Original scientific paper
UDC 613.2.099(437.6)"2000/2020"

LONG-TERM CHANGES IN THE EPIDEMIOLOGY OF FOODBORNE INTOXICATION IN SLOVAKIA FOR PAST 20 YEARS

Lucia Zeleňáková[1*], Lucia Benešová[1]

[1]Institute of Food Sciences, Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture, Tr. A. Hlinku 2, 94976 Nitra, Slovakia

[*]e-mail: lucia.zelenakova@uniag.sk

Abstract

The goal of the study was to analyze the changes in the epidemiology of bacterial alimentary intoxications in Slovakia in the last 20 years using the Epidemiological information system (EPIS).

The epidemiological situation in the occurrence of reported alimentary intoxications in the Slovakia is extremely favorable in comparison with the world. In the years 2000 - 2020, only 4,085 cases of diseases were recorded by the epidemiological information system (average morbidity of 3.78/100,000 inhabitants). Staphylococcal intoxications dominated among them (49.01%) and so-called unspecified bacterial food poisoning (44.95%). The frequency of other analyzed diagnoses did not exceed 5% in the monitored period. Statistical analysis of the collected data was performed using non-parametric tests, which are ideal for comparing independent values. For testing two selections was chosen the Mann-Whitney test, for verifying the differences in three or more files, it was necessary to use its direct generalization in the form of the Kruskal-Wallis test. Existence of a statistically significant difference was at the level of significance $\alpha = 0.05$.

In terms of regional distribution the highest concentration of cases (51%) was recorded in western Slovakia ($p > 0.05$). An increased frequency of the disease was observed in the summer months, evenly in both sexes, 2,047 in men and 2,038 in women ($p > 0.05$). The maximum morbidity 29% in children aged 0 - 14 years were represented ($p < 0.05$). There are demonstrably two specific categories, namely pre-productive and productive age, there is statistically significant difference. Most of those injured became infected after eating a mixed diet (45%), but other frequently reported transmission factors included contaminated food (18%), poultry (10%) or beverages (7%). The highest numbers of those infected were recorded in catering establishments at workplaces, schools, medical facilities, fast food stalls and public catering establishments.

Bacterial food intoxications are a serious global problem and their prevention must be one of the top priorities of the food safety system. An essential part of preventive measures is also the increase of food education, the need to comply with the prescribed production process and consumer information, each of which should master the principles of proper storage and processing of food.

Key words: *Foodborne intoxication, Food, bacteria, Epidemiological information system, Slovakia.*

1. Introduction

Due to the constant changes in the dynamics of world food trade, in consumption behavior, in the environment and processes associated with food production, as well as due to the re-development of pathogens and chemical contaminants entering the food chain, food diseases are a long-term and growing problem (WHO [33]). Bacteria are the cause of 2/3 of foodborne illnesses. Most bacteria, such as *Escherichia coli* O157:H7, *Salmonella* spp. and *Proteus mirabilis*, cause foodborne infections. If these and other bacteria are found in food or water at the time of consumption, they can cause a variety of disease states in the human body due to their pathogenic properties (Bhunia [5]; Taekeon *et al.*, [30]).

Another group of foodborne illnesses are bacterial intoxications, which are caused by toxic products of some species of microorganisms, e.g. *Bacillus cereus, Clostridium botulinum* or *Clostridium perfringens*. From a chemical point of view, these are macromolecules of a proteinaceous nature, which are generally divided into endotoxins and exotoxins (Van Seventer and Hamer, [32]). In recent decades, significant progress has been made in understanding the molecular mechanisms of action of bacterial toxins. Both complete genome sequencing methodologies and high-throughput sequencing techniques are rapidly evolving, as are biological data banks, computational analyzes, and new, more efficient ways to extract genomic data, enabling an ever better and better understanding of toxin diversity in the bacterial world (Adebe *et al.*, [1]).

Soil is regarded as the natural habitat of spore-forming bacteria. Spores present in soils can be dispersed and can colonize very diverse environmental niches. *B. cereus* and *B. subtilis* spores can be detected in the gastrointestinal tract of vertebrates and vertebrates including mammals. The food production chain can be contaminated by spores through these sources (Carlin [8], Majed *et al.*, [23]). *B. cereus* prevalence and concentrations in foods is well documented and many surveys have been performed worldwide. *B. cereus* has been detected in a very wide range of foods and this is in agreement with the large diversity of foods associated with outbreaks of foodborne poisonings. Concentrations before storage is usually lower than 100 cfu x g^{-1}. A noticeable exception is herbs and spices, which may contain concentrations greater than 10^3 cfu x g^{-1} (Jessberger *et al.*, [21]). Symptoms of food poisonings include vomiting, nausea, diarrhea, and abdominal pain. Poisonings likely result of the ingestion of toxins formed in the foods, similarly to the emetic syndrome due to *B. cereus* emetic strains and cereulide. These toxins have been described as lipopeptides, produced from rare (a few %) toxic isolates (Stenfors *et al.*, [29]). While rice, cereals and pasta, milk puddings and pasteurized cream are common sources of infection in the emetic form of the disease, in the diarhogenic (diarrheal) form they are mainly meat and vegetable dishes, soups or desserts (Hwang and Huang [19]). Neither form of the disease usually requires any specific treatment. It is recommended to supplement fluid loss (Omer *et al.*, [25]). Prevention and control of this pathogen is relatively simple. The only exception is the dairy industry, where *B. cereus* causes major problems. If food is stored for too long at a temperature of 5 - 60 ^{0}C, spores germinate and microorganisms grow. If the food is not consumed immediately, rapid cooling (or freezing) is necessary and, after subsequent administration, thorough overheating to a temperature above 75 ^{0}C (Cremonesi *et al.*, [11]).

