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Review

Foodborne disease and food control in the Gulf States



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ABSTRACT

Gulf States in the Middle East have had to change rapidly from subsistence herding, farming and fishing communities to modern states through the exploitation of revenue-generating petroleum products. Fresh water is an even more precious commodity than oil today as this is seen as a rapidly diminishing resource through over use of aquifers with scarce and unpredictable rainfall not replenishing the needs of these countries which increasingly rely on reverse-osmosis (RO) desalination of seawater but at a cost in terms of energy. Recycling of waste water and sewage is carried out and used to water urban landscaping and some crops, but there are risks of the presence of pathogens. Much food today is imported to satisfy the requirements of expanding populations, especially foreign workers on temporary visas who make up more than half the residents in many of these Gulf States. Despite limited published data on Gulf States regarding enteric and foodborne diseases and their prevention and control, profiles emerge that can describe the current situation and some future directions. Gastrointestinal diseases, such as typhoid, cholera, and amebic dysentery can be brought into these countries through workers returning from endemic regions, and also through refugees from conflict-torn neighboring countries. However, some diseases are endemic like brucellosis and fatal illnesses from the newly identified Middle East Respiratory Corona Virus (MERS-CoV) associated with camels. In the 1990s, coalition troops stationed during the Gulf War brought in external suppliers and caterers, but using local products like chickens with troops occasionally suffering from infections. The hot climate, particularly in summer, can allow rapid growth of pathogens in foods, especially where refrigeration is not available as in home-prepared lunches by workers and during transportation of foods across traffic-congested cities. One of the biggest concerns for Saudi Arabia is the health oversight of millions during the annual Hajj, and despite much care over restriction of infected pilgrims and care of food, occasional outbreaks have been reported. Government agencies are particularly concerned about restaurant food and try and follow up on complaints of customers but rarely are agents identified; those that have include *Salmonella*, *Bacillus cereus* and *Staphylococcus aureus*. Implicated foods include ethnic products such as Turkish menu items and shawarma. Local culture may play a role in allowing growth of pathogens such as serving women after men at weddings. However, deaths that have been attributed to microbial sources may have been caused by illegal use of pesticides such as aluminum phosphide. Severe penalties have been applied to owners and staff implicated in outbreaks including fines, jail sentences and deportations, which are not typical of Western nations. However, some agencies have initiatives to help educate and train foreign workers in several languages. Foodborne disease surveillance systems are generally not adequate though some countries have initiated modernization of inspection approaches and laboratories. Consumer surveys show that residents have some knowledge of foodborne disease but this could be improved especially for women who do most of the shopping and food preparation in homes. Agencies are increasing directing campaigns for general food safety in their populations, and as long as resources are available, food control is likely to improve over time in Gulf States which is good news for visitors, expatriate workers and citizens alike.

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1. Introduction

There are seven Arab states that border the Persian Gulf, from north to south Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, the United Arab Emirates (UAE), and Oman (Fig. 1). All of these nations (with the exception of Iraq) form the Cooperation Council for the Arab States of the Gulf, also known as the Gulf Cooperation Council (GCC). Those people who live very close to the Gulf are considered Eastern Arabians and speak a distinct dialect of Arabic and are ethnically and religiously similar (Sunni Muslim); this excludes most of the people in Iraq (mainly Shi'ia) and Saudi Arabia (Shi'ia minority) who live inland. However, because of the proximity of these states to Iran across the Persian Gulf, there are Shi'ia communities of Iranian origin in all the Gulf states and a majority in Bahrain. The Eastern Arabia's Gulf Arabs traditionally have had fisheries and marine industries. Inland, it has been more a Bedouin lifestyle with herding animals and limited agriculture. However, after oil was found over 100 years ago but more recently developed, today these Arab states have significant revenues from petroleum, and all Gulf States have some of the strongest currencies in the world (in ranking order, Kuwait dinar, 1; Oman riyal, 2; Bahrain

dinar, 3; Qatar riyal, 14; UAE dirham, 15; and KSA riyal, 16) (Vasileiadis, 2015). Because of the wealth today, there has been a substantial diversification of the economy, particularly in the UAE, which has more than 70% of its total GDP coming from non-oil sectors and a goal of 80% over the next 10–15 years (Rahman, 2015). The governments of these states are all conservative politically and each has a dynastic form of rule (Anthony & Hearty, 1980, chap. 7). All current member states are monarchies, including three somewhat constitutional monarchies (Kuwait, Qatar, Bahrain), two absolute monarchies (Saudi Arabia and Oman), and one federal monarchy (the United Arab Emirates, composed of seven member states, each with their own emir). These GCC members are the focus of this article which discusses the geographic and political background of each country, water availability for both agriculture and potable use, waste-water treatment, types of gastrointestinal diseases within the population, foodborne disease outbreaks (typically called food poisonings), research including surveys that impinge upon food safety issues but also more general communicable enteric diseases, and government oversight including inspection of food premises and food safety education. However, caution must be considered in considering this review as authoritative as the

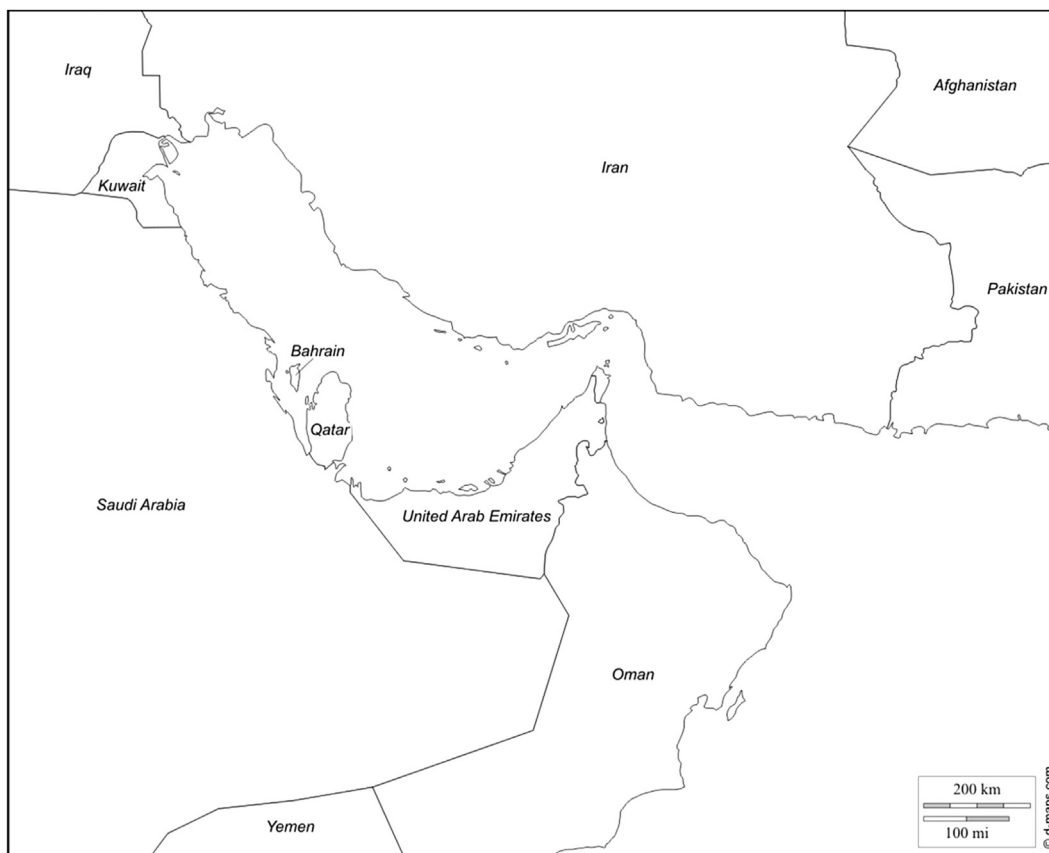


Fig. 1. Map of the Gulf States. http://www.d-maps.com/carte.php?num_car=3465&lang=en.

published data are limited and other reports not utilized may be released in Arabic-language reports. Also, some of the data presented here are derived from the news media which are by definition selective and brief. Nevertheless, as businesses expand and tourism develops, it is critical for these countries to have progressive policies to towards the risks of foodborne disease that allow visitors as well as residents to be comfortable that the food they eat is safe as well as wholesome.

2. Bahrain

2.1. Overview

The Kingdom of Bahrain is a group of 30 islands located off the central southern shores of the Persian Gulf between Saudi Arabia and the Qatar peninsula comprising 710 km². The largest island, Bahrain (al-Bahrain), is 48 km (30 mi.) long and 15.5 km (9.6 mi.) wide, and contains the capital, Manamah (Anthony & Hearty, 1980, chap. 7) with a current population of less than 90,000. The second largest island is Muharraq, which is accessible by a four-mile causeway. The vast majority of the population is Muslim – half Shi'ite and half Sunni. The important Al Khalifahs and other Bani Utub families are Sunnis, whereas the older indigenous population has a large proportion of Shi'ites, many of whom have centuries-old ties to Iran. Bahrain has a constitutional form of government that administers the emirate under the amir, a member of the Al Khalifah family. The constitution provides for separate executive, legislative, and judicial branches of government. Bahrain has an arid to extremely arid environment. Temperatures average from 17 °C in winter to 35 °C in summer. The rainy season runs from November to

April, with an annual average of 83 mm, sufficient only to support the most drought resistant desert vegetation (Aquastat-Bahrain, 2009). The population was 727,000 in 2005, of which only around 10% was rural. This is not surprising since Bahrain is one of the world's most densely populated countries, experiencing high rates of population growth (1.5 million in 2016) and urbanization since the early 1960s following the sudden increase in the country's oil revenues, leading to a fast increase in its economic base and an improved standard of living. Urban development at the expense of agricultural land has caused a significant loss of traditionally agricultural areas. In 2005, the total cultivated area was estimated at 6000 ha, or 8% of the total area of the country, of which around 95% was equipped for irrigation. There are no rivers or dams, and Bahrain receives groundwater by lateral under-flow from the Damman aquifer, a part of the extensive Eastern Arabian Aquifer, but groundwater reserves suffer from severe degradation from over-extraction and seawater intrusion (Aquastat-Bahrain, 2009). The use of reverse-osmosis (RO) desalination for saline groundwater on Bahrain Island began in 1984–1986, and includes one of the world's largest RO plants for the treatment of saline groundwater, south of the capital of Bahrain. Improvements in wastewater treatment plants and sewage effluent for irrigation are expected to significantly reduce water extraction, reserving the limited freshwater resources for potable supply and other priority uses. In 2005, agricultural products contributed <1% to the national GDP. Thus, Bahrain is heavily dependent on imports to satisfy its need for meat, dairy and eggs, at the cost of home-based production, which is mainly focused on growing date palms and alfalfa. Some northern gardens grow dates, almonds, pomegranates, figs, citrus fruit, and a wide range of vegetables. About half of the cultivated area is

covered with high water-consuming perennial date palms under traditional surface irrigation practices. Some drip irrigation for vegetables and bubbler irrigation for dates have been established, but they are rather poorly operated with no irrigation schedules. Unfortunately, overall irrigation efficiency is very low. Alfalfa tolerates high salinity and is a cash crop grown all year-round with high local demand. However, because of the very high irrigation water requirements of alfalfa, it is expected that this trend will have negative implications for the country's groundwater resources. Horticulture and agriculture flourish in the north, using water from some artesian wells or desalination plants. As of 2005, the agricultural sector's utilization of water was not subjected to any licensing system nor was it controlled by a pricing system (Aquastat-Bahrain, 2009). However, from the mid-1980s on, agricultural wells were metered by the government and the government was in the process of passing a law that would make it compulsory for all owners of wells to install meters. While the standard of living and quality of life of the people has improved in the last 20 years, these improvements have produced negative effects on the terrestrial, coastal and marine environments due to overexploitation of these ecosystems and to unsustainable development practices. Also as a consequence of two Gulf wars and unstructured economic diversification, the country has been subjected to serious environmental and health hazards. Government policy with regard to water use is to reduce groundwater dependency for the domestic water supply by constructing additional desalination plants, and that eventually groundwater will be exclusively used for irrigation. Although government policy indicates the will to develop a modern farming sector on larger production units using mechanization and up-to-date techniques, these aims have not yet been reflected clearly in the government's capital investment and subsidy programs.

