JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

QUANTITATIVE MICROBIAL RISK ASSESSMENT OF FERMENTED BEAN PASTES CONTAMINATED WITH *CLOSTRIDIUM PERFRINGENS*

Yeongeun Seo[1,2], Yewon Lee[1,2], Sejeong Kim[2], Jeeyeon Lee[3], Jimyeong Ha[2], Yukyung Choi[2], Hyemin Oh[2], Yujin Kim[1,2], Min-Suk Rhee[4], Heeyoung Lee[5,] and Yohan Yoon[1,2,*]*

Address(es): Yohan Yoon, Ph.D. and Heeyoung Lee, Ph.D.,
[1]Sookmyung Women's University, Department of Food and Nutrition, Seoul, 04310, Korea.
[2]Sookmyung Women's University, Risk Analysis Research Center, Seoul, 04310, Korea.
[3]Dong-eui University, Department of Food and Nutrition, Busan, 47340, Korea.
[4]Korea University, Department of Biotechnology, Seoul 02841, Korea.
[5]Food Standard Research Center, Korea Food Research Institute, Jeollabuk-do, 55365, Korea.

*Corresponding author: hylee06@kfri.re.kr, yyoon@sookmyung.ac.kr

https://doi.org/10.55251/jmbfs.3854

ARTICLE INFO

Received 17. 10. 2020
Revised 8. 9. 2021
Accepted 14. 9. 2021
Published 1. 4. 2023

Regular article

OPEN ACCESS

ABSTRACT

This study evaluated *Clostridium perfringens* risk in fermented bean pastes. The prevalence in fermented bean pastes, development of the predictive model, temperature, time, and consumption data were investigated. A simulation model was prepared in @RISK with the obtained data to calculate the probability of foodborne *C. perfringens* foodborne illness from fermented bean paste consumption. Only 74 of the 1,097 samples were positive for *C. perfringens*. The initial contamination level was estimated to be 0.7 log CFU/g. It showed the probability of foodborne *C. perfringens* infection per person per day upon consumption of fermented bean pastes was 8.0×10^{-12}, which is considered low risk.

Keywords: foodborne illness, quantitative microbial risk assessment, *Clostridium perfringens*, fermented bean pastes, predicted model

INTRODUCTION

Clostridium perfringens is the fourth most prevalent cause of foodborne illness in Korea, and one of the most common cause of foodborne diseases in the United States of America **(CDC, 2018; MFDS, 2020)**. *C. perfringens* is widely distributed in the environment, food, and the excrement of humans and animals **(Han et al., 2007; Heo et al., 2018; Juneja et al., 2006; Songer, 1996)**. It is a gram-positive anaerobic spore-forming bacterium **(FDA, 2017)**. Vegetative cells of *C. perfringens* mostly die during food preparation, but *C. perfringens* spores can survive extreme conditions. Clinical symptoms of *C. perfringens* infection include diarrhea and abdominal pain. Foodborne disease resulting from *C. perfringens* infection is caused by the production of *Clostridium perfringens* enterotoxin (CPE), which affects the intestines when more than 10^6 vegetative cells or spores of *C. perfringens* are consumed **(McDonel, 1980; MFDS, 2016)**.
In Korea, fermented bean pastes have been consumed for many years. In addition, the export of these pastes has recently increased **(KAT, 2016)**. Thus, to meet the safety requirements for consumption and export, studies, especially those investigating fungal toxins and biogenic amines present in these pastes, have been conducted **(Han et al., 2007; Lee et al., 2009; Sivamaruthi et al., 2018)**. **Park (2013)** detected *C. perfringens* in three traditional bean-based sauce samples (20%) and suggested that there is a possibility for *C. perfringens* contamination in fermented bean pastes. Thus, we decided to evaluate the risk of *C. perfringens* contamination in fermented bean pastes.
To evaluate the risk of *C. perfringens* contamination in foods, quantitative microbial risk assessment (QMRA) is most appropriate **(Jeong et al., 2018; WHO, 2002)**. QMRA involves hazard identification, exposure assessment, hazard characterization, and risk characterization **(CAC, 2015; Lee et al., 2019)**. However, completing QMRA for one pathogen with one food is both time-consuming and expensive. There are four fermented bean pastes [*Doenjang* (Korean fermented soy paste), *Cheonggukjang* (Korean short-fermented bean paste), *Gochujang* (Korean red pepper paste), and *Ssamjang* (mixed paste containing *Gochujang*, *Doenjang*, and other ingredients)] in Korea. Thus, if a set of various fermented bean pastes with similar physiochemical properties undergoes QMRA assuming a worst case scenario with regard to *C. perfringens* contamination, it can be assumed that the risk of consuming each fermented bean paste in this set separately is below the risk of consuming the entire set of fermented ban pastes; this can save both time and expenses. Therefore, the objective of this study was to identify fermented bean pastes that could be grouped together based on similar physiochemical properties to conduct QMRA assuming a worst case scenario with regard to *C. perfringens* contamination and to identify the fermented bean paste with the lowest death rate of *C. perfringens* during storage and cooking and the one with the highest consumption amount and frequency.