S. aureus bacteria are Gram-positive, facultative anaerobic, immobile cocci. Their globular cells are grouped into clusters resembling bunches of grapes. *S. aureus* is able to grow in a wide range of temperatures (7 ^{0}C - 48 ^{0}C with optimum at 30 - 37 ^{0}C) and pH values (4.2 - 9.3 with optimum at 7.0 - 7.5). It is not hindered even by a certain concentration of sodium chloride (NaCl) in the environment (< 15%). These properties allow *S. aureus* bacteria to survive in a variety of foods, especially those that require handling during processing. This creates a unique space for secondary contamination, especially through the human (Argaw and Addis [4]; Tessema and Tsegaye [31]). Staphylococcal enterotoxins have been found in various types of food. Among the most risky are mainly raw meat, poultry, fish and fish products, milk and dairy products, eggs, but also bakery assortment. All of the above is a medium ideal for the growth and rapid multiplication of *S. aureus* bacteria (Fetsch and Johler [14]). In addition to extraintestinal infections (e.g. septicemia, infectious endocarditis, necrotizing pneumonia), staphylococcal enterotoxins also cause food poisoning with a short incubation period. Clinical symptoms begin within 2 - 4 hours after ingestion of contaminated food. The course of the disease is characterized by nausea, vomiting, chills, headaches, abdominal cramps and diarrhea, but cases without diarrhea have also been confirmed. These symptoms are not usually accompanied by fever. In more susceptible individuals (children, the older generation), the disease rarely ends in death (Serda *et al.*, [28]).

Clostridium botulinum is a sporulating anaerobic bacterium with the ability to produce a deadly botulinum neurotoxin. It is a severe, life-threatening food poisoning. It is divided into four groups (*C. botulinum* groups I to IV) according to genotypic and phenotypic characteristics. Botulinum neurotoxins are the most potent toxins known and act in the cytoplasm of nerve cells, where they selectively cleave proteins involved in the release of neurotransmitters, leading to to a deadly weak paralysis called botulism (Brunt *et al.*, [7]). *C. botulinum* bacteria are also found in the digestive system of animals, from where they can be excreted into the environment. The transmission of clostridia to food is linked to non-compliance with the thermal range of products to be kept refrigerated, including fish and meat, and to poor hygiene in storage, production and food preparation. Canned foods rich in protein or hermetically packaged fish products and mushrooms wrapped in foil are especially risky. *C. botulinum* spores are thermoresistant and can withstand boiling for two hours. Its vegetative forms germinate from the spores and begin to produce botulinum toxin in canned or contaminated food. *C. botulinum* toxins are thermolabile, inactivated by heating at 80 ^{0}C for 10 minutes or other equivalent method. (Long [22]; Peck and Van Vlieck [27]). The incubation period is about 12 to 36 hours, but the first symptoms may appear as early as 5 hours or up to 10 days after consuming contaminated food. Symptoms begin with malaise, abdominal pain, vomiting, followed by nervous symptoms - decreased eyelids, dry mouth, difficulty swallowing and gradual paralysis of all muscles. A patient with suspected botulism must be hospitalized. The only effective treatment is early administration of a specific antidote and support of the patient's breathing (Annibali *et al.*, [2]).

Clostridium perfringens is one of the largest producers of toxins among *Clostridium* species, even among the most widespread, it is found as part of the microbiota of animals and humans and in soil contaminated with faeces. It produces four main toxins: alpha (α), beta (β), epsilon (ε) and iota (i) and in addition to more than 15 other known toxins (Hailegebreal [17]).

Common sources of *C. perfringens* infection include meat, poultry, gravies, and other foods cooked in large batches and held at an unsafe temperature. Outbreaks tend to happen in places that serve large groups of people, such as hospitals, school cafeterias, prisons, and nursing homes, and at events with catered food. *C. perfringens* outbreaks occur most often in November and December. Many of these outbreaks have been linked to foods commonly served during the holidays, such as turkey and roast beef (Center for Diseases Control and Prevention [10]).

Vibrio parahaemolyticus is known to be one of the most common food pathogens and typically causes acute gastroenteritis in humans. This bacterium preferably grows in warm and weakly salty seawater (tolerates 7 to 10% NaCl) and sometimes colonizes aquatic hosts such as molluscs, shrimp and fish. Most people become infected by consuming raw or undercooked seafood or contaminated water (Pang *et al.*, [26]).