2.2. Gastrointestinal diseases

Notifiable enteric diseases include amebiasis, typhoid and paratyphoid fevers, salmonellosis, shigellosis and viral hepatitis A, and cases over a 7–9-year period (time-frame depending on the disease) were collated by Al Shetti (2002). There were 61 cases of typhoid/paratyphoid were reported of which 48 were imported. Today, there are few indigenous cases. The average number of reported cases of non-typhoid/paratyphoid salmonellosis per year was 284, considered to be underreported with only 2556 cases noted over a 9-year period. Most of these involved children 0–4 years of age. The serogroup distribution of the cases varied from year to year with the main serogroups being C, B, D, E, and *Salmonella* species. There were 186 shigellosis cases (*S. sonnei*, 53%; *S. flexneri*, 35%; *S. boydii*, 7%; and *S. dysenteriae*, 5%), and 1111 hepatitis A cases were reported with 32% imported from travelers returning back from India, Pakistan, Syria, Egypt, Yemen and Jordan. Also, high incidence rates were reported from three communities, Muharraq, Hamad Town and Riffa, with a range of 40–79/100,000 population; contaminated leafy vegetables (local or imported) and poor hygiene may have been responsible for the transmission of hepatitis A in these communities. *Campylobacter jejuni* is a frequent cause of diarrhea in the Middle East as in other parts of the world. Strains of different virulence genetic make-up have been found circulating in the Bahraini population, especially in children under the 3 years of age. Al-Mahmeed et al. (2006) found a prevalence rate of 1.6% *Campylobacter jejuni* (7/426) of children with diarrhea, compared with higher levels in other Gulf states; however, there are also many asymptomatic carriers of the pathogen. This study lays emphasis on the importance of asymptomatic carriers as a potential source of infection and demonstrates the emergence of resistance in *Salmonella* and *Shigella* species. In

Bahrain, rotavirus infections accounted for over 40% of gastroenteritis-associated hospitalizations and particularly affected children under 2 years of age. Al Musawi, Zainaldeen, Shafi, Anis, and DeAntonio (2013) considered that these data would serve as a baseline for assessing the potential changes in the epidemiology of rotavirus infections and for evaluating the potential impact of the introduction of a vaccine.

2.3. Foodborne disease outbreaks

There were two outbreaks of cholera in the early 1970s involving long distance flights from Europe to Australia with stopovers in Bahrain where food was loaded aboard (Hatakka, 2000). In 1972, 47 persons were ill on two flights after eating an appetizer contaminated with *Vibrio cholerae* O1; in 1973, 62 passengers and 2 crew members suffered from *Vibrio cholerae* non O1 infection from an appetizer containing chopped egg. In both episodes Bahrain was experiencing outbreaks of cholera at the time. Contaminated cold plates and ice were suspected to be sources of infection. Cholera is no longer a public health issue in Bahraini population, although it is currently (2015/16) in Syria and Iraq, and has spread to Bahrain through refugees (Coles, 2015). However, other food-associated outbreaks do occur. At least 750 people were treated after the island's so-called biggest mass poisoning case ever to date, caused by contaminated egg-and-mayonnaise sandwiches served at a wedding party in a Sitra village in early July, 2002 (Correspondent, 2002). Most of the people were discharged following treatment, but a 23 year-old Bahraini man died 6 days after his admission. He was a diabetic, and had to be taken repeatedly to the hospital since the incident. His condition was made worse because of his sickle cell anemia condition. According to news sources, he might have lived if he had not refused to be admitted to the hospital with a fever but hospital staff were unable to save him when he returned later the same day when the fever was worse. Unfortunately, no further information is available on this large outbreak, but because egg and mayonnaise were implicated, *Salmonella*, possibly *S. Enteritidis*, could have been the etiological agent, as has occurred in other countries (Crane, 2015; ECDC/EFSA, 2014). In 2014, a proven salmonellosis outbreak was associated with a restaurant. Inspectors of the Bahraini Food Control and Diseases Control Section collected food samples from the restaurant and swabs from staff, and found the food samples positive for *Salmonella* (A. H. N., 2014). The inspectors then shut down the main restaurant, which was suspected of causing this outbreak, as well as two affiliated branches, which remained closed until health requirements were met. The food stocks suspected of being contaminated with *Salmonella* were destroyed, and staff suspended from work, administered proper medication and given health tips to avert any future incidence of foodborne disease. The inspectors found improper food storage conditions that would have provided conditions for growth of the *Salmonella*. The Section pledged to continue taking the necessary measures to protect public health. It called on consumers to strictly abide by health requirements in cooking and storing food, stressing the need to choose well-cooked food and observe personal hygiene, particularly hand washing before eating. Unfortunately, although the Section indicated it would announce the final results once the investigation was complete, no further details of the outbreak are available, including case numbers or a possible contaminated food vehicle. Mackerel shipped to Saudi Arabia was also contaminated with *Salmonella* (31.4% of 35 samples and 13 separate isolates) in a survey of imported fish in 2012–2013 (Elhadi, 2014), but no known incidences of illness were associated with these fish.

2.4. Research

The association between putative virulence genes in *Campylobacter jejuni* clinical isolates, *in vitro* invasive capability and severity of infection is yet to be clearly described. Three virulence genes were correlated with the severity of infection and *in vitro* invasiveness. Al-Shaikh, Senok, Ismaeel, and Botta (2007) studied 8 *C. jejuni* strains isolated from Bahraini patients whose clinical data were scored to determine severity of infection. The findings indicated a correlation between *in vitro* invasive capability, and the presence of genes for cytolethal distending toxin (*cdtB*), invasion associated marker (*iam*), and *Campylobacter* invasion antigen (*ciaB*) which were detected in isolates from patients with the most severe infection. The pattern of association between invasiveness and molecular characterization suggests that the *ciaB* gene confers a more invasive capability. Tabbara, Al Muraikhi, Bazzi, and Botta (2010) also looked at both severely and mildly ill campylobacteriosis patients in hospitals and determined that severity of disease is related to levels of TNF- α production, and where infection of macrophages induces apoptosis, potentially leading to immune evasion or suppression.

2.5. Government oversight

In July 2008, as ambient temperatures were heating up, the Ministry of Health urged people to make sure the food they consume was properly stored during the summer months to avoid microbial growth and risk of “food poisoning”, e.g., keeping meat and fish at $\leq 4^\circ\text{C}$ (Haider, 2008). The Ministry was aware that both visitors and locals want to eat safe food, especially as Bahrain at that time was moving towards more tourism and people were eating out more often. The Ministry ordered shops to provide proper coolers and refrigerators, and inspectors were to check food stalls, ice-cream parlors and vegetable shops to ensure that customers were not being sold contaminated or spoiled foods. The Ministry launched a new hotline number for general public to report food contamination and it would follow up on any complaints it received. In order to avoid foodborne disease, consumers were advised about being careful when buying salads; thoroughly washing fruits and vegetables before they are consumed; refrigerating milk, cheese and eggs; and cooking and storing food properly. In April 2015, the Ministry of Health continued to issue warnings, this time against buying food advertised on social media or sold on the street by unlicensed Bahraini retailers, either made in people's homes or by street hawkers (Anonymous, 2015a). Many homes sold food without a license and some people even had barns where they slaughtered livestock and sold the meat illegally. The Ministry admitted its role in control is limited from the purchase of these home-prepared foods, since inspectors are not allowed to go into homes. In 2014, there were 54,968 inspection visits conducted by 25 inspectors from the Food Safety and Licenses group, which closed 41 of approximately 7000 registered outlets. Because expatriates contribute largely to the Bahraini work force, including the food industry, all expatriate applicants for employment in Bahrain are required to have medical check-ups from approved medical centers at the country of origin, and also in Bahrain where they will undergo further medical examinations before they obtain their residents' permits (LMRA, 2014). This medical examination includes stool examinations for *Salmonella* and *Shigella* which should be negative.

The Smart Inspection Project launched in April 2012 is an attempt to reduce foodborne disease in Bahrain through both encouragement and penalties. Inspectors, many with Master's and PhD degrees, visit restaurants and coffee shops to take food samples, as well as explain to staff how to store foods properly

(Anonymous, 2015a). It includes positive reinforcement by awarding food outlets that achieve a 100% food safety standard a blue sticker, while those meeting 80% of standards are given a green sticker. In contrast, outlets that fail to achieve basic standards are warned with a red sticker which they must display. The total number of outlets assessed between August 2013 and February 2015 was 241; 17 were presented with blue stickers, 174 with green stickers and 50 with red stickers. The Project features daily inspections and is mostly focused on small food outlets (SMEs), some of which have previously caused foodborne disease outbreaks. Inspection visits are assigned depending on the hygiene record of each outlet and the complaints received about them; some require two visits annually while some require more than that. High-level restaurants with good records already have certified inspectors for evaluation and most of them require only one visit per year. The Ministry's ultimate goal through this project is to decrease foodborne illness cases, particularly important as Bahrain is encouraging tourism and to this end ensuring food safety is essential. To support the Ministry's initiatives, demonstrations on food safety practices are promoted in kitchens in hypermarkets. However, if enterprises with red sticker facilities fail to take advantage of educational material, they may be punished for neglecting food safety standards and guidelines though public prosecution in the courts.

The Governments of Bahrain, Kuwait, Oman, Qatar and the United Arab Emirates agreed to enforce a common standard governing conditions of Halal slaughter of animals that is to be conducted according to the Islamic Law (Shari'a), under their respective national standard numbers (Anonymous, 2004).

In 2014, Bahrain's main chicken supplier with a hatchery and slaughterhouse, was ordered to improve hygiene and safety standards or face closure, following complaints about the quality of chicks being supplied to the country's poultry farms by the firm (Anonymous, 2014b). The condition of the chicks was sufficiently poor, since many were sick, weak and likely to die within days. Also, 31 of 33 concerned farmers being supplied illegally broke their contracts with the firm; they stated they would not accept the chicks and that would mean there would be no fresh chicken available for Bahrainis. A follow-up inspection by government officials demonstrated poor hygiene in the hatchery and slaughterhouse and during transportation in old trucks which were not well maintained or cleaned properly. Eventually, the conditions improved to allow Bahrainis to have access to fresh chicken.

In Bahrain, there is also extensive legislation on imported food, and the Food Control Section of port authorities inspects all imports and exports of food, takes samples of new, unusual, suspect, or incorrectly labeled foodstuffs, and checks on-board conveyances for compliance with international standards for food safety and hygiene (Al Musawi, 2012). Staff monitor and maintain a system of imported food surveillance through the pre-notification of imported foods not of animal origin, and supervise the certification and destruction of imported foods found unfit for human consumption. The National Focal Point is informed of any unusual event reported by INFOSAN. Foods selected for examination are inspected for physical defects, composition, presence of non-permitted additives, e.g., preservatives, colors, and labeling irregularities. Samples from imported consignments are also taken at random and referred to the Public Health Laboratories. A public health specialist assessment is made in order to ascertain that the food is prepared, manufactured and stored according to the various provisions of Public Health Legislation. When, as a result of physical examination or unsatisfactory chemical or bacteriological tests, the food is considered to be unfit, unsound, unwholesome, or otherwise unacceptable, the consignment is not

released from Customs and the inspector seeks its voluntary destruction from the importer. Inspections cover imported food from ports right up to where it reaches restaurants and food outlets, and in 2014 71,886 visits were paid to these, and 1873 tonnes of imported food were considered non-edible and were rejected (Anonymous, 2015a).

