Food Research International 68 (2015) 24–30

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Correlations between climatic conditions and foodborne disease

Yong Soo Kim [b], Ki Hwan Park [c], Hyang Sook Chun [c], Changsun Choi [c], Gyung Jin Bahk [a,*]

[a] Department of Food and Nutrition, Kunsan National University, Gunsan, Jeonbuk 573-701, South Korea
[b] Quality Improvement Team, Korea Health Industry Development Institute, Cheongwon, Chungbuk 363-700, South Korea
[c] Department of Food Science and Technology, Chung-Ang University, Ansung, Gyeonggi 456-756, South Korea

ARTICLE INFO

Article history:
Received 7 January 2014
Received in revised form 8 March 2014
Accepted 25 March 2014
Available online 3 April 2014

Keywords:
Climatic conditions
Seasonal change
Foodborne diseases
Correlation analysis
Relative humidity
Temperature
South Korea

ABSTRACT

Climate change is likely to affect the incidence of foodborne disease outbreaks, but the relationship between foodborne disease and conditions of climate change is still poorly understood and may vary regionally. Therefore, this study investigated the relationship between climatic conditions/seasonal changes, with regards to temperature and relative humidity, and the incidence of foodborne disease outbreaks in South Korea during 2003–2012. Eight pathogens commonly associated with foodborne diseases were identified and the effect of changes in temperature and relative humidity on each of them was investigated. Pathogenic *Escherichia coli* had the strongest correlation with temperature and relative humidity (0.8998, 0.8803, $p < 0.001$), followed by *Vibrio parahaemolyticus* (0.6964, 0.8048, $p < 0.05$), *Campylobacter jejuni* (0.6595, 0.6142, $p < 0.05$), *Salmonella* spp. (0.7531, 0.3893, $p = 0.005, 0.211$), and *Bacillus cereus* (0.3556, 0.2040, $p > 0.05$). Norovirus had a strong negative correlation with temperature and relative humidity (−0.9791, −0.8747, $p < 0.001$), followed by *Clostridium perfringens* (−0.6457, −0.8635, $p < 0.05$). *Staphylococcus aureus* poorly correlated with both temperature and relative humidity (0.1106, −0.1169, $p > 0.05$). The statistical model in the present study could be useful for estimating the prospective effects of climate change on foodborne disease patterns.

1. Introduction

Climate change is known to affect a wide range of environmental conditions, including temperature, precipitation patterns, acidification, and alterations in the transport pathways of microorganisms (Liu, Hofstra, & Franz, 2013), which, in turn, can affect food safety. The proliferation and spread of foodborne pathogens are altered by climate change (ECDC, 2007; Miraglia et al., 2009), and studies conducted in various countries have suggested that there is an association between climate change and salmonellosis (Kovats et al., 2004), campylobacteriosis (Kovats et al., 2005), and vibriosis (Craig et al., 2013). There are clear differences in the impact of climate change on specific foodborne pathogenic species, and the findings of previous studies have suggested that these differences could be related to the region where the study was conducted (El-Fadel, Ghanimeh, Maroun, & Alameddine, 2012; Fleury, Charron, Holt, Allen, & Maarouf, 2006; Lake et al., 2012) or the pathogen under investigation (Lake et al., 2009; Miraglia et al., 2009). Despite these studies, the correlation between conditions of climate change and food safety is still poorly understood, and investigations examining the outbreak of foodborne disease in relation to climate change are limited. Semenza et al. (2012) recently conducted a meta-analysis to assess the impact of climate change on the incidence of different foodborne diseases in European countries. Similar studies of other parts of the world are necessary, but data from regions/countries outside the European Union and North America are sparse. Moreover, because of this paucity of information on the effect of climate change on foodborne diseases, few countries have, thus far, implemented measures to manage the consequences of climate change on food safety.

A statistical model that is based on foodborne disease incidence data may well be useful to assess the prospective effect of climate change on food safety in the future. Therefore, the aim of the present study was to investigate the relationship between specific foodborne pathogens and climatic conditions/seasonal changes in temperature and relative humidity in South Korea, and then to establish a statistical model, based on foodborne disease incidence data, that can be used to estimate the prospective impact of climate change on food safety. For the present study, information regarding foodborne disease outbreaks in South Korea over the past 10 years (2003 to 2012) was obtained from the KMFDS (Korea Ministry of Food and Drug Safety, 2013), and associations between the incidence of foodborne disease outbreaks and the mean monthly temperature and relative humidity were investigated.