Food poisoning is a current global public health problem. They affect not only population health, livelihoods and health care systems, but also international trade. In context with above mentioned, the goal of the study was to analyze the changes in the epidemiology of bacterial foodborne intoxications in Slovakia in the last 20 years using the Epidemiological information system (EPIS).

2. Materials and Methods

As the term "intoxication" suggests, foodborne intoxication (alimentary intoxication, food poisoning), is caused by toxins in food. Foodborne illnesses represent just one example of new classifications and new terminology found in ICD-10-CM. Understanding the reasons for the introduction of new and revised classifications of some diseases and disease processes can help coders locate and assign the correct codes. Category A05, bacterial foodborne intoxications, contains codes for the more common infectious organisms that produce toxins responsible for the disease processes.

An epidemiological analysis of the reported cases (2000 - 2020) these foodborne intoxications were performed in relation to the following indicators: incidence trends, regions (i.e. place of residence of the infected), sex/gender, age, seasonality, and transmission factors. Special attention was paid to preventive measures.

Basic data collection was performed from the Epidemiological Information System (EPIS). Additional information was also obtained from the European Center for Disease Prevention and Control (ECDC) and the scientific and professional literature.

Slovakia became a part of the European Union network for surveillance of infectious diseases. Based on the Food and Waterborne Diseases FWD, the special Epidemiological Information System (EPIS, since 2006) for the FWD was established in Slovakia. EPIS network is involved in the solutions of so-called "urgent inquires", what is a signal of a possible threats of an international epidemics. Development and introduction of EPIS in Slovakia led to a strengthening of surveillance of infectious diseases, increased operational capacity of epidemiologists in the area of control of transmissible diseases, epidemics, management and control of emergency situations, speeding up and ensuring the quality, what is a prerequisite for rapid adoption of effective antiepidemic steps and actions for the health protection.

Table 1. Bacterial foodborne intoxications A050 - A059 according according to the international classification of diseases (ICD 10CM/Codes [20])

Diagnosis code	Diagnosis name	Additional information
A05.0	Foodborne staphylococcal intoxication	
A05.1	Botulism	Foodborne intoxication due to *Clostridium botulinum*
A05.2	Foodborne *Clostridium perfringens* (*Clostridium welchii*) intoxication	Enteritis necroticans
A05.3	Foodborne *Vibrio parahaemolyticus* intoxication	
A05.4	Foodborne *Bacillus cereus intoxication*	
A05.8	Other specified bacterial foodborne intoxications	
A05.9	Other unspecified bacterial foodborne intoxications	

2.1 Statistical analysis

Statistical analysis of the collected data was performed using non-parametric tests, which are ideal for comparing independent values. For testing two selections was chosen the Mann-Whitney test, for verifying the differences in three or more files, it was necessary to use its direct generalization in the form of the Kruskal-Wallis test. Existence of a statistically significant difference was at the level of significance α = 0.05. In the case of rejection of the established hypothesis, the differing pairs were identified by means of a method consisting in the mutual comparison of all selection pairs observed in the given test.

3. Results and Discussion

Bacterial food poisoning is a group of various diseases arising from the consumption of foods heavily contaminated with toxins, which are waste products of the metabolism of specific microorganisms. After respiratory infections, foodborne infections are the second most common category of infectious diseases, which means that they contribute significantly to both morbidity and mortality (Aragrande and Canali [3]).

According to available statistics, the incidence of foodborne diseases ranges from 10 to 15% of the total population, with almost 23 million cases occurring each year in the European Union alone and more than 4 650 of them ending in death (WHO [33]).

In the United States, foodborne diseases regularly affect more than 48 million people, of whom 128,000 are in need of hospitalization and about 3,000 die despite receiving medical care. Even more alarming are those reported in Asia, where they registered up to 275 million patients and 225,000 deaths in causation of consuming contaminated food during 2020. The situation in the so-called developing countries is largely unknown due to insufficient monitoring and the influence of supervisors (Taekeon *et al.*, [30]).

The epidemiological situation in the occurrence of reported foodborne intoxications in the Slovakia is extremely favorable in comparison with the world. In the years 2000 - 2020, only 4,085 cases of diseases were recorded Epidemiological information system (average morbidity of 3.78/100,000 inhabitants). The highest number of cases 733 (13.59/100,000 inhabitants) was recorded in 2006, on the contrary, the lowest in 2012 (7 confirmed cases). The low morbidity rate in 2020 (18 reported cases) was very significantly affected by the global pandemic of Covid 19. The disease has become a public health priority. At the same time, not all people exposed to gastroenteritic toxins were treated by a doctor, or they were not sampled to confirm positivity and were therefore not reported to the EPIS system. GPs and hospitals have this responsibility through their laboratories. Most of these diseases occurred sporadically, but several family occurrences or local epidemics were also described, which are described in more detail in later sections of this article.

The number of year-on-year registered diseases clearly shows that the trend in the incidence of bacterial food intoxications in Slovakia has been declining since 2000 (Figure 1). This favorable situation can be interpreted as a result of a relatively high standard of living, a responsible approach by the food industry, and adequate regulatory measures by control authorities and good access to healthcare in the Slovakia.