MATERIALS AND METHODS

Evaluation of prevalence and initial contamination

To evaluate the prevalence of *C. perfringens* in fermented bean pastes. 1,097 fermented bean pastes samples [*Doenjang* (n=324), *Ssamjang* (n=299), *Gochujang* (n=359), and *Hansik-doenjang* (n=115)] were purchased from supermarkets and traditional markets in Korea. Twenty-five-gram portions of the fermented bean pastes were placed in filter bags (Circulator 400 standard bags; Seward, Worthing, UK) and 225 mL of sterile 0.85% saline was added to the filter bag. The samples were then homogenized for 2 min using a pummeler (Seward, Worthing, UK). Homogenate (1 mL) and diluent (100 µL) aliquots were dispersed on tryptose sulphite cycloserine agar (TSC; Difco, Sparks, MD, USA) plates and incubated at 37 °C for 18–24 h in an aerobic jar with an anaerobic pack (Oxoid, Basingstoke, Hampshire, UK). The colonies were then analyzed using the VITEK®2 ANC ID card (BioMérieux, Marcy l'Etoile, France). It was concluded that the result was positive for *C. perfringens* if it was acceptable or higher. @RISK (Palisade Corp., Ithac, NY, USA) was used to estimate the appropriate probabilistic distribution from the prevalence data.

Determination of distribution and storage temperature and time

Storage temperature and time data for the distribution of fermented bean pastes to the market, market storage, and market display were collected through personal communication with managers.

Survey of consumption pattern

According to the results from the Korea National Health and Nutrition Examination Survey **(KCDC, 2017)**, *Doenjang* was the most consumed fermented bean paste. Thus, the data regarding the amount of *Doenjang* consumption were analyzed

using the @RISK to determine an appropriate probabilistic distribution. The consumption frequency for *Doenjang* was estimated by dividing the number of total respondents (6,628 people) in the survey by the number of respondents (2,743 people) who consumed *Doenjang*.