* Corresponding author at: Department of Food and Nutrition, Kunsan National University, 1170-Daehakro, Gunsan, Jeonbuk 573-701, South Korea. Tel.: +82 63 469 4640, +82 10 2381 5175; fax: +82 63 466 2085.
E-mail address: bahk@kunsan.ac.kr (G.J. Bahk).

http://dx.doi.org/10.1016/j.foodres.2014.03.023
0963-9969/

2. Methods

2.1. Regional and climate factor-related data

The regions of South Korea included in the present study are positioned between a latitude of 33°06′ and 38°27′ and a longitude of 125°04′ and 131°52′. South Korea is part of the East Asian monsoonal region, and the country has a temperate climate with 4 distinct seasons. Climatic data used in the present study were historical data of climatic conditions in South Korea published by the KMA (Korea Metrological Administration, 2013). The study period was from January 2003 to December 2012 and the mean temperature and relative humidity were calculated, for each of the 12 months in a year after extracting data from 76 geographically representative weather stations in South Korea (Table 1).

2.2. Foodborne disease outbreak data

Epidemiological data on foodborne disease outbreaks were obtained from the KMFDS (2013) and the number and time (month) of foodborne disease outbreaks in South Korea between 2003 and 2012 were assessed (Table 2). In addition, outbreaks of foodborne disease included in the present study were caused by 7 foodborne bacteria (pathogenic *Escherichia coli*, *Salmonella* spp., *Vibrio parahaemolyticus*, *Campylobacter jejuni*, *Bacillus cereus*, *Staphylococcus aureus*, and *Clostridium perfringens*) and 1 foodborne virus (Norovirus). Foodborne disease outbreaks caused by natural toxins and chemical agents were excluded from the study. The outbreaks (total: 2510) were classified as outbreaks of known (1487 [59.2%]) and unknown origin (1023 [40.8%]) (Table 2).

2.3. Monthly incidence rates and correlation analysis

For correlation analysis, the monthly incidence rate of foodborne disease outbreaks was determined first. Incidence rates were calculated as a relative frequency (or empirical probability) (Daniel, 2009, chap. 2.3) of occurrence according to Eq. (1). The number of outbreaks in a month caused by a specific foodborne diseases species (n_i) was divided by the total number of outbreaks (N) that occurred in that specific month of the year. This yielded an incidence rate per month (F_i).

$$F_i = \frac{n_i}{N} = \frac{n_i}{\sum_i n_i} \tag{1}$$

The total number of outbreaks (N) was taken as the sum of all foodborne disease outbreaks for a particular month in the year ($\Sigma_i\, n_i$). The total number of outbreaks caused by a specific pathogen was identified and the incidence rate of pathogens was calculated, for instance, the number of outbreaks in January ($N = 97$), caused by pathogenic *E. coli* was 6 (n_i) and the incidence rate calculated as $6/97 = 0.0619$ (F_i) (Table 3).

Pearson correlation coefficients (r) and p-values were computed on the basis of the monthly incidence rates (F_i) of the 8 pathogens using Statistical Package for the Social Sciences version 12.0 (Data Solution Inc., South Korea) to assess the association between F_i and the mean temperature as well as relative humidity (Table 1). The computed coefficient values (r) served as the basis for ranking the impact of the climate change factors in relation to monthly mean temperature and relative humidity.

Table 1
The distribution of the monthly mean temperatures and relative humidity during 2003–2012 in South Korea (mean ± SD).

Month	Temperature (°C)	Relative humidity (%)
Jan	−1.09 ± 3.27	60.70 ± 9.22
Feb	1.71 ± 2.91	60.39 ± 8.20
Mar	5.83 ± 1.98	59.60 ± 7.36
Apr	11.85 ± 1.73	59.73 ± 6.51
May	17.25 ± 1.31	65.89 ± 6.19
Jun	21.38 ± 1.38	72.49 ± 6.45
Jul	24.28 ± 1.64	81.15 ± 5.11
Aug	25.20 ± 1.58	79.08 ± 4.99
Sep	20.82 ± 1.72	76.48 ± 5.11
Oct	14.69 ± 2.24	69.22 ± 5.96
Nov	8.33 ± 2.70	65.78 ± 6.99
Dec	1.46 ± 3.21	62.28 ± 9.18

3. Results

3.1. Climate characteristics and foodborne disease outbreaks

Table 1 shows the distribution of the mean monthly temperature and relative humidity in South Korea from 2003 to 2012. The average temperature and relative humidity for the 10 years were 13.7 °C and 68.2%, respectively. August showed the highest mean temperature (25.2 °C), and July showed the highest mean relative humidity (81.2%). The distribution of mean monthly temperature and relative humidity is shown in Figs. 1 and 2, respectively. Both temperature and relative humidity followed typical seasonal patterns.

Norovirus had the highest incidence rate (F_i) (Table 3) and was associated with the highest relative frequency of foodborne disease outbreaks ($F_i = 0.1987$ as a mean), followed by pathogenic *E. coli* ($F_i = 0.1024$), *Salmonella* spp. ($F_i = 0.0758$), *S. aureus* ($F_i = 0.0675$), and *V. parahaemolyticus* ($F_i = 0.0578$). *B. cereus* had the lowest incidence rate ($F_i = 0.0206$). These results were similar to those reported by the KMFDS (2013) in South Korea.

