high pressure processing and addition of soy sauce and olive oil on safety and quality characteristics of chicken breast meat. *Asian Australas. J. Anim. Sci.* **27**, 256-265.
18. Kruk, Z. A., Yun, H., Rutley, D. L., Lee, E. J., Kim, Y. J., and Jo, C. (2011) The effect of high pressure on microbial population, meat quality and sensory characteristics of chicken breast fillet. *Food Control* **22**, 6-12.
19. Labadie, J. (1999) Consequences of packaging on bacterial growth. Meat is an ecological niche. *Meat Sci.* **52**, 299-305.
20. Mackey, B. M., Forestière, K., Isaacs, N. S., Stening, R., and Brooker, B. (1994) The effect of high hydrostatic pressure on *Salmonella thompson* and *Listeria monocytogenes* examined by electron microscopy. *Lett. Appl. Microbiol.* **19**, 429-432.
21. Maidak, B. L., Cole, J. R., Lilburn, T. G., Parker Jr, C. T., Saxman, P. R., Farris, R. J., Garrity, G. M., Olsen, G. J., Schnidt, T. M., and Tiedje, J. M. (2001). The RDP-II (ribosomal database project). *Nucleic Acids Res.* **29**, 173-174.
22. Malicki, A., Sysak, Z., and Bruzewicz, S. (2005) Pressurization effect of *Salmonella* sp. within the fish meal. *Bull. Vet. Inst. Pulawy* **49**, 215-217.
23. Marchesi, J. R., Sato, T., Weightman, A. J., Martin, T. A., Fry, J. C., Hiom, S. J., and Wade, W. G. (1998). Design and evaluation of useful bacterium-specific PCR primers that amplify genes coding for bacterial 16S rRNA. *Appl. Environ. Microbiol.* **64**, 795-799.
24. Merritt, T. D. and Herlihy, C. (2003) Salmonella outbreak associated with chicks and ducklings at childcare centres. *Med. J. Aust.* **179**, 63-64.
25. Nychas, G. J. E., Skandamis, P. N., Tassou, C. C., and Koutsoumanis, K. P. (2008) Meat spoilage during distribution. *Meat Sci.* **78**, 77-89.
26. Pennacchia, C., Ercolini, D., and Villani, F. (2011) Spoilage-related microbiota associated with chilled beef stored in air or vacuum pack. *Food Microbiol.* **28**, 84-93.
27. Pietrzak, D., Cegielka, A., Fonberg-Broczek, M., and Ziamo, M. (2011) Effects of high pressure treatment on the quality of chicken patties. *High Pressure Res.* **31**, 350-357.
28. Sánchez, J., Basanta, A., Gómez-Sala, B., Herranz, C., Cintas, L. M., and Hernández, P. E. (2007) Antimicrobial and safety aspects, and biotechnological potential of bacteriocinogenic enterococci isolated from mallard ducks (*Anas platyrhynchos*). *Int. J. Food Microbiol.* **117**, 295-305.
29. Sung, S. H., Bae, Y. S., Oh, S. H., Lee, J. C., Kim, H. J. and Jo, C. (2013) Possibility of instrumental differentiation of duck breast meat with different processing and storage conditions. *Korean J. Food Sci. An.* **33**, 96-102.
30. Witak, B. (2008) Tissue composition of carcass, meat quality and fatty acid content of ducks of a commercial breeding line at different age. *Arch. Tierz. Dummerstorf* **51,** 266-275.
31. Zhang, H. and Mittal, G. S. (2008). Effects of high-pressure processing (HPP) on bacterial spores: An overview. *Food Res. Int.* **24**, 330-351.