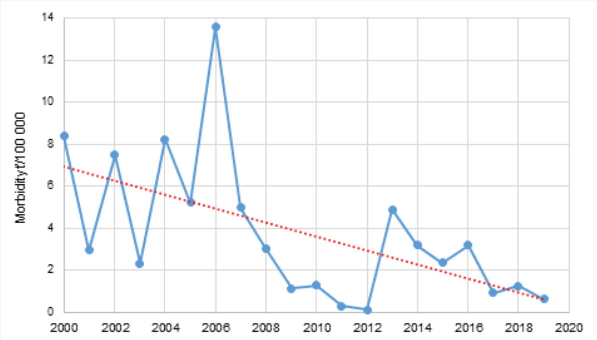

Figure 1. Incidence trend of bacterial food poisoning in Slovakia for the 20 past years

Of the selected subgroups of diagnosis A05 (Figure 2), foodborne staphylococcal intoxications (A05.0) dominated in Slovakia, which accounted for 49% (2,002 cases) of the total number of diseases.

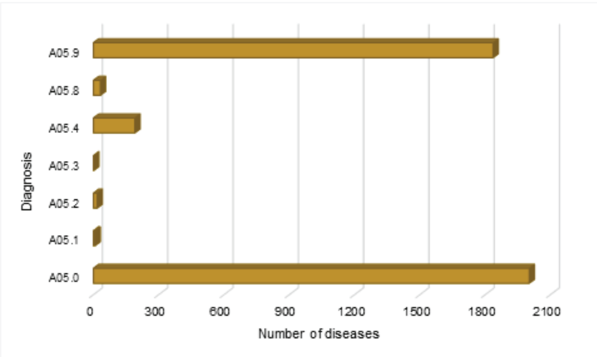

Figure 2. Comparison of the incidence of selected diagnoses of bacterial food poisoning in Slovakia for the last 20 years

The second most numerous group of diseases (45%) were unspecified bacterial foodborne intoxications with 1,836 confirmed cases (A05.9). In addition, 190 cases of poisoning caused by the bacterial species *B. cereus* (A05.4) and 32 patients with the diagnosis A05.8 (so-called other specified bacterial foodborne intoxications) were reported in the monitored period. The epidemiological situation in the occurrence of the last three analyzed diagnoses in Slovakia is more than positive. In the last 20 years, only 25 diseases have been recorded, of which 17 with a diagnosis of A05.2 (food poisoning caused by *C. perfringens*), 7 patients with botulism (A05.1) and 1 imported case of food poisoning caused by *V. parahaemolyticus* (A05 .3).

The number of recorded outbreaks of *B. cereus* food poisoning is considerably underestimated in comparison with the actual occurrence. The main reason is the relatively mild course of both forms of the disease and also the fact that complete recovery is rapid, with a few exceptions. Affected individuals generally do not seek medical attention, so their diagnosis is not subject to reporting to health authorities. In addition, epidemiological surveillance is complicated by insufficient testing for pathogens causing similar symptoms. For example, the course of food poisoning by *S. aureus* or *C. perfringens* is largely indistinguishable from poisoning by *B. cereus* (Glasset *et al.*, [16]).

The distribution of individual types of bacterial food poisoning is approximately the same in most developed countries of the world. *B. cereus* is considered to be the most important pathogen in the EU. According to statistics from the European Center for Disease Prevention and Control (ECDC), outbreaks of bacillary toxins are reported approximately twice as often as cases of diseases caused by S. aureus or *C. perfringens*. A large part of other poisonings (48.1%) attributed to the intake of bacterial toxins is not epidemiologically clarified, so they are classified as so-called. unspecified bacterial food poisoning (A05.9). Their share in the incidence of A05 diagnosis in Europe absolutely corresponds to the representation observed in Slovakia (EFSA [13]).

It is more than obvious that the incidence of bacterial food poisoning in the population is a global health, social and economic problem. Sensitivity, resp. however, susceptibility to this type of infection is an individual characteristic of individuals and can vary significantly between different population groups (Hernandez-Cortez *et al.*, [18]). The level of morbidity is closely related not only to eating habits, but also to hygienic and socio-economic conditions, which is why differences within a country tend to appear at the regional level (Donkor [12]).

Figure 3 provides a comprehensive view of the incidence of bacterial foodborne intoxication in individual regions of Slovakia. This percentage corresponds in absolute terms to the population density of these regions. Although the incidence of cases (51%) recorded in the west of the country appears to be twice as high as the numbers diagnosed in Eastern (25%) and Central Slovakia (24%), this percentage corresponds to the population density of these regions. It is the concentration of the population in the most industrialized area of Slovakia combined with a faster way of life, including diet that is most often cited by experts as a slightly higher incidence of food poisoning in this part of the country (Brtková and Revallová [6]).