3.2. The relationship of foodborne pathogens and climatic conditions

The incidence rates of foodborne disease outbreaks due to the 8 identified pathogens are shown in relation to mean monthly temperature (Fig. 1) and relative humidity (Fig. 2) that prevailed in South Korea during the study period (2003–2012). Using Pearson correlation coefficient values (r), the impact of the different foodborne pathogens on foodborne disease outbreaks were ranked in relation to mean monthly temperature as well as mean monthly relative humidity.

Considering the mean monthly temperature: Pathogenic *E. coli* ($r = 0.8898$) ranked highest, followed by *Salmonella* spp. ($r = 0.7531$), *V. parahaemolyticus* ($r = 0.6964$), *C. jejuni* ($r = 0.6595$), *B. cereus* ($r = 0.3556$), and *S. aureus* ($r = 0.1106$). There was a negative correlation ($r = -0.6457$) between temperature and the occurrence of foodborne disease outbreaks due to *C. perfringens*.

Considering the monthly mean relative humidity, pathogenic *E. coli* ($r = 0.8803$) ranked the highest, followed by *V. parahaemolyticus* ($r = 0.8048$), *C. jejuni* ($r = 0.6142$), *Salmonella* spp. ($r = 0.3893$), and *B. cereus* ($r = 0.2040$). There was a negative correlation between relative humidity and the occurrence of foodborne disease outbreaks due to *S. aureus* ($r = -0.1169$) and *C. perfringens* ($r = -0.8635$). Furthermore, the number of foodborne disease outbreaks associated with Norovirus infections was higher in winter months than in summer months (Fig. 1): foodborne disease outbreaks due to Norovirus were negatively correlated with temperature ($r = -0.9791$) as well as relative humidity ($r = -0.8747$, Fig. 2), but the correlation was stronger with temperature than with relative humidity.

The following pathogens were more affected by changes in temperature than changes in relative humidity: pathogenic *E. coli* ($0.8998 > 0.8803$), *C. jejuni* ($0.6595 > 0.6142$), *Salmonella* spp. ($0.7531 > 0.3893$), *B. cereus* $0.3556 > 0.2040$) and Norovirus ($-0.9791 > -0.8747$), whilst, *V. parahaemolyticus* ($0.6964 < 0.8048$) and *C. perfringens* ($-0.6457 < -0.8635$) were more affected by the relative humidity than by temperature. Neither temperature nor relative humidity seems to have an effect on foodborne disease outbreaks due to

Table 2
The total number of foodborne diseases outbreaks (N) and the number of outbreaks for specific foodborne diseases species (n_i) per month, during 2003–2012 in South Korea.

Month	Total outbreaks number (N)	The number of outbreaks for a specific foodborne diseases species (n_i)										
		Pathogenic *Escherichia coli*	*Salmonella* spp.	*Vibrio parahaemolyticus*	*Campylobacter jejuni*	*Bacillus cereus*	*Staphylococcus aureus*	*Clostridium perfringens*	Norovirus	Other bacteria	Other virus	Unknown
Jan	97	6	0	0	0	1	7	2	38	1	1	41
Feb	122	0	3	1	1	3	8	5	45	1	1	54
Mar	168	6	10	1	0	3	10	6	50	4	1	77
Apr	203	20	29	1	6	5	14	8	45	3	0	72
May	267	25	43	4	8	8	27	6	37	5	4	100
Jun	335	59	38	6	12	4	26	6	33	3	2	146
Jul	230	37	23	22	16	7	16	1	10	1	2	95
Aug	317	61	29	70	8	5	17	0	4	2	2	119
Sep	309	58	34	62	4	7	18	4	11	1	2	108
Oct	154	14	10	16	1	4	9	3	15	1	1	80
Nov	138	10	5	2	4	3	10	3	40	0	2	59
Dec	170	10	1	1	2	2	9	3	66	1	3	72
Total	2,510	306	225	186	62	52	171	47	394	23	21	1,023
(%)	(100.0)	(12.2)	(9.0)	(7.4)	(2.5)	(2.1)	(6.8)	(1.9)	(15.7)	(0.9)	(0.8)	(40.8)

S. aureus (0.1106, −0.1169). There were highly significant correlations ($r > 0.9$, $p < 0.001$) between temperature and relative humidity and the incidence of foodborne disease outbreaks in some of the pathogens that were studied: pathogenic *E. coli*, Norovirus, and *C. perfringens* were significantly correlated ($p < 0.001$) with relative humidity. In contrast, *B. cereus* and *S. aureus* were not correlated ($p > 0.05$) with either temperature or relative humidity, and *Salmonella* spp. was not significantly correlated ($p > 0.05$) with relative humidity (Figs. 1 and 2).

Fig. 3 also gives an overview of the relationships between the 8 pathogens responsible for foodborne diseases and the monthly mean temperature as well as relative humidity. Pathogenic *E. coli* had the highest positive correlation coefficient with temperature as well as with relative humidity, followed by *V. parahaemolyticus*, *C. jejuni*, *Salmonella* spp., and *B. cereus*. Considering negative correlation coefficients, Norovirus had the strongest negative correlation with temperature and relative humidity, followed by *C. perfringens*. *S. aureus* had the poorest correlation with temperature and relative humidity.