Evaluation of kinetic behavior of *C. perfringens* in fermented bean pastes

For *C. perfringens* strains, KCCM12098, KCCM40946, KCCM40947, and KCTC 5101 with toxin-producing genes were used. Four *C. perfringens* strains were cultured in 10 mL cooked meat medium (Oxoid, Basingstoke, Hampshire, UK) at 37°C for 24 h under anaerobic conditions created using an anaerobic pack, and 3 mL aliquots of the culture were inoculated in 30 mL Duncan and strong medium (15.0 g proteose peptone, 10.0 g sodium phosphate, 4.0 g raffinose, 4.0 g yeast extract, 1.0 g sodium thioglycolate, and 50.0 mL 0.51 mM caffeine in 1 L distilled water) and anaerobically incubated at 37°C for 48 h. The *C. perfringens* strains were harvested by centrifugation at 1,912× g and 4°C for 15 min. The supernatant was discarded and the cells were washed twice with phosphate buffered saline (PBS; pH 7.4, 8.0 g NaCl, 1.5 g $NaHPO_4$, 0.2 g KH_2PO_4, and 0.2 g KCl in 1 L distilled water). To make the inoculum, the cell pellet was resuspended in 3 mL PBS and the strains were mixed together **(Seo et al., 2021)**. *C. perfringens* inoculum (4 mL) was added to 400 g *Cheonggukjang* to achieve a final concentration of 3.0 log CFU/g; the inoculated samples were placed in sample bags (3M, St. Paul, MN, USA) and stored at 7, 15, 25, and 35°C for up to 10 days. The physicochemical properties (pH and Aw) of *Cheonggukjang* (pH=6.96, Aw=0.934) offered better growth conditions for *C. perfringens* than those of other fermented bean pastes [*Doenjang* (pH=5.20, Aw=0.827), *Gochujang* (pH=4.79 Aw=0.79), and *Ssamjang* (pH=5.29-5.78) (Kim and Lee, 2001; Kim et al., 2016)]. Thus, *C. perfringens* in *Cheonggukjang* survived longer than in *Doenjang*. During storage, 10 g portions of the *Cheonggukjang* were placed into sample bags with 20 mL buffered peptone water (Dickinson and Company, Sparks, MD, USA). The homogenates were spread on TSC agar, which were then incubated anaerobically at 37°C for 24 h, and typical black colonies with halos sére counted. The kinetic behavior of *C. perfringens* was evaluated via development of a primary model with the Weibull model parameters [$\log(N) = \log(N_0) - (\text{time}/\delta)^{\rho}$; N, cell counts; N_0, initial cell counts; δ, treatment time for the first decimal reduction; ρ, curve shape], and a secondary model with an exponential model [$\delta = a \times \exp(k \times T)$; a, constant; k, the rate constant; T, storage temperature] was developed as a function of temperature. To evaluate the model performance, *C. perfringens* was inoculated in *Cheonggukjang*, as described above, and the samples were stored at 20 and 30°C. During storage, *C. perfringens* cells were counted as described above to obtain the observed values. The observed values were compared to the values derived using the predictive models. The observed values were compared to the values derived using the prediction models, and the differences between the observed and predicted data were indicated by the root mean square error (*RMSE*) values **(Ross, 1996)**.

Determination of dose-response model

Dose response models were searched through published literatures to estimate the probability of foodborne illness after *C. perfringens* consumption.

Preparation of simulation model

A simulation model was prepared in Excel® (Microsoft Corp., Redmond, WA, USA) spreadsheet with the initial concentration of *C. perfringens*, predictive models, probabilistic distributions for time and temperature used in the predictive models to describe the bacterial growth, a probabilistic distribution of consumption amount of *Doenjang*, the most consumed fermented bean paste, and consumption frequency, followed by the dose-response model. By Monte Carlo simulation in @RISK, the probability of foodborne *C. perfringens* foodborne illness by fermented bean paste consumption per person per day and the correlation coefficient were calculated (Tab 1).

Table 1 Simulation model and formula in Excel spreadsheet used to calculate the risk of *Clostridium perfringens* on the fermented bean pastes with @RISK

Input model	Unit	Variable	Formula	References
PRODUCT				
Pathogens contamination level				
C. perfringens concentration	CFU/g	PR	=RiskExpon(0.95716,RiskShift(0.99913), RiskTruncate(0,1000))	This research
	CFU/g	C	=IF(<10, RiskUniform(1,10), PR)	This research
	log CFU/g	IC	=log(C)	This research
MARKET TRANSPORTATION				
Transportation time	h	$Time_{trans}$	=RiskPert(0.5,3,5)	This research
Food temperature during transportation	℃	$Temp_{trans}$	=RiskWeibull(1.3219,2.8404,RiskShift(3.1093),Risktruncate(1,40))	This research
Death				
Delta		δ	$=1/(0.007+0.001\times\exp(0.1108\times Temp_{trans}))$	This research
ρ		ρ	Fixed 0.7310	This research
C. perfringens survival model		C1	$=IC-(Time_{trans}/\delta)^{\rho}$	Mafart et al., 2002
Market storage				
Storage time	h	$Time_{st}$	=RiskUniform(0.1,48)	This research
Food temperature during storage	℃	$Temp_{st}$	=RiskPert(22,25,26)	This research
Death				
Delta		δ	$=1/(0.007+0.001\times\exp(0.1108\times Temp_{st}))$	This research
ρ		ρ	Fixed 0.7310	This research
C. perfringens growth model		C2	$=C1-(Time_{st}/\delta)^{\rho}$	Mafart et al., 2002
MARKET DISPLAY				
Display time	h	$Time_{dis}$	=RiskUniform(0,336)	This research
Food temperature during display	℃	$Temp_{dis}$	=RiskLogLogistic(16.608,5.6198,14.584,Risk Truncate(1,40))	This research
Death				
Delta		δ	$=1/(0.007+0.001\times\exp(0.1108\times Temp_{dis}))$	This research
ρ		ρ	Fixed 0.7310	This research
C. perfringens growth model		C3	$=C2-(Time_{dis}/\delta)^{\rho}$	Mafart et al., 2002
COMSUMPTION				
Daily consumption average amount	g	Consump	=RiskExpon(12.114, RiskShift(0.0055837), RiskTruncate(0,350))	KCDC, 2017
Daily consumption frequency	%	ConFre	Fixed 41.4	KCDC, 2017
		CF(0)	=1-41.4/100	KCDC, 2017
		CF(1)	=41.4/100	KCDC, 2017
		CF	=RiskDiscrete({0,1},{CF(0),CF(1)})	KCDC, 2017
		Amount	=IF(CF=0,0,Consump)	KCDC, 2017
DOSE-RESPONSE				
C. perfringens amount	CFU	N	$=10^{C3}\times$Amount	
Parameter of r		r	$=$Fixed 1.82×10^{-11}	Golden et al., 2009
RISK				
Probability of illness/person/day		Risk	=1-exp(-r×N)	Golden et al., 2009