3. Kuwait

3.1. Overview

Kuwait, with a total area of 17,820 km², lies at the head of the Persian Gulf. In 2005, the population was 2.69 million, of which only 4% was rural (4.2 million in August 2015). Kuwait is a constitutional monarchy whose rulers have traditionally been chosen from the Al Sabah family. However, the constitution, inaugurated in 1962 under its ruling amir, provides for the establishment of a legislature (the National Assembly), an executive branch, and an independent judicial system (Anthony & Hearty, 1980, chap. 7). The legislature was granted powers including the right to petition the amir concerning cabinet appointees and the prime minister. The electoral base, however, has remained narrow and is limited to citizens of Kuwait who are male, literate, and over twenty-one years old. About 31% are Kuwaiti nationals and the rest are expatriates, mainly from India and Egypt, since Kuwait like other GCC countries makes it practically impossible to acquire nationality, hence all immigration to the country is “temporary” (Snoj, 2015a,b). The land is generally flat with slightly undulating desert plains sloping gently towards the northeast, reaching an altitude of about 300 m above sea level. Most of the area is desert with a few oases (Aquastat-Kuwait, 2009). The arable land is characterized by sandy soil poor in organic matter and a very low water retention capacity. Kuwait has a desert climate characterized by a long, dry, hot summer, with temperatures reaching more than 45 °C with frequent sandstorms, and a cooler winter, with temperatures sometimes even falling below 4 °C. The rainy season extends from October to May (106–134 mm/year). The economy is dominated by petroleum, which accounts for 90–95% of merchandise export earnings, and agriculture (including fisheries) accounts for almost 0% of GDP and does not offer an important source of employment. Livestock production is an important component of the agricultural sector and contributes about two-thirds to total agricultural GDP, as compared to one third for plant production and fisheries combined. Groundwater quality and quantity are deteriorating due to the continuous pumping of water. Desalination is now a major source of potable water, but the problem with seawater distillation is the high cost of the multi-stage flash (MSF) evaporation process, which can account for as much as about 50% of the water unit cost, thus being sensitive to the unstable world market price of crude oil. Over 90% of the population is connected to a central sewerage system, which allows for wastewater collection for irrigation to compensate for the water deficit. In 2002, water sources for all uses were 46% from desalination, 45% from primary groundwater, and 9% from wastewater treatment (Aquastat-Kuwait, 2009). In Kuwait, as in other countries, the main concerns in water recycling and reuse are: (a) reliable treatment of wastewater to meet strict water quality requirements for the intended reuse, (b) protection of public health, and (c) gaining public acceptance. There are public health concerns for reusing recycled water to irrigate vegetables and other crops that are consumed uncooked or for green residential spaces with high public contact, and for groundwater recharge. For irrigation, farmers are not charged for groundwater use, but they are for desalinated water and wastewater treatment use; surface irrigation and to a lesser extent sprinklers are the main methods to water crops. In 2006, about 45% of the harvested land

was devoted to vegetable production, mainly tomatoes, eggplants, cucumbers, potatoes, and sweet peppers, and 19% for cereals, mainly barley and wheat. Date palm trees are the most important fruit trees grown, which occupy about 20% of the cultivated land. Kuwait is planning to reclaim more land in order to provide food for the population by putting it under irrigation. This will increase irrigated areas and boost demand for water in the irrigation sector, all of which will put stress on existing water delivery systems.

3.2. Gastrointestinal infections including foodborne disease

The quality of health care in Kuwait is generally high and equal to that in western Europe and the USA, except for highly specialized treatment. The public health service provides free or very low cost health care for its nationals and expatriates. Obesity is more likely to be cited as a health issue than gastroenteritis, but such acute illnesses do occur. Khuffash, Sethi, and Shaltout (1988) found that clinical manifestations in 595 children hospitalized with gastroenteritis during a 15-month time frame were caused by rotavirus (203 patients); salmonellae (98); *Escherichia coli* (55); *Campylobacter* (36); *Shigella* (22); combined rotavirus and salmonellae (44); combined rotavirus and other bacteria (26); and no pathogen (111). The mean duration of diarrhea was shortest in the rotavirus and “no pathogen” groups (4.8 and 5.6 days, respectively) and longest with pure and mixed *Salmonella* infections (12.3 and 12.9 days, respectively). Today, we might suspect viral agents like norovirus for the no pathogen group. In the late 1980s, oocysts of the protozoan *Cryptosporidium* were detected in young children who suffered from green watery diarrhea, vomiting, dehydration, fever and abdominal pain, which lasted a 3–14 days (mean 8.2 days) (Daoud et al., 1990). Five children were infected with other enteropathogens. The illness was self-limiting in all cases and none were excreting oocysts 2 weeks after cessation of diarrhea. Peak incidence occurred during the months of March and April, with no cases during the hottest months of July and August. There was no known contact with animals or pets; 4 children had other siblings affected and 2 conformed to cases of travelers' diarrhea. Just a little later during the Gulf War, the leading cause of morbidity among American forces deployed to the Persian Gulf region, particularly Saudi Arabia and Kuwait, was diarrheal disease (Mitchell, Sivitz, & Black, 2007). From 432 soldiers who sought medical care one or more bacterial enteropathogens were identified in 49.5% of the stool cultures, including enterotoxigenic *E. coli* (ETEC), *Shigella sonnei*, nontyphoid *Salmonella* spp., enteroinvasive *E. coli*, and *Campylobacter*. Tests for viruses yielded positive results for norovirus and rotavirus. In the Operation Iraqi Freedom War an epidemiologic survey of 15,459 deployed troops conducted in January–March 2004 revealed that 74.5% of military personnel had experienced at least one episode of diarrhea, mainly caused by norovirus and *Shigella*. Today, rotavirus or norovirus is more likely to be suspected as a cause of gastroenteritis than any other enteropathogen. Of the 75 rotavirus-positive samples from 172 children (aged <5 years) with severe diarrhea in Kuwait, 69 were genotyped by Marmash et al. (2007). The distribution of genotypes was G1 (63.8%) followed by G9 (10.2%), G2 (7.3%), G4 (7.3%) and G3 (4.4%). These results show that G1 is the predominant serotype in Kuwait and that a vaccine that contains G1 would be the most effective against rotavirus infections. The study by Al-Rashidi, Chehadeh, Szücs, and Albert (2013) highlights the importance of screening for norovirus infection in acute gastroenteritis and having a reporting system to better understand the epidemiology of norovirus infection in Kuwait. Eight out of 100 stool samples (8.0%) from children up to 5 years of age with gastroenteritis studied during 2006–2007 from one hospital, and 6 out of 70 stool samples (8.5%) from similar children studied from another hospital during

2010–2011 were positive for norovirus by RT-PCR. Of these 170 samples studied from both hospitals, 10 samples were positive for norovirus when tested by ELISA. Phylogenetic tree analysis of norovirus strains showed that 50% of the norovirus strains belonged to genotype GII.4, and the predominant strain was GII.4 2006b. Other detected genotypes were GII.12, GII.b, GII.3, GII.8, and GII.7. All these data indicate that Kuwait has the same range of pathogens as might be found in Western nations. However, in none of these was the source identified. It is likely, however, that food or water could have been the vehicle for many of these infections, as has occurred elsewhere. Kuwait does not report its foodborne disease surveillance data or information on food contaminant monitoring to the WHO Eastern Mediterranean Regional Office (WHO-EMR), as there is no mechanism for the regional collection of this data, although 13 types of foodborne disease are listed as reportable (FAO/WHO, 2005). No foodborne disease or even waterborne disease outbreaks from Kuwait were published, unlike most other Middle Eastern countries which reflects the non-reporting of outbreaks already mentioned (FAO/WHO, 2005). However, *Salmonella enterica* serovar Typhi continues to be an important public health problem in Kuwait. Analysis of the isolates from 163 patients, collected between 1995 and 2003, showed that the majority were from patients from the Indian sub-continent where typhoid is endemic, and many strains were drug resistant (Dashti et al., 2008), and also in two recently returned Bangladeshi expatriate patients to Kuwait were ciprofloxacin-resistant (Dimitrov et al., 2009). Both had been previously unsuccessfully treated at private clinics. These were eventually cured of their infections, as were two persons arriving in Kuwait from Iraq who tested positive for cholera in 2015 (Anonymous, 2015b). Although these reports indicate that the source of the typhoid infections is from endemic countries other than Kuwait, some of these returning workers work in Kuwaiti food establishments and could infect customers. Fattahova (2014) reports that cases of foodborne disease are common and increase during the summer months due to high temperatures and consumption of fast food. In December, 2002, 271 US soldiers, sailors and marines at a camp south of Kuwait City were treated for salmonellosis and 13 were briefly hospitalized. The U.S. military concluded that the outbreak was caused by unsanitary conditions for which the food caterer was responsible (Associated Press, 2002).

3.3. Research

Research in food and the environment is conducted at the Kuwait Institute for Scientific Research (<http://www.kisr.edu.kw/en/>) with research and development activities focused on eight research programs: Environmental Pollution and Climate, Ecosystem-based Management of Marine Resources, Coastal Management, Aquaculture, Desert Agriculture and Ecosystems, Food and Nutrition, Biotechnology, and Crisis Decision Support. Notable problems include poor air quality, due to dust storms arising from mobile sand movement, and the impacts of oil production and sewage discharge, due to development in the coastal zone. Key issues also relate to excessive water use in agriculture and greenery maintenance, and an inadequate national food control system. In addition, at the food consumption level, poor diets and inactive lifestyles have resulted in a high incidence of nutrition-related diseases, notably, obesity, coronary heart disease, diabetes, and high blood pressure. One research area has been in poultry, likely to be a major source of *Salmonella* as it is in other parts of the world. Al-Zenki et al. (2007) found that of 2882 samples collected from farms, the prevalence of *Salmonella* was 5.4% with prevalence rates of 10%, 1.5%, 0.7%, 0.2%, 13.5%, and 12.6% for hatching eggs, litter, feed, drinkers, bird rinse and ceca, respectively. Out of 360 samples

collected from the processing plant, the overall *Salmonella* prevalence was 4.7% with specific rates of 6.1% and 3.3% for carcass rinse and ceca samples, respectively. *Salmonella* Enteritidis (SE) was the most prevalent serotype.

3.4. Government oversight

The Kuwait Municipal Council is well aware of the risks of food workers causing foodborne disease and it mandates a compulsory screening of restaurant workers to detect *Staphylococcus aureus* carriers; in one study, 200 *S. aureus* isolates recovered from food handlers in Kuwait City restaurants yielded a carriage rate of 53.2% (Udo, Al-Mufti, & Albert, 2009). The study also included 67 isolates obtained from 31 stool samples, 9 throat swabs and 27 nasal samples obtained from food handlers during routine investigations of suspected foodborne disease cases in different restaurants. Most isolates were found to be resistant to antibacterial agents (92.5%) and 71.0% contained genes for staphylococcal enterotoxins (SE) with the gene for SE1 being the most common. This is one reason that the Kuwaiti Municipality conducts regular inspections of restaurants, particularly in the summer when the temperatures are hotter (Ramadan, 2012). If there are consumer complaints, the inspectors check facility licenses, employee health certificates, compliance with health standards, cleanliness of the establishments including foods, utensils and other tools. Foods samples and clinical specimens may be tested at Ministry of Health laboratories. Penalties include warnings for minor offenses up to fines and complete facility shut-down for major violations. In the summer months, specific attention is paid to the high quality of meat and vegetables, the safety of the origin of the food, proper storage through adequate cooling, and, where relevant, thorough cooking. Even though it is impossible to totally eliminate *Salmonella* from carcasses even in the USA (Schwartz, 2015), frozen or chilled chicken at retail may be recalled in Kuwait because of presence of the organism. This occurred in December, 2004 and also in December 2011, because the carcasses were considered unfit for human consumption, and citations were handed out against the retailers (Anonymous, 2011; Janssen, 2004).

The Food Safety Review (FSR) is a partnership between industry, government, academia, and the Kuwaiti consumer (Al-Mazeedi, Abbas, Al-Jouhar, Al-Mufti, & Al-Mendicar, 2015). The mission of the FSR is to work in collaboration with the Department of Health in developing advisory technical interpretations of the state food service regulations and other matters relating to Kuwait Administrative Code, interpretation of food handling practices and processes, guidance on 'equivalency' determinations, providing recommendations for revisions to the Kuwait State Board of Health, and finally, facilitating communications to all stakeholders regarding FSR activities and actions. The eventual goal is to develop a detailed action plan for the strengthening of Kuwait Food Safety System.

4. Oman

4.1. Overview

The Sultanate of Oman occupies the south-eastern corner of the Arabian Peninsula and has a total area of 309,500 km². The climate is arid and semi-arid but differs from one region to another with 20 mm in the internal desert regions to over 300 mm in the mountain areas (Aquistat-Oman, 2009). In 2005, the population was 2.57 million with 21% rural. Oman's population, which is Sunni Muslim, rose to 3.5 million in 2015, and the majority is found along the Batinah coast, which has the greatest agricultural potential in the country. An important fishing center and traditional port is at

Sur, southeast of Muscat (Anthony & Hearty, 1980, chap. 7). Many of the merchants of the capital region and the coast are Hindu Indians, and also some Shi'ia Iranians. There are four politically important groups in Oman: the royal family, the tribes, the expatriate advisors, and the merchant class, of which the royal family is the most important. Islamic law is the law of the land and is administered through traditional Islamic courts with judges appointed by the sultan. However, the Council of Ministers, headed by the prime minister, who is also appointed by the sultan, have considerable latitude in formulating day-to-day policies. In the most remote regions, tribal law may still function.