4. Discussion

The present study investigated the relationship between foodborne disease outbreaks due to specific foodborne pathogens and temperature as well as relative humidity. Both these climatic conditions are known to have a role in the outbreak of foodborne disease and they are also known to be affected by climate change (Tirado, Clarke, Jaykus, McQuatters-Gollop, & Frank, 2010). It is therefore very likely that the incidence of foodborne disease outbreaks would alter with climatic changes.

Previous studies conducted in European countries showed that among foodborne bacterial pathogens, *C. jejuni* and *Salmonella* spp. were influenced most by changes in air temperature and precipitation (i.e. relative humidity), followed by *Vibrio* spp. (Semenza et al., 2012). From the results of the present study, it is clear that there are differences between the relative importance of these pathogens in foodborne disease outbreaks in Europe and in South Korea. The present study shows that in South Korea foodborne disease outbreaks due to pathogenic *E. coli* were strongly correlated with changes in temperature and relative humidity. A Canadian study also reported that for every degree increase in weekly mean temperature, the increase in the number of pathogenic *E. coli* foodborne disease cases was greater than that caused by *Salmonella* spp. and *Campylobacter* (Fleury et al., 2006). The recent increase in the incidence of pathogenic *E. coli* infections also suggests that this bacterium is, to some extent, associated with climate change (Lipkin, 2013). Pathogenic *E. coli* comprise several different species such as EAEC, EHEC, EPEC, and EIEC, which may have different characteristics relating to temperature and humidity. However, this distinction was not considered in the present analysis because of the limited data available during the study period. This analysis should be performed in future studies.

Among the 8 foodborne pathogens investigated, *C. perfringens* was clearly different from the other bacterial species because it had a highly significant negative correlation with temperature as well as the monthly mean relative humidity. The only known characteristic difference between *C. perfringens* and other bacterial pathogens is its anaerobic spore formation. Further studies, to elucidate the effect of temperature and relative humidity on this pathogen, are clearly needed.

Table 3
The distribution of monthly incidence rate (F_i)[a)] as the relative frequency of occurrence of foodborne disease outbreaks during 2003–2012 in South Korea.

Month	Pathogenic *Escherichia coli*	*Salmonella* spp.	*Vibrio parahaemolyticus*	*Campylobacter jejuni*	*Bacillus cereus*	*Staphylococcus aureus*	*Clostridium perfringens*	Norovirus
Jan	0.0619 [a)]	0.0000	0.0000	0.0000	0.0103	0.0722	0.0206	0.3918
Feb	0.0000	0.0246	0.0082	0.0082	0.0246	0.0656	0.0410	0.3689
Mar	0.0357	0.0595	0.0060	0.0000	0.0179	0.0595	0.0357	0.2976
Apr	0.0985	0.1429	0.0049	0.0296	0.0246	0.0690	0.0394	0.2217
May	0.0936	0.1610	0.0150	0.0300	0.0300	0.1011	0.0225	0.1386
Jun	0.1761	0.1134	0.0179	0.0358	0.0119	0.0776	0.0179	0.0985
Jul	0.1609	0.1000	0.0957	0.0696	0.0304	0.0696	0.0043	0.0435
Aug	0.1924	0.0915	0.2208	0.0252	0.0158	0.0536	0.0000	0.0126
Sep	0.1877	0.1100	0.2006	0.0129	0.0227	0.0583	0.0129	0.0356
Oct	0.0909	0.0649	0.1039	0.0065	0.0260	0.0584	0.0195	0.0974
Nov	0.0725	0.0362	0.0145	0.0290	0.0217	0.0725	0.0217	0.2899
Dec	0.0588	0.0059	0.0059	0.0118	0.0118	0.0529	0.0176	0.3882
Mean ± SD	0.1024 ± 0.0631	0.0758 ± 0.0526	0.0578 ± 0.0797	0.0215 ± 0.0196	0.0206 ± 0.0070	0.0675 ± 0.0132	0.0211 ± 0.0127	0.1987 ± 0.1446

[a)] Reference to Eq. (1).