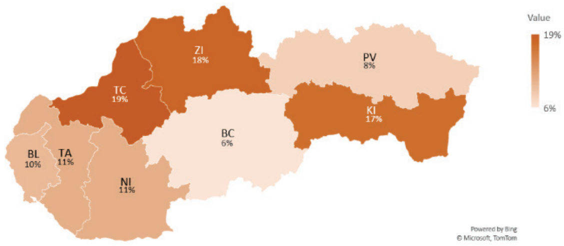

Figure 3. Percentages of regions in the incidence of bacterial food poisoning
Note: BL - Bratislava region, TA - Trnava region, TC - Trenčín region, NI - Nitra region, ZI - Žilina region, BC - Banská Bystrica region, PV - Prešov region, KI - Košice region

We also verified the difference in the distribution of intoxications between the three Slovak regions statistically. The median agreement of the number of cases recorded in each region (H0) was tested against the alternative, according to which at least one of the medians differs (H1). The calculation was performed using the Kruskal-Wallis test (Table 2). Since the obtained p-value is higher (0.086) than the determined level of significance α (0.05), we do not reject the null hypothesis.

Table 2. The result of the Kruskal-Wallis test for the influence of the region on the occurrence of bacterial food poisoning

Independent variable (n)	Region
Significance level α	0.05
p - value	0.086
Evaluation	$p \geq 0.05 \rightarrow$ not reject H_0

Women and men are exposed to special health problems and risks due to their biological differences, gender-based lifestyles, stress experiences and stressful situations. However, the occurrence of foodborne illnesses is not directly affected by any of the above, so members of both sexes are equally at risk (CDC [9]). There was no significant difference between the number of infected men and women in Slovakia either. In the years 2000 - 2020, food intoxications of bacterial origin affected just 2,047 men (50.1%) and only 9 fewer women (49.9%). However, an analysis of their age structure yielded more interesting results (Figure 4). It follows that the representation of individual age categories was almost identical between patients of both sexes.

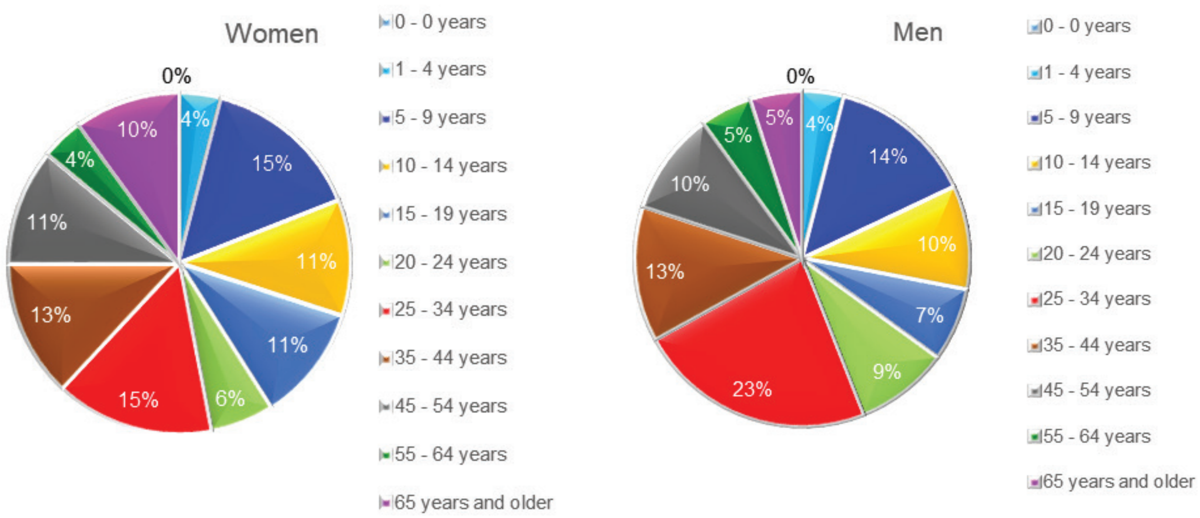

Figure 4. Percentages of individual age categories in the incidence of bacterial food poisoning in both sexes

The existence of a significant difference between the number of infected men and women was assessed using the Mann-Whitney statistical test (Table 3). This time we tested the hypothesis that the medians of the number of infected are the same for both sexes (H0) compared to the alternative hypothesis, which stated that at least one median is different (H1). A calculated p-value (0.414) higher than the significance level α (0.05) means that there is no statistically significant difference in the number of poisons diagnosed in men and women.

Table 3. The result of the Mann-Whitney test for the effect of gender on the incidence of bacterial food poisoning

Independent variable (n)	Region
Significance level α	0.05
p-value	0.414
Evaluation	$p \geq 0.05 \rightarrow$ not reject H_0

Within the set time horizon, cases of bacterial food poisoning were recorded in all age categories except infants, i. children up to 1 year. An overview of the percentages of individual population groups in the incidence of the disease is shown in Figure 4.