In 2000, 85% of the urban and 73% of the rural population had access to improved drinking water sources; and in 2006 the sanitation coverage was 97% for the urban population (Aquastat-Oman, 2009). Agriculture is less important today for the country because oil revenues are the major source of its GDP. Nevertheless, the contribution of local agricultural products to food security is 36% of the total consumption. All cultivated areas are irrigated and the main crops are dates (more than half of the cultivated area) and fodder (more than one-fifth). Despite the fact that almost all agriculture is based on small farm units, production is market-oriented and uses new farming technologies including hybrid seeds, commercial fertilizers and pesticides, mechanization, and water-saving irrigation systems. While agricultural production has improved greatly, water shortage in some regions, salinity increase in wells, and wasteful surface irrigation are limiting factors in terms of productivity. In fact, increasing salinity is probably the single most economically devastating water resource problem facing the country at present. Aquifers are used to supply water for urban use and as a reserve for the future, and desalination plants currently provide about 80% of the potable water. In 2003, the total water withdrawal was 1321 million m³ of which 88.4% was withdrawn for agricultural purposes, 10.1% for municipal purposes and 1.5% for industrial purposes. In 2006, 37 million m³ of wastewater were treated and reused for landscape irrigation using sprinkler, drip, and bubbler systems. In order to encourage farmers to take up the new techniques, the Ministry of Agriculture and Fisheries (MAF) has approved financial and technical assistance to small farmers, and productivity has improved with modern irrigation systems with yield increase combined with less water use. According to the agricultural census of 2004–2005, 19% of the harvested area was under modern irrigation, mainly harvested vegetables and fodder, but only 9% of field crops and 6% of dates and other fruits.

4.2. Gastrointestinal diseases

Gastrointestinal illnesses in Oman seem to be typical of many countries in the region and also in the West, but shigellosis appears to one of the more common enteric diseases. To elucidate the bacterial etiology of childhood diarrhea in Dhahira, Oman, Patel, Shenoy and Ashwini (2008) studied 856 children <12 years admitted for diarrhea, often bloody, to Ibra Regional Referral Hospital from 2000 to 2002. Bacterial etiology was found in 15.2% of cases, and this study suggests that *Shigella* (mainly *S. sonnei* but also *S. flexneri*), *Salmonella*, and enteropathogenic *E. coli* are the most important bacterial pathogens among pediatric diarrheal cases admitted to hospital in the Dhahira region. A very few cases were associated with *Vibrio cholerae* and *Morganella*, and the authors stated that the cases that had no bacterial etiology were likely of viral origin. In August 2012, another study was carried out following a *Shigella flexneri* outbreak of acute gastroenteritis in three villages in the Al Batinah South Governorate, after 114 outpatients presented to the Wadi Sahtan Health Center between mid-August and the beginning of September (Abaidani et al.,

2015). A total of 142 cases of acute gastroenteritis were reported from these villages, and of these, 26 were admitted to Rustaq Hospital. Stool samples were collected from 21 out of the 26 admitted cases; 7 of these were positive for *S. flexneri*. All of the isolates had the same antibiotic sensitivity pattern (sensitive to nalidixic acid, ciprofloxacin, cefotaxime, co-trimoxazole, and resistant to ampicillin, augmentin and chloramphenicol). Households from the three affected villages shared a common water source which contained a mixture of water originally pumped from four tube wells and chlorinated water from a desalination plant in Rustaq which had been transported to the villages by water tankers. Although the tanker water proved to be satisfactory, fecal coliforms were found in two water samples and coliforms in three samples from village supplies. The risk of shigellosis was 1.5 times greater in households using water from the common tank water source compared to those using other sources of drinking water. Case and control households were compared to determine possible exposure avenues, including place of residence, source of drinking water, hand hygiene levels and practices related to drinking water, food preparation and environmental sanitation. It was found that drinking water was boiled and cooled in only 3.2% of households before consumption. This could have been because the majority of households used filters to purify water. However, infrequent cleaning of water tanks and changing of water filters as well as the use of open waste collection containers were also observed in the interviewed households. The only variables that significantly impacted the risk of acute gastroenteritis were residing in Fassa (one of the three villages) and only average hand hygiene practices. However, septic tank sanitation and water and food consumption practices were not satisfactory in all of the villages. While the source of the outbreak could not be identified, the study found that practices related to water tank and septic tank maintenance and the consumption of freshly cooked food were not satisfactory in these villages. The authors claim this was the first study conducted in Oman regarding an outbreak of shigellosis in a community setting, and that proper hygienic practices needed to be addressed to prevent future outbreaks of acute gastroenteritis in this region.

As to be expected, *Staphylococcus aureus* is frequently found in Omani residents. However, the prevalence of methicillin-resistant *S. aureus* (MRSA) in Oman was unknown until Pathare et al. (2015) compared MRSA carriage in the community visiting hospital patients (CA-MRSA) with those working in the hospitals (HA-MRSA). This study showed a relatively higher overall prevalence of CA-MRSA nasal carriage in an urban setting of 18% compared to 13.8% HA-MRSA nasal colonization. The authors recognized that one of the reasons for the high MRSA prevalence was cell phone use in both the community cohort and the health care worker cohort which they considered to be a public health concern. Although no risk factors were significantly associated with this high prevalence, Pathare et al. (2015) recommended that universal measures of hand washing, personal sanitation and hygiene need immediate attention, through community awareness campaign programs. Cell phones have been implicated in carriage of *S. aureus*, including MRSA, and other bacteria in hospital settings in Ontario (Julian, Singh, Rousseau, & Weese, 2012), Kuwait (Heyba et al., 2015), and Saudi Arabia (Zakai et al., 2016). Cell phone are commonly used in healthcare settings for rapid communication within hospitals, and are even used in toilets, but are rarely cleaned unless they are visibly dirty. Julian et al. (2012) in an Ontario veterinary college setting found that methicillin-resistant *S. pseudintermedius* (MRSP), an opportunistic pathogen, was isolated from 1.6% (2/123) and MRSA was isolated from 0.8% (1/123) of cellular phones. Only 21.9% (27/123) of participants in the study indicated that they routinely cleaned their cellular phone. Thus, regular cleaning of phones and

proper and frequent hand hygiene should be advocated. Pathare et al. (2015) indicates this should be a community message as well as in hospitals, and this strategy should be implemented for all food workers, who also use cell phones.

4.3. Foodborne disease outbreaks

From the above information, gastroenteric pathogens are known to be present in the environment and are carried by many Omani residents; so, it is not surprising that foodborne infections are frequent (Blackwell & Hasan, 2015). For instance, in 2014, 60 people became ill after eating contaminated food at restaurants around the country, while in 2013 more than 360 people fell victim to “food poisoning” (including 300 oil company employees discussed below). The authors indicate that it is likely many other cases occur but are not reported. Some details are available on the outbreak at the Qarn Alam Camp of the state-owned Petroleum Development Oman (PDO) in January 2013 (Vaidya, 2013); the employees had reported to the camp's clinic, mostly with a mild to moderate symptoms of vomiting and diarrhea. However, despite the fact that some were hospitalized and clinical specimens could have been taken, no information on the cause of the outbreak was indicated. If the incubation period was 24 h or more, the etiological agent could be *Salmonella* or even norovirus, but if the time to onset was short, it would likely be enterotoxins produced by *Staphylococcus aureus* or *Bacillus cereus*. That *B. cereus* could cause an outbreak is illustrated by one of the few well-investigated and published episodes in Oman. On May 3–5, 2008, 58 cases of gastroenteritis were reported among patients and their attendants in a referral hospital in Oman (Al-Abri et al., 2011). All affected had eaten at least one meal served by the hospital kitchen the previous day. An outbreak investigation team conducted active surveillance and interviewed people about symptoms and food consumed on the preceding day in the hospital. Food samples from the kitchen and fecal specimens from the kitchen staff and those affected were cultured, and an environmental audit of the kitchen was conducted. The majority of the 58 persons affected by the outbreak were adult females, predominantly attendants of patients. Their symptoms were typically mild occurring from 2 to 24 h (mean, 15 h) after eating the lunch on May 3; 90% had diarrhea and 10% had vomiting. Only two patient attendants required intravenous rehydration. Many violations of basic food hygiene standards were observed in the kitchen. Prepared food was maintained in the danger zone and correct storage procedures were not followed. In addition, there was poor labeling of available food samples. Cockroaches were found and there were no pest control records. Food items such as biscuits and juices were found hidden behind the bread slicing machine, together with more cockroaches. The refuse conveyor belt was not working, thus preventing immediate removal of refuse from food processing areas. Furthermore, no quarantine facilities were available in the kitchen area for the spoiled and expired food items. The tray line staff did not fully cover their noses, and hand gloves were not used. The staff rest area was also untidy and the toilet was dirty. Enterotoxin-producing *Bacillus cereus* was isolated from feces of 3/12 (25%) patients and 19/25 (76%) of food handlers, and 35/61 (57%) of food samples from the kitchen. This is the first report of an outbreak of foodborne *B. cereus* infection from the region. Even though the hygienic practices in the hospital kitchen were deplorable, the actual cause of the *B. cereus* contamination and growth was not specified. A whole variety of foods were culture- and toxin-positive: egg, sewia (a milky dessert), vegetables, meat, chicken, macaroni, noodles, oats, dhal, and foul (beans) masala. Since *B. cereus* is common environmental contaminant, any of these food items could have been easily contaminated with the organism, especially through cockroach contact, but the spores

would have to germinate and the cells have enough time to grow. Molecular typing of the different isolates and counts in the different foods would have given additional confirmatory information. The initial contamination dosage on foods with *B. cereus* is in most cases very low ($<10^2$ – 10^3 CFU/g) (BfR, 2015). Typically, multiplication in foods to a total bacterial count of 10^5 – 10^8 CFU/g is required to generate relevant amounts of toxins in foods or in the small intestine. That would mean food would have to be left between 4 °C and 50 °C (optimum, 30 °C–40 °C) for many hours to allow this kind of growth, which seems conceivable because of the conditions observed in the kitchen. The need for continuing training of food handlers and rigorous enforcement of food hygiene regulations was stressed (Al-Abri et al., 2011).

More typical of investigations are brief reports illustrated by the following. In August 2014, forty nationals suffered from gastroenteritis after reportedly consuming contaminated food at a restaurant in Ibbri province. Also, a massive quantity of foodstuffs found to be contaminated, improperly labeled, and not considered fit for consumption was confiscated early in 2015. In late August, 2015, 20 Omanis were ill after consuming contaminated food at a restaurant in Saham province, and some were hospitalized (Al Mukrashi, 2015). Although food samples were taken, the results are not known. The restaurant initially remained open but later Omani authorities closed the restaurant, jailed the staff, and fined them, but no specific reasons were given.

4.4. Research

One hundred and five samples of seven spices (cumin, cinnamon, clove, black pepper, cardamom, ginger, and coriander) were purchased from five Omani companies, and analyzed for their mycoflora and aflatoxins by Elshafie, Al-Rashdi, Al-Bahry, and Bakheit (2002). Twenty fungal species were isolated in which *Aspergillus flavus*, *A. niger*, *Penicillium*, *Rhizopus*, and *Syncephalastrum racemosum* were the most dominant. Of the seven spices studied, clove was found to be the least contaminated, while cumin was the most contaminated. None of the 15 selected samples of the spices contaminated by *A. flavus* were found to contain aflatoxins. Nevertheless, nine isolates (45%) of the twenty *A. flavus* strains screened for aflatoxins were aflatoxigenic. The moisture content of most of the spices was below the maximum standard limit. The results showed that the spices were contaminated by some fungi that might constitute health hazards for humans. Although the spices had low levels of fungi, if they were added to a food and left for some time, the fungi could outgrow to produce mycotoxins.

Al-Bahry, Elshafie, Al-Busaidy, Al-Hinai, and Al-Shidi (2007) investigated the antibiotic resistance of various strains of *Salmonella* isolated from food handlers, chicken, and sewage water in Oman. Stool specimens were obtained in 1998–99 from all 100,000 food handlers working at different places in the country who are checked annually according to Omani regulations. Of these, 1242 contained *Salmonella* (1.24%), of which 15 (1.2%) were resistant to one or more antibiotic (ampicillin, co-trimoxazole and chloramphenicol); none of the isolates was resistant to ciprofloxacin. *Salmonella* isolates were obtained from 123 imported frozen chicken carcasses, 191 live chickens at private chicken farms and 201 live chickens from commercial chicken farms. In addition, *Salmonella* isolates were collected from 232 samples taken from different sewage treatment plants in the Muscat area. Of 515 isolates from chicken and 432 from sewage water, 23.7% and 14.1%, respectively, were resistant to one or more antibiotic.