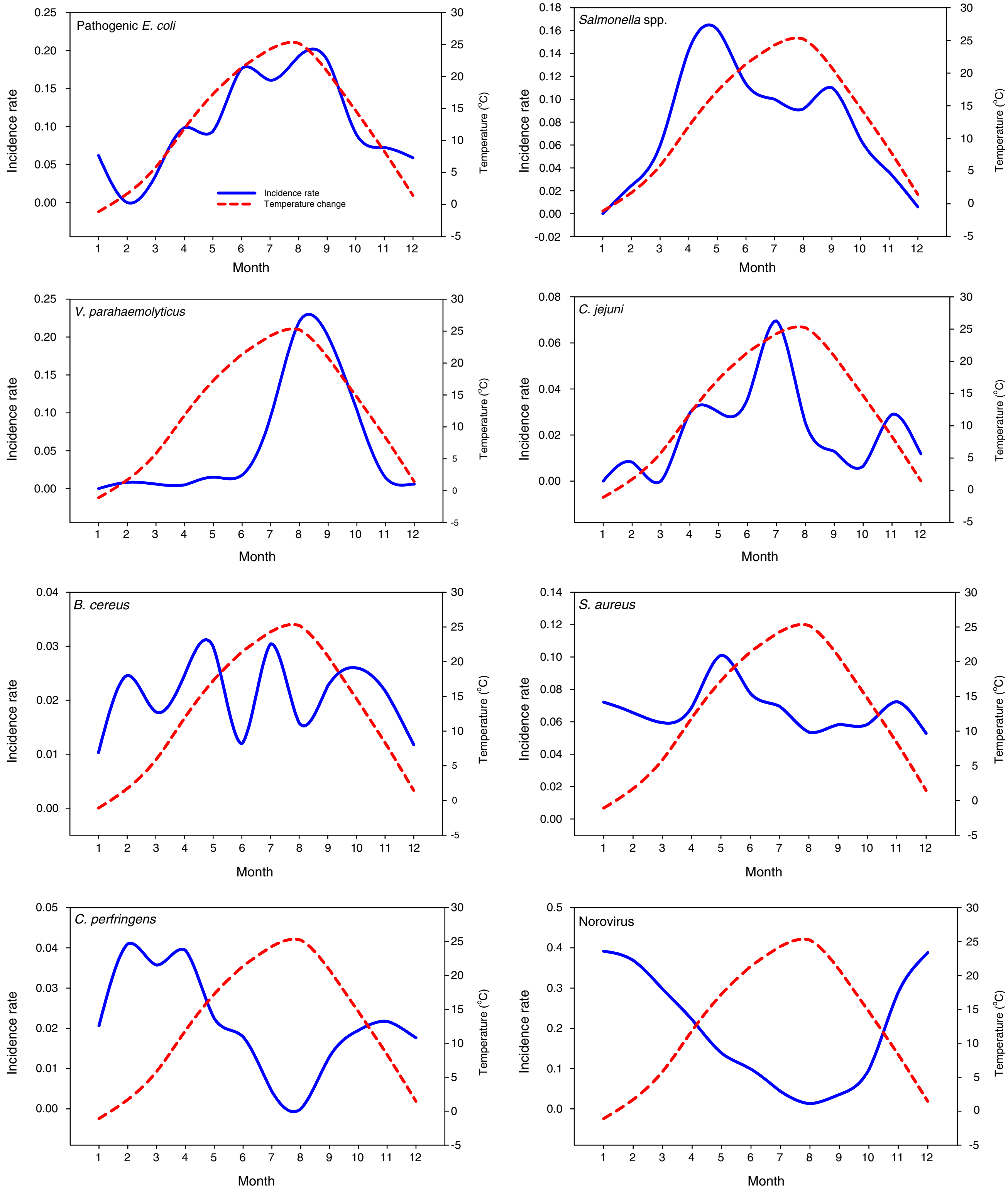

Fig. 1. Comparison of the incidence rates for 8 foodborne diseases and the distributions of monthly mean temperature during 2003–2012 in South Korea. The Pearson correlation coefficients (r) and p-values were as follows: pathogenic *Escherichia coli* ($r = 0.8998$, $p < 0.001$), *Salmonella spp.* ($r = 0.7531$, $p = 0.005$), *Vibrio parahaemolyticus* ($r = 0.6964$, $p = 0.012$), *Campylobacter. jejuni* ($r = 0.6595$, $p = 0.020$), *Bacillus cereus* ($r = 0.3556$, $p = 0.253$), *Staphylococcus aureus* ($r = 0.1106$, $p = 0.732$), *Clostridium perfringens* ($r = -0.6457$, $p = 0.023$), and *Norovirus* ($r = -0.9791$, $p < 0.001$).