RESULTS AND DISCUSSION

Initial contamination level of *C. perfringens*

Of the 1,097 samples tested, only 74 samples were *C. perfringens* positive, and 93 .3% of samples had a bacterial load below the detection limit (1 log CFU/g). Thus , only cell counts for the positive samples were analyzed by @RISK, and the expo nential distribution [Riskexpon (Riskexpon (0.95716, RiskShift (0.99913))] was d etermined as an appropriate probabilistic distribution. To estimate the initial conta mination levels, for *C. perfringens* positive samples, the exponential distribution was determined, otherwise data were extracted between 0 and 1 log CFU/g becau se "below detection" means the cell counts were between 0 and 1 log CFU/g. Wit h this simulation, the mean of the initial *C. perfringens* contamination level in fer mented bean pastes was estimated to be 0.7 log CFU/g (Fig 1).

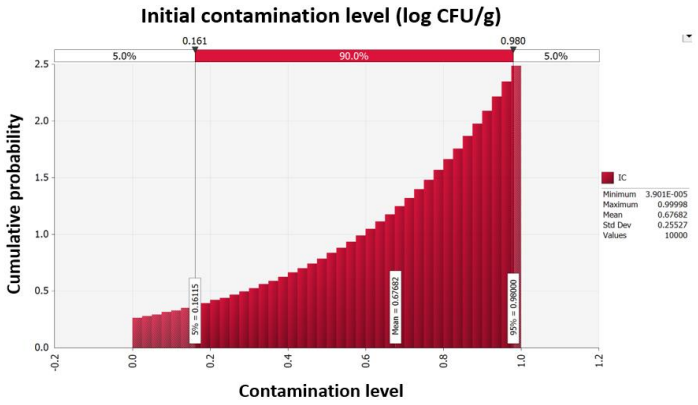

Figure 1 Probability density for simulated initial contamination level of *Clostridium perfringens* in fermented bean pastes.

Temperature and time for transportation and storage

Transportation and storage time and temperature for fermented bean pastes were d etermined through survey or interview with market managers. The probabilistic di stribution for the temperature of the transport vehicle was appropriate with the W eibull distribution [RiskWeibull(1.3219,2.8404,Riskshift(3.1093),RiskTruncate(1, 40))] and the Pert distribution was appropriate for transportation time. because the transportation time was 0.5–5 h. According to the probabilistic distribution, when the fermented bean pastes were transported from the site of production to the site of sale, the mean temperature was 5.7°C. According to market staff, the products were stored at 22–26°C using the automatic control system for 0.1–48 h. Hence, t he temperatures were fitted to the Pert distribution [RiskPert (22,25,26)] because t he minimum, mode, and maximum temperatures were 22, 25, and 26ºC, respectiv ely. And, the storage time was fitted to the uniform distribution [RiskUniform(0.1 ,48)]. The probabilistic distribution for the display temperature was adequate with loglogistic distribution [RiskLogLogistic(16.608,5.6198,14.584,RiskTruncate(1,4 0))] and the uniform distribution [RiskUniform(0,336)] was appropriate for displa y time distribution because the display time was 0–336 h.