Al-Bahry et al. (2014) also examined water samples from hundreds of wells and treated sewage effluent in Muscat over several years. Nickel, zinc, nitrates, total dissolved solids, and total microbial counts were unacceptably high in many of these samples. The

authors considered that the reuse of sewage effluent along with cracked septic tanks, cesspits, fertilizers and recycled treated sewage effluent were the major causes of underground water pollution. The presence of trihalomethanes and antimicrobial resistant strains in well-water was an indication of sewage contamination, indicating that the existing methods of sewage water treatment with chlorination was not effective in eradicating microbial contamination. This study showed that the community was at risk for infectious diseases as illustrated by the shigellosis outbreak in 2012 (Abaidani et al., 2015), either directly from water consumption, or from food derived from crops using contaminated irrigation water, or after washing produce and clean and freshen it. A frequent analysis and stringent regulations by responsible agencies must be implemented to avoid further environmental deterioration, and prevent the spread of disease.

4.5. Government oversight

The Central Public Health Laboratory (CPHL) in Oman is one of the reference laboratories for WHO-EMR, and has six sections: Virology, Bacteriology, Biochemistry, Parasitology, External Quality Assurance (EQA) and Chemistry Laboratory (Mohammed, 2008). The CPHL has adopted newer technologies that include molecular techniques for the identification and confirmation of infectious agents, high throughput DNA sequencing, chromatography HPLC and GC procedures, and real time-PCR for the viral agents. The CPHL Oman was the first laboratory in the Middle East to establish DNA fingerprinting for foodborne bacterial isolates, and it belongs to the PulseNet Middle East network. Oman also has a National Inter-Ministry Committee on the Implementation of International Health Regulations, and Food Safety and Security fall under the Ministry of Regional Municipality and Ministry of Health. There is a specific Technical Task Force under Food Safety and Security that can relate events of concern to the WHO, after event verification and transmission through a Focal Point. It was argued that inadequate standards regarding food safety could actually damage the Sultanate's tourism industry, because foreign tour companies employ food safety experts and send them to countries like Oman to assess standards to verify whether they want to send their tourists to the country. The National Hospitality Institute (NHI) has been working to increase food safety standards in the Sultanate since 1997, providing internationally recognized food safety certification up to level four as well as Hazard Analysis Critical Control Point (HACCP) training. The NHI focuses on putting food safety management systems into company properties; it trains employees to international standards, installs food safety management systems, and also returns to the premises to complete auditing and conduct inspections.

It is mainly the municipalities that conduct inspections, but monitoring all the outlets that serve food is difficult, and Muscat Municipality inspectors are not always as thorough as they could be in their timing or quality of the inspections (Blackwell and Hasan, 2015). If they find any problem, they will give a notice of warning and then return after a week or two to check whether the problem is solved. If not, the restaurant will pay a fine which may be only a few hundred rials. Some of the most common faults in restaurants are temperature control, particularly when dealing with buffets; lack of care with deliveries, which are sometimes left out for a long time; not checking the standard of food when it comes in; cross contamination between food, surfaces and equipment; under-cooking of food; defrosting and refreezing; and inadequate washing of hands. Blackwell and Hasan (2015) consider that small fines may not be enough to force the owner of a business to change his ways and adopt new practices, and they question if stricter measures should not be implemented. After many cases defined as food

poisoning in 2013, the Council of Ministers gave approval for the establishment of a National Food Quality and Safety Centre, to be started in 2015. The Centre aims to bring all food inspection and regulatory bodies in one oversight system and will test imported and locally produced food items for contaminants. In addition, the New Consumer Act has more powers to punish restaurants by increasing the penalties for violations. In 2015, surprise inspections by the Muscat Municipality at 125 restaurants in Bausher found that around 53 restaurants did not meet food safety standards and were violating rules formulated by the Municipality (Staff, 2015a). Also, in the same time frame, Ibri Municipality officials shut down 42 commercial shops and destroyed more than 3000 kg of outdated food in 2015. According to the Municipality's officials, 698 health violation letters were issued throughout the year, as well as 541 warnings were issued to different institutions operating in Ibri. The NHI has also worked with Muscat Municipality on a Ministry of Manpower-endorsed initiative, coming up with a 50-h mandatory training program for anyone supervising a coffee shop or food outlet; managers should have a minimum amount of training or risk having their food licenses revoked. The NHI is also in the process of introducing stickers for those establishments that meet food hygiene and safety standards. All these initiatives should see improvements in food safety in Oman.

5. Qatar

5.1. Overview

The state of Qatar is situated on a peninsula that extends for about 170 km (ca. 106 mi.) north from Arabia into the Persian Gulf covering an area of approximately 10,360 km² (about 4000 sq. mi) including a number of small offshore islands. Qatar is a rocky or sandy desert area with scattered oases formed by 850 separate depressions (Aquistat-Qatar, 2008). In these depressions colluvial soils made up of calcareous loam, sandy loam and sandy clay loam have accumulated to depths ranging from 30 to 150 cm, overlying limestone debris and bedrock. These depression soils are locally known as *rodad* and constitute the main agricultural soils of the country. The arid desert climate is characterized by scanty and unpredictable rainfall with an annual average of about 80 mm over the period 1972–2005. Because of rain low intensity and variability, it is not considered reliable for supplementing irrigation and maintaining agriculture; yet, it represents the main source of irrigation water in the form of recharge to groundwater. In 2005, the population was estimated at 813,000 inhabitants, but had grown to 2.1 million in 2015, 90% of whom live in Doha, the capital. Foreign workers with temporary residence status make up almost 90% of the population, with Indians being the largest community numbering around 545,000. The amir is selected by a careful process of consensus within the Al-Thani family dynasty, which also holds many of the cabinet portfolios (Anthony & Hearty, 1980, chap. 7). The power of the merchants is primarily exerted on the commercial aspects of the emirate's developmental projects. As in many other Gulf states, oil and gas and their derivatives are responsible for most of the GDP, and Qatar enjoys one of the highest economic growth rates and high levels of human progress in the region. The development of the agricultural sector is limited by several factors, such as scarce water resources, low water quality, infertile soils, harsh climatic conditions, and poor water management, all of which contribute to low crop yields, resulting in the importation of most agricultural products, dates being the only exception. Qatar uses desalinated sea water for drinking water and treated sewage effluent for landscaping and forage crops. Most of the water used in irrigation is primary groundwater, with very low water use efficiency. All agricultural land in Qatar is owned by Qatari nationals,

but farming is carried out by expatriates, mainly Palestinians, Iranians and Egyptians, either employed as farm managers or as tenants on short-term leases. Major irrigated crops are green fodder (alfalfa), vegetables (tomatoes in the winter and melons in the summer), fruit trees (dates and citrus), and cereals (barley). Seawater intrusion is severe in Qatar, because the high permeability of the fractured limestone, withdrawal of water from the aquifer permits the rapid intrusion of seawater into the freshwater. Also, drainage water analysis shows a significant increase in nitrate derived from nitrogenous fertilizers. The future demand to meet the municipal and industrial requirements can be achieved by increasing the capacity of the existing desalination plants and building new desalination plants. However, although food self-sufficiency is not a practical policy, Qataris can afford to import their food as long as revenue from oil and gas is maintained (the current drop in crude oil prices from 2015 may have a long term effect on the economy).

5.2. Gastrointestinal diseases

Qatar employs a large number of workforce to support its economy, and sporadic *Shigella* cases and some outbreaks are known to occur in the country (Wilson, 2012). To understand the etiology of the disease in more detail, a 3-year analysis of diarrheal stool specimens was conducted. This showed that children 0–10 were those most affected, with *S. sonnei* (48.7%) and *S. flexneri* (44%) being the major serotypes, and the more serious *S. dysenteriae* (*S. shigae*) being only 2.7%. Isolates were resistant to several antibiotics. The affected individuals originated mainly in the Middle East (54.5%) compared with those from other parts of the world (South Asia, 39.7%; Africa, 6.3%; Europe, 0.5%). Because shigellosis is highly contagious, the author stressed that awareness of the prevalence of disease, the identity of the dominant strain, and the antimicrobial susceptibility of the dominant strain is crucial to ensuring proper clinical treatment and patient management and for epidemiological investigation processes.

Intestinal parasitic infections were surveyed among recently arrived immigrant workers in Qatar destined for employment in food handling occupations (Abu-Madi, Behnke, & Ismail, 2008). Two overlapping datasets (female workers surveyed in 2005 and 2006, and both sexes in 2006) were analyzed. Seven species were detected, 3 nematodes (*Trichuris trichiura*, hookworms, and *Ascaris lumbricoides*) and 4 protozoans (*Entamoeba histolytica/dispar*, non-pathogenic *Entamoeba*, *Blastocystis hominis* and *Giardia lamblia*). Overall prevalence of infections, all species combined was 33.9% (13.6% for nematodes and 24.8% for protozoa). There was a significant female bias in the prevalence of all species combined, all protozoans combined, *T. trichiura* and *A. lumbricoides*. Among females, the prevalence of many species fell between 2005 and 2006, but *G. lamblia* almost tripled and *E. histolytica/dispar* increased 10-fold. African workers were less likely to carry *T. trichiura* and hookworms but more likely to have gastrointestinal protozoa. The highest overall prevalence of *T. trichiura* was 26.3% among females from the Philippines in 2005. None of the Indonesian workers were infected with *A. lumbricoides* whereas those from the Indian sub-continent and the Philippines were more likely to carry hookworms. Multiple species infections were not common, although a few individuals (0.1%) had 5 species concurrently. This study showed that significant numbers of immigrant workers to Qatar, who eventually ended up in employment involving handling food, carried intestinal parasitic infections when they arrived in the country. These findings are important to the public health in the country, particularly in the food industry. In a follow-up study, Abu-Madi, Behnke, and Doiphode (2013) found that all prevalence values for the period 2009–2011 were numerically lower than

those recorded for 2005–2008. Combined intestinal protozoan infections fell from 8.0% to 5.3%, and combined helminth infections fell from 2.6% to 1.9%. The main reason for this decline is that since 2009 it is mandatory for all applicants for jobs in Qatar to have pre-employment certificates (PEC), which are provided at local Qatar embassy-approved clinical centers in the countries of origin before arrival in Qatar, and require medical examinations that include fecal examination. Before obtaining a certificate, subjects who are found to be positive for parasites, are required to have treatment (usually albendazole for helminths and metronidazole for protozoa) and then are subjected to re-examination. However, the good news for the decline is tempered by the fact that resident workers from some geographic regions still maintain a relatively high prevalence of helminth infections despite their long-term residence in Qatar.

The genetic relatedness among *Salmonella* isolates recovered from human gastroenteritis cases in hospitals and food animals in Qatar were investigated by Chang et al. (2016) to discover sources and possible transmission routes. A repeat cross-sectional study was conducted in which the samples and associated data were collected from both populations (gastroenteritis cases and animals). The non-human samples consisted of cow feces, udder swabs of cows, and carcass swabs of camels. Twenty-seven different sequence types (STs) were identified in this study; among them, seven were novel. The pattern of overall ST distribution was diverse; in particular, it was revealed that ST11 and ST19 were the most common sequence types, presenting 29.5% and 11.5% within the whole population. In addition, 20 eBURST Groups (eBGs) were identified, which indicates that ST11 and ST19 belonged to eBG4 and eBG1, respectively. In addition, the potential association between the putative risk factors and eBGs were evaluated. In this study, *Salmonella* Enteritidis (eBG4) and *S. Typhimurium* (eBG1) were therefore predicted as the most frequent serovars, which is similar to those identified in other countries. There was no significant clustering of these eBGs by season (hot summer and cooler winter); however, a significant association was identified in terms of nationality in that Qataris were six times more likely to present with eBG1 compared to non-Qataris. Qatar relies on an expatriate labor force to the point that foreigners outnumber Qataris by almost seven to one; most of these workers originate from the Indian sub-continent, Southeast Asia and Africa. This migrant population, combined with the large-scale import of food and food animals, could introduce a variety of serovars into Qatar. The relatedness among the isolates was assessed using the minimum spanning tree (MST) which showed four major clusters, namely, ST11, ST19, ST16, and ST31. The linkages between the clusters alluded to a possible transmission route. Seven new STs were detected that could be unique to the region or could have been transmitted to Qatar by migrant workers from other countries. Further analysis, possibly sequencing the genome of these strains, could help to define the characteristics of these new STs. The authors claim that the results of the study provide insight into the ST distributions of *S. enterica* and their possible zoonotic associations in Qatar. However, the types of food and environmental samples were limited to cows and camels; ground meat, chicken, leafy greens, known to have caused outbreaks, for example, were not sampled and tested.