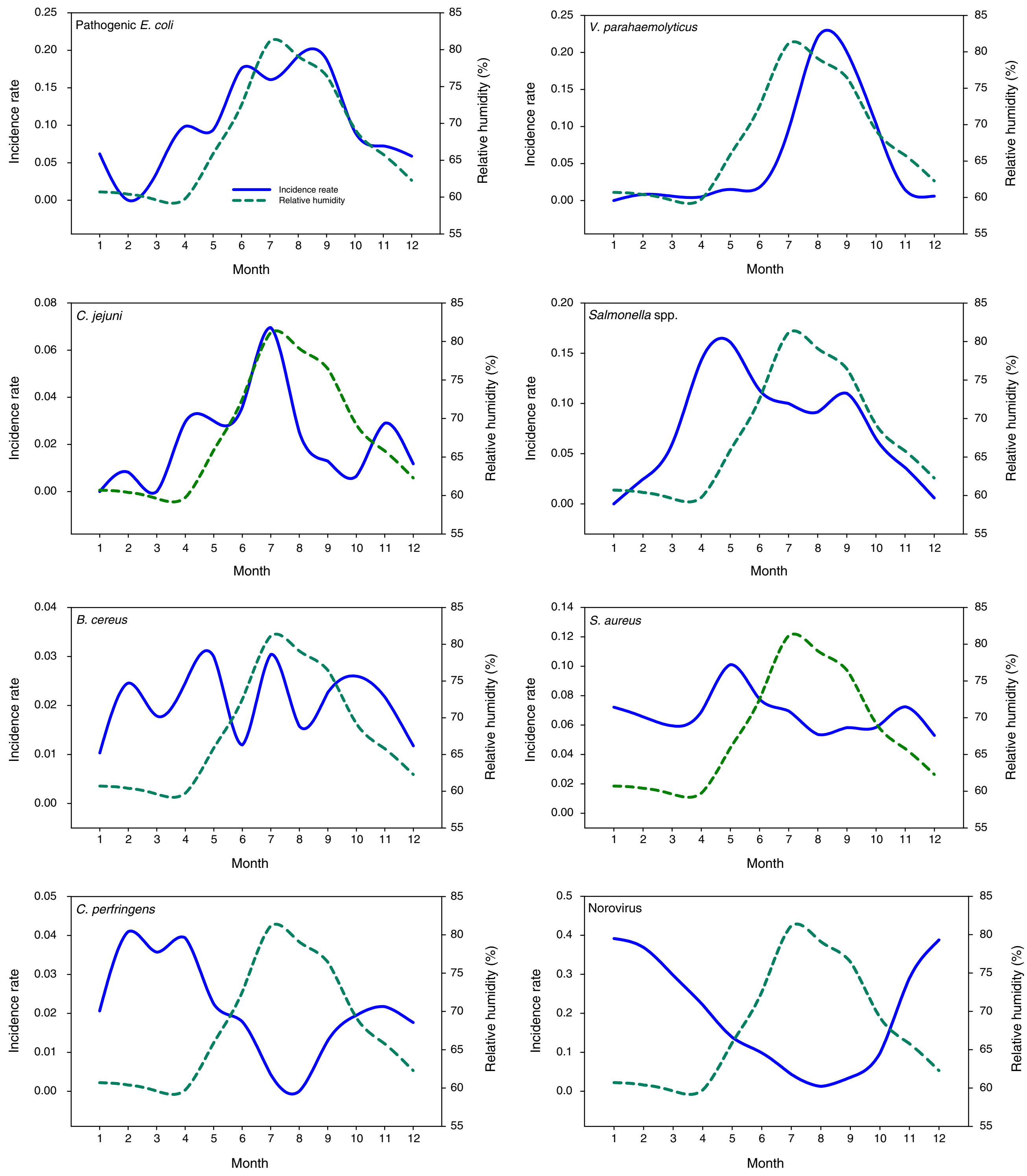

Fig. 2. Comparison of the incidence rates for 8 foodborne diseases and the distribution of the monthly mean relative humidity during 2003–2012 in South Korea. The Pearson correlation coefficients (r) and p-values were as follows: pathogenic *Escherichia coli* ($r = 0.8803$, $p < 0.001$), *Vibrio parahaemolyticus* ($r = 0.8048$, $p = 0.002$), *Campylobacter jejuni* ($r = 0.6142$, $p = 0.034$), *Salmonella spp.* ($r = 0.3893$, $p = 0.211$), *Bacillus cereus* ($r = 0.2040$, $p = 0.525$), *Staphylococcus aureus* ($r = -0.1169$, $p = 0.718$), *Clostridium perfringens* ($r = -0.8635$, $p < 0.001$), and *Norovirus* ($r = -0.8737$, $p < 0.001$).

The relationship between pathogens and the mean monthly temperature and that with relative humidity were similar, except for *Salmonella* spp., which seemed to be less affected by changes in relative humidity than by changes in temperature. The correlation between foodborne disease outbreaks due to *Salmonella* spp. and relative humidity was poor ($r = 0.3893$) and non-significant ($p = 0.221$). Iturriaga, Tamplin, and Escartín (2007) investigated the influence of the relative humidity and storage temperature on *Salmonella* Montevideo

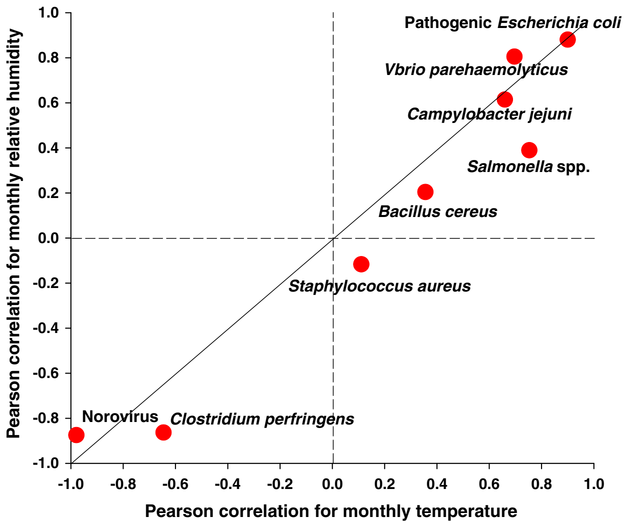

Fig. 3. Comparison of the Pearson correlation coefficients for the incidence rates of 8 foodborne diseases and the distribution of the monthly mean temperature and relative humidity during 2003–2012 in South Korea.