Consumption of fermented bean pastes

Of the fermented bean pastes consumed widely in Korea, *Doenjang* was the most consumed. Hence, the raw data for daily consumption amounts of *Doenjang* deriv ed from KNHANES **(KCDC, 2017)** were fitted with @RISK. "Exponential distri bution (12.114, Riskshift (0.0055837))" was selected to be the appropriate probab ilistic distribution to describe the consumption of fermented bean pastes and the p robabilistic distribution showed that the average daily consumption of *Doenjang* was 12.12 g, with the consumption frequency being 41.4% in Korea.

Kinetic behavior of *C. perfringens* during distribution

The prediction model was developed to describe the kinetic behavior of *C. perfrin gens* in fermented bean pastes during transportation, storage, and display. To sele ct products for predictive model development, survival of *C. perfringens* contami nants was compared among fermented bean pastes during storage, and *Cheonggu kjang* had the slowest decrease in cell counts. Thus, the predictive model was dev eloped with *Cheonggukjang*. Cell counts of *C. perfringens* were enumerated at 7, 15, 25, and 35ºC. The Weibull model was then used to fit the data and calculate δ and ρ values. δ decreased as temperature increased. R^2 values were 0.833−0.944, i ndicating that the developed model was appropriate. The ρ values ranged from 0.4 7 to 1.20 (Tab 2). To evaluate the effect of temperature on the δ values, a seconda ry model was developed using the exponential growth model. The model was [δ = 1/(0.007)+(0.001×exp (0.1108×T))], with 0.981 of R^2, indicating that the seconda ry model was developed properly. Validation of model performance showed that t he *RMSE* values were 0.723 and 0.238 at 20 and 30ºC, respectively. This indicate s that the developed predictive models were appropriate to predict the number of *C. perfringens* cells in *Cheonggukjang* during transportation, storage, and display. In addition, the extrapolation verification for *Hansik-doenjang* showed an *RMSE* value of 0.505, implying that the predictive model developed using *Cheonggukjan g* can be applied to other fermented bean pastes.

Table 2 Parameters calculated by the Weibull model for *Clostridium perfringens* in fermented be an pastes during storage at 7°C, 15°C, 25°C, and 35°C

Parameters	Temperature (°C)			
	7	15	25	35
δ	145.50 ± 64.35	66.52 ± 4.94	45.22 ± 9.46	17.34 ± 0.33
ρ	1.20 ± 0.76	0.54 ± 0.12	0.71 ± 0.10	0.47 ± 0.10
R^2	0.882 ± 0.076	0.869 ± 0.011	0.944 ± 0.003	0.833 ± 0.006

Dose response model

There was only one dose-response model for *C. perfringens* infection, and it was t he exponential model [P = 1−exp (−*r*×*N*), $r = 1.82\times10^{-11}$] developed by Golden et al. (2009), where P is the probability of illness, *r* is the probability of *C. perfringe ns* cells causing foodborne illness, and *N* is the *C. perfringens* cell number (CFU/ serving) ingested. As a result, this model was contained in the simulation model.

Risk characterization

The simulation model was prepared as shown in Table 2 with the data for *C. perfr ingens* contamination level, predictive models used to simulate the kinetic behavi or of *C. perfringens* with the probabilistic distributions of temperature and time, p robabilistic distribution of consumption amounts, consumption frequency, and do se response model. According to the simulation, the probability of *C. perfringens* infection per person per day from consuming fermented bean paste was 8.0×10^{-12} (Tab 3). The cumulative density determined using this simulation showed that est imated the number of *C. perfringens* cells decreased gradually from initial contam ination (IC) to display (C3) (Fig 2). In addition, the correlation coefficient determ ined using this simulation showed that the consumption amount and contaminatio n level had positive correlations with the risk, and that market storage time, marke t display time, market storage temperature, transportation time, and market displa y temperature were negatively correlated with the risk.