Because data regarding MRSA epidemiology in regions of the Middle East, including Qatar, were considered insufficient, El-Mahdy, El-Ahmady, and Goering (2014) examined *Staphylococcus aureus* isolates from multinational patients in Qatari hospitals in 2009/2010. Molecular characterization for MRSA isolates was performed by pulsed-field gel electrophoresis (PFGE), SCCmec, spa and dru typing, and PCR for the presence of the arginine catabolic mobile element and genes for the Pantone-Valentine leukocidin

(PVL). Prevalence of MRSA among *S. aureus* isolated was 176/840 (21%). Of the 61 MRSA isolates examined, three (5%) represented hospital-acquired infection. By PFGE, 32 isolates (52%) were community-associated (CA-MRSA), and other isolates were well-known healthcare-associated MRSA. Four isolates were unrelated to any known strains in the international database. The high prevalence of CA-MRSA, especially in this setting underscores the importance of global epidemiological monitoring to better understand and hopefully help prevent the emergence and spread of these problem pathogens in patient populations. Although it is unknown if any of the patients were food handlers, the potential for spread of MRSA through food cannot be ignored.

5.3. Research

One hundred and six samples of cereals and cereal products, nuts and nut products, spices, dry fruits and beverages were collected from the market of Qatar and analyzed for aflatoxin, ochratoxin, zearalenone and deoxynivalenone (Abdulkadar, Al-Ali, Al-Kildi, & Al-Jedah, 2004). Twenty-eight samples were found contaminated with aflatoxin (0.14–81.64 µg/kg); 11 samples with ochratoxin (0.20–4.91 µg/kg); 13 samples with zearalenone (0.18–6.81 µg/kg); and 4 samples with deoxynivalenol (86.43–182.94 µg/kg). The authors stated that contamination of various commodities by mycotoxin is a result of adverse pre-harvest conditions of temperature and humidity in the field and improper postharvest handling and storage. Since Qatar and other Gulf countries are at the consumer end of the food chain, they do not have direct control over the prevention of contamination by mycotoxins in the field and during storage in the producing countries. However, it is possible to estimate the levels of contamination and thereby assess the preventive measures undertaken by the producing countries by analyzing the susceptible commodities for mycotoxins before sales in Qatar.

Foodborne illness has been identified as a high priority in the Qatar National Food Security Program (QNFSP) master plan. Although it is estimated that up to 30% of the population in industrialized countries suffer from foodborne diseases, data in Qatar are lacking. Mohammed (2008) investigated the epidemiology and ecology of *Salmonella* spp., *Escherichia coli*, *Campylobacter* spp., and *Listeria monocytogenes* at the preharvest level in dairy operations and processing plants in Qatar to develop cost-effective strategies to mitigate the associated risk to human health. All samples were screened for these pathogens and their toxins using a combination of culture enrichment and real-time polymerase chain reaction (PCR) diagnostic approach. Shiga-toxin producing (non-O157) *E. coli* serogroups had the highest rate of occurrence (58%), and *E. coli* O157:H7 was detected at a rate of 6%. *Salmonella* and *Campylobacter* spp. were detected at a much higher rate than expected. A higher percentage of the recovered pathogens were confirmed to have toxin genes.

To gain an understanding on the safety of traditional street vended foods in Qatar, often eaten by tourists, Elobeid, Aziz, Mousa, and Alzahiri (2014) tested the microbiological quality of 14 different Qatari foods sold in Souk Wagif, the main traditional market in Qatar. A total of 56 samples were purchased from 10 different street vendors with samples being collected randomly on different days. These were tested for microbial contaminants using real time-PCR to screen for *Salmonella*, *Listeria monocytogenes*, *Escherichia coli* O157:H7, and generic *E. coli*. Out of the 56 samples, only two samples “Biryani” and “Khabess” contained *E. coli*, but were negative for *E. coli* O157:H7. The microbial contamination of the Qatari traditional street vended foods was 3%. According to the authors, the low microbial contamination rate was probably linked to the fact that the vendors were licensed by the Ministry of

Municipalities, they had to pass a medical checkup, and they were determined to be fit to work. More importantly, they followed the food safety, food protocols such as washing hands, wearing gloves, keeping short nails, and maintaining a clean environment for serving the food. The vendors were very careful while serving the food for customers, they did not remove or widely open the food container covers to keep the food they served hot. Since the foods were served hot (above 65 °C) the most likely reason for the low contamination rate was that even if there was contamination through handling pathogens could not grow at this temperature; in addition, salt and sugar ingredients may have reduced the foods' water activity, and some spices have antibacterial activity. It appears no dairy products, leafy greens, or fruits were vended in this study, ready-to-eat cold foods which could well have higher counts.

5.4. Foodborne disease outbreaks

Foodborne disease can affect tourists and residents alike, including foreign workers on temporary visas.

Within 72 h of finishing an event dinner at a Doha hospital on December 6, 2010, 44 staff and 7 patients experienced gastrointestinal illness, and subsequently 7 staff and all 7 patients were confirmed to have *Salmonella* group D in their stools (Alajmi et al., 2011, p. P93). Screening of 130 staff from catering areas showed 6 catering staff were found to be positive for *Salmonella* group D; two of them had returned from vacation and resumed their duties before receiving their clearance to resume work. All available food and environmental samples were negative for *Salmonella*. The authors deduced that at least one of the employees had contaminated one or more food items served on December 6, and that the outbreak illustrated the potential for infected food handlers in health care settings to be a source of transmission. They recommended routine stool culture of food handlers, combined with education and proper hygienic practices to prevent such outbreaks in the future. The role of food handlers/workers in causing outbreaks in both health care institutions and food establishments is well established but routine stool testing is questionable unless they are returning from developing countries with many endemic enteric diseases (which is likely for the positive handlers in this outbreak, although not specifically stated) (Todd, Greig, Bartleson, & Michaels, 2007). An example of an expatriate worker being infected with *Salmonella* and returning to Qatar was illustrated by an ill Nepali man who returned from Nepal 20 days before admission to Hamad General Hospital, Doha, suffering from Guillain-Barré syndrome that was caused by a *Salmonella* Paratyphi A infection contracted in Nepal (Khan, Kamha, Abbas, Miyares, & Elshafie, 2007). Since expatriate workers (mainly Indian or other Asian) comprise 90% of the Qatari population, the many returning workers are liable to bring infections into the country on a regular basis.

In November, 2014, four members of a family were rushed for emergency medical care after suffering from nausea, vomiting, abdominal pains, and diarrhea immediately after eating a meal of chicken, rice and salad from a famous restaurant in Doha's Old Airport area (Anonymous, 2014c). A medical certificate issued by the emergency unit said all four suffered from “food poisoning”, and needed treatment for two days. Doctors attending on them said they had treated other four people for “food poisoning” earlier after eating from the same restaurant. The affected family filed a police complaint. No further details are given, but clearly when two separate groups of people are ill on the same day from the same restaurant, the food must have been contaminated. Rapid onset would indicate a preformed enterotoxin or a inadvertently-added chemical such as a pesticide.

Since foreign workers make up the majority of the population, it

is not surprising that these suffer from foodborne illnesses but they are often not reported. However, this was not the case on November 17, 2010, when an outbreak of acute gastroenteritis occurred among laborers at the Rass Laffan industrial city, where hundreds of thousands of laborers work in the gas and oil industry. Most of these laborers live inside the city in different camps. In one of these camps that mainly accommodates Filipino workers, many hundreds developed acute gastroenteritis (Nazzal, Said, Al-Hajri, & Tamim, 2012). A case was defined as a person with diarrhea (three or more loose stools during a 24-h period) who had attended the Filipino Mess Hall in the five days after November 16, 2010. The total number of gastroenteritis cases in this outbreak was 300 among the approximately 1050 attendees, giving an overall attack rate of 28.5%. A total of 84 cases was randomly selected together with 80 controls to complete a structured questionnaire. In addition, stool culture from patients and food handlers as well as food samples were analyzed to determine the pathogen and the possible source of infection. It was found that about 300 laborers developed diarrhea and abdominal cramps with a median incubation period of 15 h after eating macaroni salad at dinner (breakfast and lunch meals were ruled out). Cases were more likely than controls to have eaten macaroni salad 97.6% and 27.3%, respectively with OR 109.3 (CI: 25–484). Stool culture of 6 patients and 3 food handlers were positive for *Salmonella* group D but none of the food items obtained showed microbial growth. Food samples included all leftover food of the three meals served on November 16 and random samples of the leftover food served on 17th, 18th, and 19th November. However, no leftover eggs were found from November 16. The personal hygiene of the Mess Hall employees was satisfactory and all food handlers had valid health certificates (stool cultures were not required during regular check-ups). The investigation showed that the chief cook used around 225 raw eggs, discarding the yolk and pouring the egg white to complement the mayonnaise of the macaroni. This occurred 5–6 h before serving the meal, time sufficient to allow multiplication of any *Salmonella* present. The authors recognized limitations of the findings: 1) no eggs remained for testing; 2) the lack of the molecular analysis and typing of the *Salmonella* subgroups; 3) and recall bias taking the meal history many days after the outbreak had occurred. The findings of this study indicate that the causative agent of this outbreak was *Salmonella* group D and the likely vehicle of infection was macaroni salad, which was mixed with raw eggs. Since three workers were asymptomatic carriers, they could have been the source of the *Salmonella*, but most likely the pathogen came from the eggs and the employees ate some of the macaroni salad (not determined from the investigation) and were infected similarly to the laborers. *Salmonella* group D includes *S. Enteritidis* which is well-established as causing many egg-related outbreaks (ECDC/EFSA, 2014).

Expatriate workers not only have occasional problems with catered food at work, but also more regularly in food they take from home, like Vijay K., an Indian worker in Doha, who suffered from pain and diarrhea every week (Taqjudin, 2014). The problem recurred so frequently that he gave up on seeking medical consultation but instead bought the same medicine again with an old prescription, and within a day or two he would feel fine. His reasoning for the illness is that it was from his home-made lunch meal. He, along with other workers, had to prepare it at night along with their dinners and storing them in containers before they go to sleep, as there is no time for preparing them in the morning. They carried their lunch containers to work with them, and the food remained outside throughout the morning while they worked with temperatures reaching 45 °C–47 °C. Under these conditions Vijay said that the food went “stale” quickly. He said: “We need to be strong to work so we just eat our food and don't care about its taste.” Another worker said: “We have to rest very near to the work

site as our boss wants us to report back on time”. Even though the lunch break was quite long because of the peak high ambient temperatures then, most companies would not transport the workers back to residences or cooler buildings. The majority of the workers were from South Asia, with a dietary staple of rice. This means that *Bacillus cereus*, common in rice, is a likely pathogen causing Vijay's ailment, unpleasant enough to cause gastroenteritis but not severe enough to send him and others to hospital.

5.5. Government oversight

Sufficient and safe food is one of the major challenges facing the Middle East, particularly that currently several epidemic animal diseases are spreading in the region of which control requires collaboration and cooperation with other Gulf states (Anonymous, 2015c). Limited access to water and food is a major challenge for Qatar, which has begun investing in agricultural land in Kenya, Vietnam, and India, as well as establishing the Qatar National Food Security Programme (QNFS). Within Qatar, a master plan for food security includes establishing 1400 farms and an agro-industrial park for food processing, developing best practices with the help of international expertise from the field of agriculture. Sewage has to be better treated. Al-Bahry et al. (2009) found that sewage treated effluent (STE) discharged straight into the sea caused contamination of marine wildlife including fish along coastal areas. One major venture is the creation of solar powered desalination plants, such as the pilot 1-ha Sahara Forest Project (SFP) to produce three food crops year-round with half the fresh water used in comparable greenhouses (Clery, 2013; miss22, 2013). The concentrated solar power plant uses parabolic mirrors to heat a fluid flowing through a pipe at its focus. The heated fluid then boils water, and the steam drives a turbine to generate electrical power to run its control systems and pumps, and can use any excess to desalinate water for irrigating the plants. The SFP pilot demonstrated that using saltwater can be effectively used for the integration of food production, revegetation and renewable processes: 1) seawater cooling system for greenhouses supports production of high-quality vegetables throughout the Qatari summer, and reduces freshwater usage to less than half that of comparable greenhouses in the region; 2) solar and desalination technologies such as the greenhouse and evaporative hedges provide wet-cooling efficiencies without cooling towers; 3) the external evaporative hedges provide cooling of up to 10 °C for agricultural crops and desert revegetation with vegetable and grain crops growing outdoors throughout the year; 4) commercially interesting algae showed good tolerance to heat and high evaporation rates in the leftover salty water. On the basis of the Qatari venture, a planned 20-ha facility was being considered for Jordan.