colonization of tomato surfaces and suggested that high relative humidity had a growth-promoting effect. In contrast, Semenza et al. (2012) reported that *Salmonella* spp. was the most vulnerable to precipitation (i.e. relative humidity). Further studies investigating the effect of relative humidity on this pathogen are needed.

Among all viral foodborne diseases, human noroviruses are known to be the most common viral pathogen responsible for foodborne disease outbreaks in South Korea (KMFDS, 2013) (Table 2) and several other countries (Lopman et al., 2003; Widdowson et al., 2005). The survival and transmission of noroviruses may be dependent on environmental factors, such as temperature and relative humidity (FAO/WHO, 2008). Lopman, Armstrong, Atchison, and Gray (2009) previously reported that cold and dry temperatures increase the occurrence of Norovirus infection. The present study results corroborate this finding. However, the impact of climate change on Norovirus infection is still not clear (Rohayem, 2009).

Although this study only investigated the effect of temperature and relative humidity on pathogenic foodborne disease, it is plausible that other contributing factors, such as a change in consumer behavior food handling, and food storage (e.g. temperature abuse in the establishment preparing the food) could influence foodborne disease outbreaks. Considering the role of climate change in foodborne diseases, Semenza and Menne (2009) suggested that health-behavior interventions and food-safety regulations could potentially negate the negative consequences of outbreaks on public health, regardless of climatic factors. Therefore, the relationship between climate change and foodborne disease, unlike infectious disease, has to be considered a contributing factor to foodborne disease outbreaks.

Thus far, the majority of studies investigating foodborne disease outbreaks report the number of individual cases affected during an outbreak or the number of outbreaks in a specific time period (Greig & Ravel, 2009), and most studies assessing the effects of climate change on foodborne disease report the number of cases of illness (e.g. Kovats et al., 2004). The present study focused on the number of foodborne disease outbreaks and showed that the number of outbreaks can be affected by changes in temperature and relative humidity.

Even though the present study only investigated the effects of temperature and relative humidity on foodborne disease outbreaks, the priority impact ranking may be adequate for decision-making strategies that would allow for the monitoring of different pathogens in the face of environmental change (Lake et al., 2012). Furthermore, climate change variables, such as increased air temperatures due to global warming and an increased relative humidity due to heavy rainfall, could potentially lead to an increase in pathogens in food. This, in turn, would be closely associated with a rise in the incidence of foodborne diseases and could trigger a change in risks associated with foodborne infectious diseases (El-Fadel et al., 2012; Fleury et al., 2006; Rose et al., 2001). In this way, global climate change could potentially change disease patterns (McMichael et al., 2003). The statistical model used in the present study can be used to estimate the change in foodborne disease patterns according to forecasted climatic conditions. Further, the results of the present study analysis can be utilized in the design and development of species-based food safety management and policies.

In conclusion, the present study reports the extent to which climatic conditions affect the above-mentioned 8 foodborne pathogens in South Korea. The results show that pathogenic *E. coli* and *V. parahaemolyticus* are likely to be most affected by the conditions of climate change. Because of regional climatic differences, these results may not be applicable to other countries or regions. It is therefore important to ascertain the regional effects and pathogen-dependent differences with regard to foodborne disease outbreaks so as to better understand the potential effects of climate change on food safety.

Acknowledgments

This research was supported by a grant (10162MFDS995) from the Ministry of Food and Drug Safety in 2013.