Table 3 Probability of foodborne illness by *Clostridium perfringens* per person per day with consumption of fermented bean paste

Probability of illness/person/day	5%	25%	50%	95%	99%	Mean
	0	0	0	2.5×10^{-11}	1.7×10^{-10}	8.0×10^{-12}

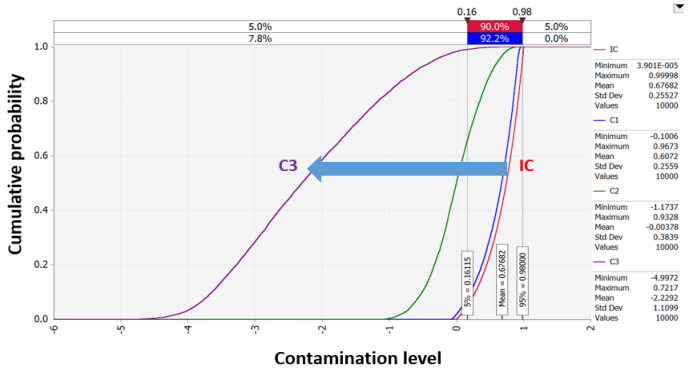

Figure 2 Changes of *Clostridium perfringens* contamination level, predicted by distributions in fermented bean pastes during transportation; initial concentration (IC), concentration after market transportation (C1), concentration after market storage (C2) and concentration after market display (C3).

CONCLUSION

The risk for *C. perfringens* foodborne illness from the intake of the assessed ferm ented bean pastes produced in Korea can be considered low, and it might be cause d by low initial concentration of *C. perfringens* in the samples and decreased *C. p erfringens* cell counts during transport and storage.

Acknowledgement: This research was supported by a grant (17162MFDS035) from Ministry of Food and Drug Safety in 2017.

REFERENCES

Centers for Disease Control and Prevention (CDC). (2018). Frequently asked questions. CDC, Atlanta, USA: http://www.cdc.gov/foodsafety/diseases/clostridium-perfringens.html

Codex Alimentarius Commission (CAC). (2015). Procedural manual 24th edition. CAC, Rome, Italy: http://www.fao.org/3/a-i5079e.pdf

Golden, N. J., Crouch, E. A., Latimer, H., Kadry, A. R., & Kause, J. (2009). Risk assessment for *Clostridium perfringens* in ready-to-eat and partially cooked meat and poultry products. *Journal of food protection*, *72*(7), 1376-1384. https://doi.org/10.4315/0362-028X-72.7.1376

Han, G. H., Cho, T. Y., Yoo, M. S., Kim, C. S., Kim, J. M., Kim, H. A., Kim, M. O., Kim, S. C., Lee, S. A., Ko, Y. S., Kim, S. H., & Kim, D. B. (2007). Biogenic Amines Formation and Content in Fermented Soybean Paste (*Cheonggukjang*). *Korean Journal of Food Science and Technology*, *39*(5), 541-545.

Heo, S., Kim, M. G., Kwon, M., Lee, H. S., & Kim, G. B. (2018). Inhibition of *Clostridium perfringens* using bacteriophages and bacteriocin producing strains. *Korean Journal for Food Science of Animal Resources*, *38*(1), 88. https://doi.org/10.5851/kosfa.2018.38.1.88

Jeong, J., Chon, J. W., Kim, H., Song, K. Y., & Seo, K. H. (2018). Risk Assessment for Salmonellosis in Chicken in South Korea: The Effect of *Salmonella* Concentration in Chicken at Retail. *Korean journal for food science of animal resources*, *38*(5), 1043–1054. https://doi.org/10.5851/kosfa.2018.e37

Juneja, V. K., Huang, L., & Thippareddi, H. H. (2006). Predictive model for growth of *Clostridium perfringens* in cooked cured pork. *International journal of food microbiology*, *110*(1), 85-92. https://doi.org/10.1016/j.ijfoodmicro.2006.01.038

Kim, D. H., & Lee, J. S. (2001). Effect of condiments on the physicochemical characteristics of traditional kochujang during fermentation. *Korean Journal of Food Science and Technology*, *33*(3), 353-360.