For the food industry itself, the Qatar's Supreme Council of Health (SCH) has begun an intensive inspection campaign, collecting food samples from all restaurants and food outlets in the country including suppliers, as well as checking food workers to be free of enteric pathogens (Walker, 2014). Any workers seen to be handling food unhygienically would not be allowed to work in that field again. The public can use a hotline to complain about a food facility and initiate a SCH team to visit the affected people and inspect the related food outlet including collecting samples for laboratory examination. One example of this was illness in a family of four who claimed to have suffered from foodborne disease after eating chicken, rice and salad at a popular Turkish Doha restaurant. Three pathogens were found in the family as well as in the food served by the restaurant, and one of the restaurant workers. The SCH closed down the restaurant because the investigation showed that it had served contaminated food and also violated health regulations. Another popular Turkish restaurant was closed for two

months after it was found that several customers were treated in the hospital for intense nausea, vomiting and diarrhea. The SCH also has an educational thrust with community awareness campaigns, as well as seminars and training sessions about food contamination to improve understanding among owners and workers in food establishments. The 2014 amendments to the food law gave greater powers to authorities to fine and close down venues that break the law if they have violated food safety and hygiene regulations. Some of the judgments seem very harsh as occurred following the closure of one of these Doha Turkish restaurants. At the trial, five staff were each handed fines, jail sentences and deportation orders after they were found guilty of causing “food poisoning” to approximately 20 customers who suffered from vomiting, nausea and diarrhea (Santacruz, 2015). The manager of the restaurant was also fined and sentenced to spend three months in jail while three other staff members were fined and sentenced to one month in jail; in addition, another staff member who did not hold the necessary health certificate was also sentenced to one month in jail. The owners of the restaurant were given the largest fines and it was closed for a further three months in punitive judgment.

As its food production gears up for the domestic market, there may also be opportunities for international trade. However, there may be stiffer requirements for importing food to other countries. For instance, the United States Department of Agriculture has issued specific instructions for export of products from Qatar (USDA, 2015). These include eligible/ineligible products; requirements for labeling and certification, handling/storage; information regarding halal certification.

6. Saudi Arabia (the Kingdom of Saudi Arabia)

6.1. Overview

The Kingdom of Saudi Arabia (KSA) is the largest of the Gulf states and indeed of all the Middle Eastern countries, with a land area of about 2 million sq. km (800,000 sq. mi.), about one-fourth the size of the continental United States (Embassy, 2015). In 2005 the population was 24.6 million of which 11.5% was rural, and about 76% were estimated to be Saudi nationals. In 2015, the population was closer to 27 million. Despite harsh conditions for both living and agriculture in the desert climate with limited rainfall (from none at all for up to 10 years in the Rub Al-Khali, to 50 cm a year in the mountains of Asir Province), and summer temperatures over 44 °C midday in the desert and humidity in coastal regions up to 100%, large areas of desert have been turned into agricultural fields. The KSA has built a network of dams to trap and utilize seasonal floods, and has tapped vast underground water reservoirs through deep wells. However, groundwater resources are being depleted at a very fast rate with some predictions suggesting that these resources may not last more than about 25 years (Aqastat-Saudi Arabia, 2009). KSA is the largest producer of desalinated water in the world, sufficient to produce enough fresh water from the sea for urban and industrial use, allowing the other sources for agriculture. Treated urban and industrial wastewater is used to irrigate non-edible crops, for landscape irrigation and for industrial cooling. In 2006, 97% of the urban population had access to improved water sources, and improved sanitation. Land under cultivation, less than 160,000 ha (400,000 acres) in 1976, reached millions of hectares by the 21st century. In 2006 the harvested irrigated crop area was mainly cereals (wheat, sorghum, and barley), and less for fodder, vegetables, and date palms. Irrigation is becoming more efficient and the government is seeking ways to expand the use of treated wastewater in the agriculture. Currently, Saudi Arabia is self-sufficient in meat, milk and eggs, and also has an export market

for wheat, dates, dairy products, eggs, fish, poultry, fruits, vegetables, and flowers. The private sector has played a major role in the Kingdom's agricultural development. This is mostly due to government programs that offer long-term, interest-free loans, technical and support services, and incentives such as free seeds and fertilizers, low-cost water, fuel and electricity, and duty-free imports of raw materials and machinery. All of this is possible because of the revenue from crude oil, with the largest deposits in the MENA region. However, because of finite water resources from aquifers, the government is seeking ways to expanding the use of treated wastewater in the agriculture and industry sector, and orienting and supporting research aimed at producing crop varieties that are resistant to drought, and saline or acid soils. For administrative purposes, KSA is currently divided into 13 administrative regions, which are subdivided into governorates, and then sub-governorates and municipalities (Al-Mutairi, Connerton, & Dingwall, 2015). Food safety enforcement at a local level is predominantly the responsibility of municipal authorities, although policymaking and regulatory development are divided between several central government agencies.

6.2. Gastrointestinal diseases

To determine the causes of diarrhea in Riyadh from 2005 to 2010, Somily, Al-Othman, and Kambal (2014) examined 22, 321 stools of patients complaining of diarrhea at King Khalid University Hospital; 2% of specimens tested were positive, of which 89.1% of grew *Salmonella* spp., 5.6% *Shigella* species, and 5.3% grew *Campylobacter jejuni*. Most of these isolates were from the age group >1–5 years old. Cefotaxime was the most active agent against *Salmonella* and *Shigella*, while erythromycin was the most active agent against the *C. jejuni*. No *Aeromonas*, *Yersinia*, *Vibrio* species or *E. coli* O157:H7 was isolated, and no viral or parasite isolations were attempted. The fact that 98% of stools had no etiology determined indicates that viruses are probably the more important pathogens causing diarrhea, particularly in children, e.g., rotavirus, adenoviruses, and other enteric viruses (Todd & Greig, 2015). This is borne out by the study of Johargy, Mumenah, and Ghazi (2010) who analyzed a smaller number of stool samples (270), all pediatric patients (<5 years of age) in various hospitals of Makkah and Jeddah, but with a higher percentage of isolates (39%). Of these, 90 (33%) had viral etiology, of which rotavirus type A (serotype G) was found in the majority of cases 60 (22%), adenovirus in 20 (7%) patients, and astrovirus in the remaining 10 (4%) patients. Thirteen (5%) were of bacterial origin, of which 9 (3%) were *Salmonella* species, 4 (2%) were *Shigella* species and only 3 (1%) of the specimens were positive for *Giardia lamblia*. The authors do not discuss the two-thirds of the stools that were negative. This could be partially explained by the fact that the agents were no longer present in the stools, or they were unable to be isolated because of the methodology issues, or were other specific agents not looked for.

In 2008–2011, a much larger study was carried out at an Eastern Province teaching hospital in Damman; a total of 17,436 fecal samples were analyzed (Elhadi, Aljindan, & Aljeldah, 2013). Of these specimens, 158 tested positive (0.9%) for non-typhoid *Salmonella* (NTS). Of 158 NTS cases, serogroup D1 (25.3%) was the most prevalent, followed by serogroup B (19.6%), and serogroup C1 (18.9%). Many of the NTS serogroup strains were resistant to tetracycline (33%), ampicillin (31%), amoxicillin/clavulanic acid (29.9%), trimethoprim/sulfamethoxazole (20.9%), and cefotaxime (14.9%). Although the prevalence of NTS in the Eastern Province of Saudi Arabia was very low compared with other studies worldwide, the authors had concerns that the use of antibiotics in animal feeds may contribute to increased acquisition of resistance in foodborne

bacteria, including *Salmonella*.

Zoonotic and foodborne diseases, such as brucellosis, salmonellosis, typhoid and paratyphoid fevers, shigellosis, amebic dysentery, and hepatitis A are reportable diseases in KSA with yearly statistical records of the Ministry of Health (MOH) (Alsaiyegh, 2015) indicating relatively low incidence of these enteric diseases. With few specialists in food safety, few accredited laboratories, ill persons not always seeking medical help, and illness data are not always available from private hospitals, these enteric diseases are likely underreported. The author states that along with minimal spending on food safety research, there is insufficient knowledge and lack of related published data to estimate the burden of all foodborne diseases in Saudi Arabia. If we use the estimates for the United States (48 million annual cases, Scallan et al., 2011), we would expect about 4 million cases a year in KSA based on a comparative population. Alsaiyegh (2015) attempted to determine the burden of foodborne diseases through hospital records but foodborne disease cases in Saudi Arabia are not typically clearly defined in patients who were admitted to hospital emergency rooms. For non-notifiable foodborne diseases, a literature search (for the period from 2003 to 2013) was performed online in seven databases for outbreak-related data. The incidence rates per 100,000 ranged from 0.55 for typhoid/paratyphoid to 114.7 for “food poisoning”, the most frequently recorded enteric disease, which is not defined by etiological agent, but probably excludes those notifiable diseases often or sometimes associated with food intake, e.g., salmonellosis or amebic dysentery. Alsaiyegh (2015) suggests four possible agents for food poisoning (*Campylobacter jejuni*, *Staphylococcus aureus*, *Bacillus cereus*, *Clostridium perfringens*), but most likely the term is more often a catch-all for those cases linked to foods by the victims or the investigating team but with no specific agent isolated. Risk factors contributing to outbreaks are listed as contaminated food and water, cross-contamination, inadequate cooking, food from unsafe sources, infected food handlers, and raw milk.

An older study by Qadri, Al-Gamdi, and Al-Harfi (1995) looked at reservoirs of bacterial and parasitic enteropathogens in the population by studying the stools of 3258 asymptomatic KSA primary school children (6–11 years) in the Eastern Province. The overall prevalence of enteropathogens was 10.44%. Non typhoidal *Salmonella* and *Shigella* species (*Shigella dysenteriae*, *S. flexneri*, *S. boydii* and *S. sonnei*) were isolated from the children at 0.74% and 0.73%, respectively (total, 1.14%), and intestinal parasites higher at 9.3%. The most common parasite found was *Giardia lamblia*, 8.16%, followed by *Entamoeba histolytica* (0.74%); *Hemenolepis nana*, *Ascaris lumbricoides*, *Trichuris trichiura*, *Enterobius vermicularis*, were less frequent; however, these are not typically foodborne. Multiple drug resistance was common in the *Salmonella* and *Shigella* isolates. Whether these reservoirs exist today is not known. Certainly it is likely that food workers constitute a reservoir. Although pre-employment stool examinations are mandatory for food handlers (one stool specimen tested annually) in Saudi Arabia before they can get their pre-employment health certificates, there was no community study on working employees in the food business, especially from expatriates who come from parasite endemic countries. Thus, in 1995, Kalantan, Al-Faris, and Al-Taweel (2001) requested stools from randomly selected 700 food handlers in different parts of Riyadh to determine parasite carriage status. Of these, 461 (65.8%) responded, and it was found that all food handlers working in kitchens and public restaurants in the study area were non-Saudi men, ranging in age from 21 to 48 years. They represented 11 different countries, the majority of them (65.9%) from South East Asian countries and the Indian subcontinent. There was a significant association between the nationality of the food handlers and the likelihood of them having a positive stool

specimen for parasites ($p = 0.006$); the highest prevalence was among the Bangladeshis (20.5%), followed by the Indians (18.5%), Turks (10%), and Arabs (3.4%). Of the 461 stool specimens examined, 59 (12.8%) were found to be positive for parasites. *Giardia lamblia* constituted 33.8% of total positive specimens, 42.9% of which were found among Indians, followed by Bangladeshis (33.3%), Pakistanis (14.3%), and Turks (9.5%). No parasites were found among Arabs and the other nationalities. *Enterobius vermicularis* was the second most common parasite (27.4%) of the total positive specimens; 43.8% of which were found among Indians, followed by Bangladeshis, Turks and Pakistanis (18.8, 18.8, and 12.3%, respectively). *Entamoeba histolytica* (19.4%) was equally prevalent among Arabs, Pakistanis, Turks and others. Overall, only 8.4% of the Arab food handlers had positive results, compared to 15.0% of the non-Arab employees. Although this study is over 15 years old, expatriates come from countries where enteropathogens, including parasites, are still endemic, and their carriage by workers is still likely.