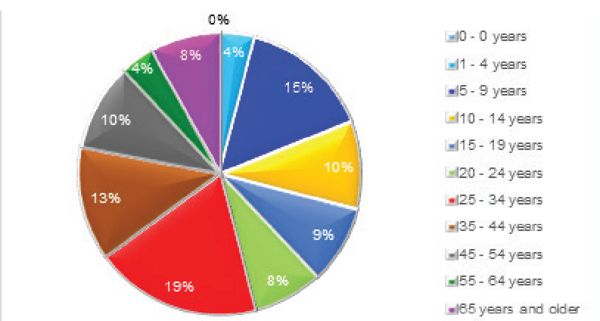

Figure 4. Percentages of age groups in the incidence of bacterial food poisoning

The results of our analyses confirmed that children, the elderly and anyone with a weakened immune system (postoperative conditions, chemotherapy, radiotherapy, long-term use of corticosteroids, HIV, etc.), chronic illness or reduced stomach acidity are more susceptible to food poisoning. In such individuals, a much lower amount of bacteria, resp. toxins and regardless of their age, the disease can result in serious health problems such as kidney failure or nerve damage (Gill and Hamer [15]).

Using the Kruskal-Wallis test (Table 4), we evaluated the significance of the difference between the numbers of diseases recorded in each age category. For the purposes of the test, the population was divided into three groups: pre-productive (0 - 14 years), productive (15 - 64 years), and post-productive age (65 and older).

Table 4. The result of the Kruskal-Wallis test for the effect of age on the incidence of bacterial food poisoning

Independent variable (n)	Region
Significance level α	0.05
p-value	$1.96.10^{-5}$
Evaluation	$p \geq 0.05 \rightarrow$ reject H_0

We tested the hypothesis that the medians of the number of patients in pre-productive, productive and post-productive age are the same (H0). We opposed the alternative that at least one of the medians is different (H1). Based on the comparison of the obtained p-value ($1.96.10^{-5}$) and the significance level α (0.05), we reject the null hypothesis. Thus, there is a statistically significant difference between the numbers of patients within the selected age groups. There are demonstrably two specific categories, namely pre-productive and productive age. We can therefore state that the higher morbidity of children aged 0 - 14 years was also confirmed at the statistical level.

Cases of foodborne bacterial poisoning have always been reported relatively evenly throughout the year. The only exception was perhaps the period from April to September (spring/summer), when a slightly increased frequency was repeatedly observed, as illustrated in Figure 6.

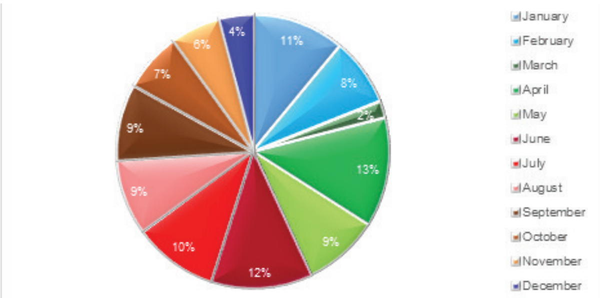

Figure 6. Percentages of months in the occurrence of bacterial food poisoning

Morya *et al.*, [24], interpret this as a natural consequence of the frequent mistakes of consumers, namely the inappropriate way of storing and transporting food during the warmer, especially summer months. Higher temperatures are ideal for the processes of growth and multiplication of bacteria, which trigger unwanted changes in food.

According to current statistics, the subsequent consumption of such foods is one of the most frequently reported causes of foodborne infections. We also statistically verified the effect of the season on the occurrence of bacterial food poisoning. This time, the median agreement of the number of diseases reported during each season (H0) was tested against the alternative that at least some of these medians are significantly different (H1). We again chose the Kruskal-Wallis test for the calculation (Table 5).

Table 5. The result of the Kruskal-Wallis test for the influence of the season on the incidence of bacterial food poisoning

Independent variable (n)	Region
Significance level α	0.05
p-value	0.268
Evaluation	$p \geq 0.05 \rightarrow$ not reject H_0

Given that the resulting p-value (0.268) exceeded the specified level of significance α (0.05) several times, we do not reject the null hypothesis. In practice, this result means that none of the four seasons tested affects the frequency of foodborne illnesses.

In the years 2000 - 2020, a total of 54 epidemics of bacterial food poisoning were investigated and reported to the EPIS system in Slovakia, of which in 50 cases more than 5 people became ill within one outbreak. Injuries were most often infected after eating a mixed diet (45%). By this phrase we mean a ready-to-eat meal consisting of various types of food prepared for immediate consumption. Other frequently cited sources of disease included, for example, contaminated food (18%), poultry (10%) and beverages (7%). A detailed overview of other factors applied in the transmission of foodborne diseases is given in Figure 7.

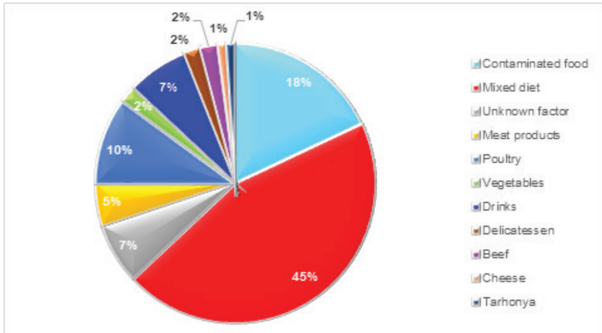

Figure 7. Percentages of transmission factors in the occurrence of bacterial food poisoning

The highest numbers of those infected were recorded by epidemiologists in catering establishments at workplaces, schools, medical facilities, fast food stalls and public catering establishments. To contaminate the food served, resp. beverages could therefore occur at any stage of their production or preparation.