Kim, S. Y., Park, B. R., & Yoo, S. M. (2016). Quality Characteristics of Factory-Style and Handmade-Style Ssamjang. *Journal of the Korean Society of Food Science and Nutrition*, *45*(1), 100-108. http://doi.org/10.3746/jkfn.2016.45.1.100

Korea Agro-Fisheries & Food Trade Corporation (AT). (2016). Segment market of processed food current state: *Doenjang* market. AT, Seoul, Korea: http://www.atfis.or.kr/article/M001050000/view.do?articleId=2030

Korea Centers for Disease Control and Prevention (KCDC). (2017). Korea health statistics 2015: Korean National Health and Nutrition Examination Surveys (KNHNES V-6). KCDC, Cheongju-si, Korea: https://knhanes.kdca.go.kr/knhanes/main.do

Ross, T. (1996). Indices for performance evaluation of predictive models in food microbiology. Journal of Applied Bacteriology, *81*(5), 501–508. https://doi.org/10.1111/j.1365-2672.1996.tb03539.x

Lee, H. T., Kim, J. H., & Lee, S. S. (2009). Analysis of microbiological contamination and biogenic amines content in traditional and commercial Doenjang. *Journal of Food Hygiene and Safety*, *24*(1), 102-109.

Lee, J., Lee, H., Lee, S., Kim, S., Ha, J., Choi, Y., Oh, H., Kim, Y., Lee, Y., Yoon, K. S., Seo, K., & Yoon, Y. (2019). Quantitative Microbial Risk Assessment for *Campylobacter jejuni* in Ground Meat Products in Korea. *Food science of animal resources*, *39*(4), 565–575. http://doi.org/10.5851/kosfa.2019.e39

Mafart, P., Couvert, O., Gaillard, S., & Leguerinel, I. (2002). On calculating sterility in thermal preservation methods: application of the Weibull frequency distribution model. *International journal of food microbiology*, *72*(1-2), 107–113. http://doi.org/10.1016/s0168-1605(01)00624-9

McDonel J. L. (1980). *Clostridium perfringens* toxins (type A, B, C, D, E). *Pharmacology & therapeutics*, *10*(3), 617–655. https://doi.org/10.1016/0163-7258(80)90031-5

Ministry of Food and Drug Safety (MFDS). (2016). Microbial Risk Profile. MFDS, Cheongju-si, Korea: https://mfds.go.kr/brd/m_227/view.do?seq=25230&srchFr=&srchTo=&srchWord=&srchTp=&itm_seq_1=0&itm_seq_2=0&multi_itm_seq=0&company_cd=&company_nm=&page=13.

Ministry of Food and Drug Safety (MFDS). (2020). Status of foodborne illness outbreaks in Korea. MFDS, Cheongju-si, Korea: http://www.foodsafetykorea.go.kr/portal/healthyfoodlife/foodPoisoningStat.do?menu_grp=MENU_NEW02&menu_no=2786.

Park S. (2013). Microbiological Analysis of Private Brand (PB) Food Products in Hypermarket. Master thesis, Chung-ang University, Seoul, Korea.

Seo, Y., Lee, Y., Kim, S., Ha, J., Choi, Y., Oh, H., … Yoon, Y. (2021). Contamination of *Clostridium perfringens* in soy sauce, and quantitative microbial risk assessment for *C. perfringens* through soy sauce consumption. Food Science & Nutrition, *9*(4), 2139–2146. https://doi.org/10.1002/fsn3.2182

Sivamaruthi, B. S., Kesika, P., & Chaiyasut, C. (2019). Toxins in fermented foods: prevalence and preventions—a mini review. *Toxins*, *11*(1), 4. https://doi.org/10.3390/toxins11010004

Songer J. G. (1996). Clostridial enteric diseases of domestic animals. *Clinical microbiology reviews*, *9*(2), 216–234. https://doi.org/10.1128/CMR.9.2.216

U.S Food and Drug Administration (FDA). (2017). Bacteriological Analytical Manual. FDA, Maryland, USA: https://www.fda.gov/food/laboratory-methods-food/bam-clostridium-perfringens.

World Health Organization (WHO). (2002). Risk assessments of *Salmonella* in eg gs and broiler chickens. WHO, Geneva, Swiss: https://apps.who.int/iris/handle/10665/342257?search-result=true&query=Risk+assessments+of+Salmonella+in+eggs+and+broiler+chickens&scope=&rpp=10&sort_by=score&order=desc