References

Craig, B. -A., Trinanes, J. A., Taylor, N. G. H., Hartnell, R., Siitonen, A., & Martinez-Urtaza, J. (2013). Emerging Vibrio risk at high latitudes in response to ocean warming. *Nature Climate Change*, *3*, 73–77.
Daniel, W. W. (2009). *Biostatistics: A Foundation for Analysis in the Health Sciences* Grouped data: The frequency distribution (9th ed.). New York: John Wiley & Sons Inc, 22.
ECDC (2007). Environmental change and infectious disease workshop. *Meeting report. Stockholm, 29–30 March*.
El-Fadel, M., Ghanimeh, S., Maroun, R., & Alameddine, I. (2012). Climate change and temperature rise: Implications on food- and water-borne diseases. *Science of the Total Environment*, *437*, 15–21.
FAO/WHO (2008). Viruses in food: Scientific advice to support risk management activities. *Meeting report. Microbiological risk assessment series 13*.
Fleury, M., Charron, D. F., Holt, J.D., Allen, O. B., & Maarouf, A.R. A. (2006). A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. *International Journal of Biometeorology*, *50*, 385–391, http://dx.doi.org/10.1007/s00484-006-0028-9.
Greig, J.D., & Ravel, A. (2009). Analysis of foodborne outbreak data reported internationally for source attribution. *International Journal of Food Microbiology*, *130*, 77–87.
Iturriaga, M. H., Tamplin, M., & Escartín, E. F. (2007). Colonization of tomatoes by Salmonella montevideo is affected by relative humidity and storage temperature. *Journal of Food Protection*, *70*, 30–34.
KMA (Korea Metrological Administration) (2013). Climate statistics in Korea. Accessed at July 2013; available at: www.climate.go.kr/index.html
KMFDS (Korea Ministry of Food and Drug Safety) (2013). The statistics for reported foodborne outbreaks in Korea. Accessed at July 2013; available at: www.mfds.go.ke/e-state
Kovats, S., Edwards, S., Charron, D., Cowden, J., D'Souza, R., & Ebi, K. (2005). Climate variability and campylobacter infection: An international study. *International Journal of Biometeorology*, *49*, 207–214.
Kovats, S., Edwards, S., Hajat, S., Armstrong, B., Ebi, K., & Menne, B. (2004). The effect of temperature on food poisoning: Time series analysis in 10 European countries. *Epidemiology and Infection*, *132*, 443–453.
Lake, I. R., Gillespie, I. A., Bentham, G., Nichols, G. L., Lane, C., & Adak, G. K. (2009). A re-evaluation of the impact of temperature and climate change on foodborne illness. *Epidemiology and Infection*, *137*, 1538–1547.
Lake, I. R., Hooper, L., Abdelhamid, A., Bentham, G., Boxall, A.B. A., Draper, A., et al. (2012). Climate change and food security: Health impacts in developed countries. *Environmental Health Perspectives*, *120*, 1520–1526.
Lipkin, W. I. (2013). The changing face of pathogen discovery and surveillance. *Nature Reviews Microbiology*, *11*, 133–141.
Liu, C., Hofstra, N., & Franz, E. (2013). Impacts of climate change on the microbial safety of pre-harvest leafy green vegetables as indicated by *Escherichia coli* O157 and *Salmonella* spp. *International Journal of Food Microbiology*, *163*, 119–128.
Lopman, B., Armstrong, B., Atchison, C., & Gray, J. J. (2009). Host, weather and virological factors drive norovirus epidemiology: Time-series analysis of laboratory surveillance data in England and Wales. *PLoS One*, *4*, e6671.

Lopman, B., Reacher, M., van Duijnhoven, Y., Hanon, F. X., Brown, D., & Koopmans, M. (2003). Viral gastroenteritis outbreaks in Europe, 1995-2000. *Emerging Infectious Diseases*, *9*, 90–96, http://dx.doi.org/10.3201/eid0901.020184PMCID: PMC2873740.

McMichael, A. J., Campbell Lendrum, D. H., Corvalán, C. F., Ebi, K. L., Githeko, A., Scheraga, J.D., et al. (2003). *Climate change and human health—Risks and responses.* Geneva: World Health Organization (Accessed at November, 2012; available at: www.who.int/globalchange/publications/cchhbook/en/index.html).

Miraglia, M., Marvin, H. J. B., Kleter, G. A., Battilani, P., Brera, C., Coni, E., et al. (2009). Climate change and food safety: An emerging issue with special focus on Europe. *Food and Chemical Toxicology*, *47*, 1009–1021.

Rohayem, J. (2009). Norovirus seasonality and the potential impact of climate change. *Clinical Microbiology and Infection*, *15*, 524–527.

Rose, J. B., Epstein, P. R., Lipp, E. K., Sherman, B. H., Bernard, S. M., & Patz, J. A. (2001). Climate variability and change in the United States: Potential impacts on water and foodborne diseases caused by microbiologic agents. *Environmental Health Perspectives*, *109*, 211–221.

Semenza, J. C., & Menne, B. (2009). Climate change and infectious diseases in Europe. *The Lancet infectious diseases*, *9*, 365–375.

Semenza, J. C., Herbst, S., Rechenburg, A., Suk, J. E., Höser, C., Schreiber, C., et al. (2012). Climate change impact assessment of food and waterborne diseases. *Critical Reviews in Environmental Science and Technology*, *42*, 857–890.

Tirado, M. C., Clarke, R., Jaykus, L. A., McQuatters-Gollop, A., & Frank, J. M. (2010). Climate change and food safety: A review. *Food Research International*, *43*, 1745–1765.

Widdowson, M.A., Sulka, A., Bulens, S. N., Beard, R. S., Chaves, S. S., Hammond, R., et al. (2005). Norovirus and foodborne disease, United States, 1991–2000. *Emerging Infectious Diseases*, *11*, 95–102, http://dx.doi.org/10.3201/eid1101.040426PMCID: PMC3294339.