It is therefore clear that bacterial food poisoning is a serious global problem and its prevention must be one of the top priorities of the food safety system. In the area of official controls, therefore, there should be more frequent examinations of samples of risky foods, which would significantly improve the system for identifying agents, subsequent exposure and disease until they are reported by the competent authorities. An essential part of preventive measures is also the increase of food education, the need to comply with the prescribed production process and consumer information, each of which should master the principles of proper storage and processing of food.

Acknowledgement

This publication was supported by the project KEGA no. 020SPU-4/2021 "Innovation of the methodological background and content of profile food and gastronomic subjects with a focus on increasing the competitiveness of graduates".

4. Conclusions

- Foodborne intoxications are caused by bacterial toxins, which are produced either directly in food, as a result of bacterial growth or in the digestive tract after ingestion. Important bacterial species that are most involved in the onset of food poisoning are *Clostridium botulinum, Clostridium perfringens, Staphylococcus aureus* and *Bacillus cereus*.

- Poisoning occurs most often after eating. Bacterial toxins act mainly on the digestive or nervous system, leading to serious disorders and sometimes death. Food poisoning most often occurs due to poor food hygiene or storage of food products.

- Therefore, it is possible to prevent these intoxications by good hygienic practice or ensuring adequate heat treatment, proper dietary conditions, handling and proper storage of food (e.g. food preservation).

5. References

[1] Adebe E., Gugsa G., and Ahmed M. (2020). *Review on Major Food-Borne Zoonotic Bacterial Pathogens*. Journal of Tropical Disease, 2020, pp. 1-19.

[2] Anniballi F., Auricchio B., Fiore A., Lonati D., Alessandro L., Locatelli A., Lista F., Fillo S., Mandarino G., Medi D. (2017). *Botulism in Italy*, *1986 to 2015*. Euro Surveill., 22, (24), pp. 1-8.

[3] Aragrande M., and Canali M. (2020). *Integrating epidemiological and economic models to identify the cost of foodborne diseases.* Experimental Parasitology, 210. <URL:https//doi.org/10.1016/j.exppara.2020.107832>. Accessed 15 May 2021.

[4] Argaw S., and Addis M. (2015). *A review on staphylococcal food poisoning*. Food Science and Quality Management, 40, pp. 59-71.

[5] Bhunia A. (2018). *Clostridium botulinum*, *Clostridium perfringens, Clostridium difficile.* Foodborne Microbial Pathogens, Springer, New York, USA, pp. 209-228.

[6] Brtková A., and Revallová M. (2010). *Contamination of animal husbandary with Campylobacter spp.* Zoonozes, 2010, pp. 127-132.

[7] Brunt J., van Vliet A. H. M., Stringer S. C., Carter A. C., Lindstrom M., and Peck M. W. (2020). *Pan-genomic analysis of Clostridium botulinum Group II (Non-Proteolytic C. botulinum) associated with foodborne botulism and isolated from the environment.* Toxins, 12, (5), 306. <URL:https//doi.org/10.3390/toxins12050306>. Accessed 15 May 2021.

[8] Carlin F. (2016). *Bacillus cereus and Other Bacillus sp. Causing Foodborne Poisonings*. In: Caballero B., Finglas M. P., and Fidel Toldrá F. (Eds.), Encyclopedia of Food and Health, Academic Press, Cambridge, USA, pp. 301-306.

[9] CDC. (2015). *FoodNet Surveillance*. <URL:https://www.cdc.gov/surveillance.html. Accessed 15 May 2021.

[10] Center for disease control and prevention. (2018). *Staphylococcal (Staph) Food Poisoning*. <URL:https//www.cdc.gov/foodsafety/diseases/staphylococcal.html>. Accessed 15 July 2021.

[11] Cremonesi P., Monistero V., Moroni P., Barbeiro A., Almeida R, Latorre, and Castiglionia B. (2020). *Detection Methods.* In: McSweeney H. L. P, and McNamara P. J., (Eds.), Encyclopedia of Dairy Sciences (3rd Ed.), pp. 457-468.

[12] Donkor E. (2020). *Cockroaches and Food-borne Pathogens*. Environmental Health Insight, 14. <URL:https://doi.org/10.1177/1178630220913365>. Accessed 25 August 2021.

[13] EFSA. (2021). *The European Union One Health 2019 Zoonoses Report*. <URL:https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2021.6406>. Accessed 25 August 2021.

[14] Fetsch A., and Johler S. (2018). *Staphylococcus aureus as a Foodborne Pathogen*. Current Clinical Microbiology Reports, 5, pp. 88-96.

[15] Gill C., and Hamer D. (2020). *Food Poisoning Due to Ex Vivo Toxins*. In: Kuipers E., (Ed.), Encyclopedia of Gastroenterology, Academic press, Amsterdam, Netherlands, pp. 456-466.

[16] Glasset B., Herbin S., Granier S. A., Cavalié L., Lafeuille E., Guérin C., Ruimy R., Casagrande-Magne F., Levast M., Chautemps N., Decousser W. J., Belotti L., Pelloux I., Robert J., Brisabois A., Ramarao N. (2018). *Bacillus cereus, a serious cause of nosocomial infections: Epidemiologic and genetic survey.* Plos One, 13. <URL:https//doi.org/10.1371/journal.pone.0194346>. Accessed 25 September 2021.

[17] Hailegebreal G. (2017). *A review on Clostridium perfringens food poisoning*. Global Research Journal of Public Health and Epidemiology, 4, (3), pp. 104-109.

[18] Hernandez-Cortez C., Palma-Martínez I., Gonzalez-Avila L.U., Guerrero-Mandujano A., Solís R. C., and Castro-Escarpulli G. (2017). *Food Poisoning Caused by Bacteria (Food Toxins).* In: Malangu N. (Ed.), Poisoning - From Specific Toxic Agents to Novel Rapid and Simplified Techniques for Analysis, InTech Open, London, UK, pp. 33-73.

[19] Hwang C., and Huang L. (2019). *Growth and survival of Bacillus cereus from spores in cooked rice - One-step dynamic analysis and predictive modeling*. Food Control, 96, pp. 403-409.

[20] ICD 10 Data com. *ICD 10CM/Codes*. <URL:https//www.icd10data.com/ICD10CM/Codes/A00-B99/A00-A09/A05-/A05.0>. Accessed 5 October 2021.

[21] Jessberger N., Dietrich R., Granum P. E., and Märtlbauer E. (2020). *The Bacillus cereus Food Infection as Multifactorial Process*. Toxins, 12, (11), pp. 701-737.

[22] Long S. (2018). *Clostridium botulinum (Botulism).* Principles and Practice of Pediatric Infectious Diseases. Elsevier, Amsterdam, Netherlands, pp. 999-1006.

[23] Majed R., Faille Ch., Kallassy M., and Gohar M. (2016). *Bacillus cereus Biofilms - Same, Only Different*. Frontiers in Microbiology, 7 (1054). <URL:https://doi.org/10.3389/fmicb.2016.01054>. Accessed 15 November 2021.

[24] Morya S., Amoah A. E. D. D., and Snaebjornsson S. O. (2020). *Food poisoning hazards and their consequences over food safety.* Microorganisms for Sustainable Enviroment and Health. Elsevier, Amsterdam, Netherlands, pp. 383-400.

[25] Omer M., Alvarez-Ordónez A., Prieto M., Skjerve E., Asehun T., and Alvseike O. (2018). *A Systematic Review of Bacterial Foodborne Outbreaks Related to Red Meat and Meat Products*. Foodborne Pathogens and Disease, 15, (10), pp. 598-611.

[26] [26] Pang R. Li Y., Chen M., Zeng H., Lei T., Zhang J., Ding Y., Wang J., Wu S., Ye Q., Zhang J., Wu Q. (2020). *A database*

for risk assessment and comparative genomic analysis of foodborne Vibrio parahaemolyticus in China. SciData, 7, (321), pp. 1-8.

[27] Peck M., and Van Vliet A. (2016). *Impact of Clostridium botulinum genomic diversity on food safety*. Current Opinion in Food Science, 10, pp. 52-59.

[28] Serda B., Bekele A., and Abebe D. (2018). *Prevalence and Contamination Level of Staphylococcus aureus in Raw Camel Milk and Associated Risk Factors in Jigjiga District, Eastern Ethiopia*. Journal of Veterinary Science and Technology, 9, pp 1-5.

[29] Stenfors A. L. P., Fagerlund A., and Granum P. E. (2008). *From soil to gut: Bacillus cereus and its food poisoning toxins*. FEMS Microbiology Reviews, 32, (4), pp. 579-606.

[30] Taekeon J., Yugyung J., Jaehyeon A., and Sung Y. (2020). *Continuous, rapid concentration of foodborne bacteria (Staphylococcus aureus, Salmonella typhimurium, and Listeria monocytogenes) using magnetophoresis-based microfluidic device.* Food Control, 114, 107229. <URL:https//doi.org/10.1016/j.foodcont.2020.107229>. Accessed 5 December 2021.

[31] Tessema D., and Tsegaye S. (2017). *Study on the Prevalence and Distribution of Staphylococcus aureus in Raw Cow Milk Originated from Alage Atvet College Dairy Farm, Ethiopia*. Journal of Nutrition and Food Sciences, 7, (2), pp. 1-4.

[32] Van Seventer J. M., and Hamer D. (2017). *Foodborne Diseases*. In: Maguire van Seventer J. (Ed.), International Encyclopedia of Public Health, Academic Press, Cabridge, USA, pp. 160-173.

[33] WHO. (2020). *Food Safety*. <URL:https//www.who.int/news-room/fact-sheets/detail/food-safety>. Accessed 15 Janary 2022.