6.3. Foodborne disease outbreaks

In Saudi Arabia, a national policy for reporting, notifying, and recording incidents of “bacterial food poisoning” was established in 1984 (Al-Joudi, Al-Mazam, & Choudhry, 2010). In 2010, there were 264 reported foodborne disease outbreaks from households and commercial sources, with 1647 ill persons and one death. It was claimed that commercial sources were responsible for 62% of those who fell ill. In 2011, 255 outbreaks were reported, causing illness in 2066 people (Al-Mutairi et al., 2015). However, these figures probably are less than the real numbers of patients and incidents since many incidents remain undocumented because people do not attend health institutions for medical treatment, or because of acknowledged inaccuracies in sampling, analysis and investigation. *Salmonella* foodborne disease outbreaks are some of the more frequent in KSA, exhibiting seasonal and regional variations, and chicken, meat, and rice being commonly incriminated food items, and frequently reported in the Saudi Epidemiological Bulletin. Al-Joudi et al. (2010) lists 12 publications, but even if these are not a full record of the foodborne salmonellosis outbreaks in the country, they clearly show the large burden of this disease, involving a variety of foods including chicken shawarma, mayonnaise and watermelon. *S. Enteritidis* was the most frequent *Salmonella* serovar isolated from foodborne disease outbreaks in recent decades. According to ProMED-MENA editorials (<http://www.promedmail.org>), restaurants and communal feasts and institutional feeding (such as in school cafeterias, hospitals, nursing homes, prisons, etc.) where large quantities of food are prepared several hours before serving are the most common settings in which foodborne illness incidents occur. In 2006, 31 foodborne illness outbreaks, accounting for 251 cases, were reported in Qassim (Al-Goblan & Jahan, 2010). The highest proportion (64.5%) of the 31 outbreaks was reported from June to August. Similar to that of the Al-Joudi et al. (2010) report, *Salmonella* species was the commonest etiological agent, followed by *Staphylococcus aureus*. The majority (68.9%) in the Qassim study of the cases were ill after consuming foodservice prepared foods. Consumption of contaminated meat, such as chicken with rice or shawarma sandwiches of chicken or mutton caused about two-thirds of the cases (67.7%). Shawarma outbreaks had been previously recorded in Riyadh (Al-Amoud and Al-Mazrooa, 2000). Other implicated foods included laban, camel milk, appetizer, mixed and green salads, as well as rice, potato chips and French fries, unspecified snacks, mayonnaise, popcorn and chocolate.

More typically, however, was that no agent or final conclusion was reached in many investigations, as occurred in a Jizan Regional

hospital in 2005, which received 19 suspected “food poisoning” cases that were ill after eating at a restaurant (Fagbo, 2005). Even though no specific cause was determined, the restaurant was closed down and three of its workers were detained. The etiology or conditions leading to an even larger outbreak in the Najran region with 80 cases suffering from mild symptoms after eating a meal at a restaurant in 2015 could not be determined, but again the restaurant was temporarily closed (AlHayat, 2015). One outbreak, however, where the investigation was complete along with advice to prevent future failures was a wedding outbreak in 2002, in which 88 of 238 guest developed gastroenteritis. This was most commonly manifested by diarrhea (100%), abdominal pain (94.3%) and fever (86.4%). The median incubation period was 20.6 ± 2.8 h and the epidemic curve suggested a common point source outbreak (Al-Joudi et al., 2010). Two food items were most significantly associated with illness: meat and rice. Non-typhoid *Salmonella* Group C was isolated from 40 of 62 stool specimens, but unfortunately no food served at the wedding was available for testing. None of the nine restaurant workers had a valid health certificate, and all had *Salmonella* Group C isolated from their stools; since they stated that they did not have any diarrhea at that time, they were probably asymptomatic carriers. According to the health inspector's report, the food preparation room, the floor and tables were not clean; the ambient temperature was high since there was no air-conditioning. The food preparation room was connected by a backdoor to a toilet at the back of the restaurant. The swabs taken from the restaurant were positive for coliforms. After the meat and rice had been cooked and combined, it had been kept at room temperature or under low heat for many hours. It was first served to the male guests, and then 4 h later to the female guests and any males who wanted a second helping. Of the 88 cases, 19 (21.6%) were males and 69 (78.4%) were females. The traditional way of serving food first to the males and then serving the remaining food, which was stored at ambient temperatures throughout the reception, to the females no doubt allowed any *Salmonella* present in the meat or rice (or both) to multiply to numbers sufficient to cause more infections in the females than the males. This is an example of how certain traditions can influence food handling and increase the risk of outbreaks of foodborne diseases (Al-Joudi et al., 2010). The authors recommended that education should be focused on improved supervision and hygiene of food handlers, as well as the public, to prevent occurrence of such incidents in future.

Enteric illnesses among construction workers are liable to occur frequently (but are not always reported) because hygienic conditions at workers' camps and work situations are not always at the same standard as for Saudi residents and visitors. In 1994, 19 Filipino workers suffered from salmonellosis after eating catered chicken adobo at a camp in Dammam City (Al-Awaidy & Fontaine, 1996). The chicken had been poorly prepared with improper temperature storage that allowed growth of *Salmonella* which had either survived the thawing and cooking, or the chicken had been recontaminated by using the same utensils for raw and cooked meat. A more recent example occurred in February 2011, when a group of construction employees working on new university buildings suffered from abdominal pain and severe diarrhea with a median incubation period of 6.5 h after eating a prepared lunch (Maslamani, AlMazroa, & Nooh, 2011). *Staphylococcus aureus* was isolated from a green salad and rice, as well as from nasal swabs of two food handlers, and from under nails of one food handler. In addition, the salad served showed a strong epidemiologic association to the outbreak. On inspection, the restaurant was found to have poor hygienic conditions. None of the food handlers had a health certificate to legally prepare the food, and the food handlers and workers were friends and colleagues, living and eating together. *Staphylococci* have been implicated in 41% of “bacterial

food poisoning” cases in the KSA and they have been found in dairy products including raw cow, camel, and goat milk, and processed cheeses including Romy and Feta (El Sheikh, 2015), though there are probably more reservoirs not identified because of the limited studies done.

With millions of Muslims participating each year in the Hajj to Mecca, it is to be expected that communicable disease outbreaks of various infectious diseases would be reported repeatedly, during and following the pilgrimage with concern for cholera, polio, and travelers' diarrhea (Memish, 2010). To this end, the KSA implements stringent infection control measures for pilgrims through the ports of entry, provides free health care, hospitalization, and 39 public health teams are distributed around where the Hajj takes place. Extensive reviews cover the infectious diseases and their control during the Hajj (Bowron & Maalim, 2015; Memish et al., 2014). Occasional foodborne disease outbreaks are reported, such as occurred in March, 2003, when over 400 Iranian Hajjis were hospitalized in Madinah complaining of vomiting, nausea, abdominal pain and diarrhea after eating food prepared in the kitchen of their caterer (AlMagheri & AlMazroa, 2003). Based on the foods consumed, rice and chicken were the most implicated food items. *Staphylococcus aureus* was considered to be the etiological agent, as it was isolated from nasal and throat swabs of two workers, stool cultures of 13 of the workers responsible for food preparation, vomitus of 10 cases, and leftover chicken and rice. At 6:00 a.m. the cooked food was placed in special heaters, which were transported 4 km in special trucks to the hotels where the Hajjis were staying. Each leader received one electrical heater (containing up to 300 meals) according to the number of Hajjis in his group. The group leader and his assistants served the lunch at 1:00 p.m., and illnesses began 3–7 h afterwards. It is likely that the food was contaminated by one or more of the food preparers, and *Staphylococcus aureus* growth could have taken place during and following preparation and delivery, but 80 °C heater temperature would have been sufficient to eliminate any *S. aureus* present in food during their storage in the hotels. Thus, either *S. aureus* enterotoxin had been produced before the food had arrived at the hotels, or one or more heaters were at fault or improperly maintained to allow growth of the organism for a further 7 h till the lunch time with adequate opportunity for enterotoxin production. In 2006, an outbreak during the Hajj occurred where all the cases were from one tent occupied by 50 soldiers located in a government camp in Mina (Al-Joudi, 2007). The camp was served by a catering company that prepared and distributed three meals daily. Diarrhea (100%), and abdominal pains (87.5%) were the most frequent symptoms occurring 12.6 ± 4.9 h after ingestion of a rice meal served for lunch. No pathogen could be isolated from stools of patients or food handlers, and there was no leftover food for sampling. Based on the incubation period, symptomatology, and previous outbreak history, *Bacillus cereus* would be the most likely etiological agent, especially as temperature abuse of the food was suspected. In 2011, 81 Bangladeshi pilgrims were hospitalized briefly in Madina with abdominal pains, diarrhea and vomiting after eating a meal served by an unlicensed caterer (ProMED, 2011). No further information is available on this outbreak.

6.4. Research and surveys

Yersinia enterocolitica, a pathogen more often found in cooler climates, was isolated from environmental samples in Riyadh many decades ago; 106 samples of sewage water, irrigation water and chicken cecal contents yielded this organism but not from 110 samples of milk, chocolate milk, drinking water and rain water (Salamah & Makki, 1991). All of the known *Y. enterocolitica* biotypes were represented and 58% of the isolates were virulent. Thus, there

is a concern that this pathogen could cause gastroenteritis but may be missed since its symptoms mimic appendicitis, and it is not typically tested for in suspected foodborne disease outbreaks (Fredriksson-Ahomaa, 2007, chap. 4).

Fifteen spices obtained from markets in the Aseer region, Saudi Arabia, were examined by Hashema and Alamria (2010) for their mold profile, and 520 fungal isolates, representing 57 species, were recovered and identified. The most heavily contaminated spice samples examined were in ginger at 5325–6800 cfu mold/g with the most predominant fungi in all spices being *Aspergillus* (particularly *A. flavus* and *A. niger*), *Penicillium* (particularly *P. arenicola*), and *Rhizopus*, with several potentially mycotoxigenic fungi isolated from the majority of samples. Samples obtained from sumac encountered very rare colony counts indicating its antifungal prosperities. This study raises the potential risk for mycotoxin contamination if these spices are used in foods, especially in great quantities. The authors strongly recommend reduction in application of heavily contaminated spices like ginger in food processing and using some others like clove and sumac due to their antimicrobial properties.

Several studies on knowledge and practice of food safety have been conducted recently in KSA. They indicate some reasonable degree of knowledge and practice, but respondents do not always understand why. It seems that age and education are important factors in performing current food safety procedures, and education should be mostly directed to younger food preparers. A cross sectional study covering purchasing, storage, preparation, cooking, utensils, equipment, and personal hygiene was conducted from October 2011 till June 2012 on 811 Saudi women responsible for food preparation for 4625 family members in four KSA provinces by Farahat, El-Shafie, and Waly (2015). Both knowledge and practices aspects of food safety were determined through interviews and not through observed practices. The educational level of about 80% of the interviewed women was secondary or bachelor's degrees, but most were not working (72.4%). During the interviews it was found that their practices were better than their knowledge concerning overall food safety (i.e., they usually performed safe actions without always knowing why). Personal hygiene was the parameter where they reported higher mean knowledge and practice (63.4% and 73.8%, respectively) while the lowest mean knowledge was in utensils and equipment (49.8%) and cooking had the lowest mean practice (60.2%). The present study revealed that working women, those in the age group (60+ years) and with higher study levels reported higher mean knowledge and practice than non-working and those in other age groups and educational levels. Although, the majority of the interviewed women reported reading expiry dates and purchasing food of animal origin only displayed in refrigerators, some of them reported that they did not know: 1) that bacteria can grow faster outside the fridge, 2) that so-called food poisoning can result from consumption of "grossly unspoiled" foods, and 3) that foods of animal origin or salads should not be displayed outside refrigerators. Most of the interviewed women believed that bacteria can be destroyed in the fridge or in the freezers. Although, the majority of the interviewed Saudi women reported using separate cutting boards for raw and cooked foods or using the same boards after proper cleaning, some of them reported that they did not know that using the same improperly cleaned cutting boards, or that eating raw or "half-cooked foods", could both lead to foodborne illness. Another study by Sharif and Malki (2010) showed that over 50% of Saudi college students consumed raw eggs and raw white cheese and 34% believed that there is no risk of disease from eating cooked food kept at room temperature for one day, provided it was covered. However, most of the interviewed women reported cooking of foods in quantities sufficient for one meal, eating within 4 h after cooking, and

avoiding leaving the cooked foods outside the refrigerator for more than 4 h, but some of them failed to specify the period where cooked foods could be kept safely outside the fridge. Although most of the interviewed Saudi women reported proper washing and drying of their hands, avoiding tasting of foods by fingers, or using the same spoon several times, some of them reported that they did not know if it is safe to taste foods by fingers or by using the same spoons several times. Although most of the interviewed Saudi women reported that foods should not be handled by ill persons, some of them reported preparing foods during their illnesses. Also, most of the interviewed women reported that they did not know if apparently healthy persons (asymptomatic carriers) can contaminate foods. Limitations of the study were recognized by the authors including interviewing the women who were most easily accessible to the students, thus not representative of all Saudi women, and food safety practices were assessed through self-reporting that may overestimate the actual safe practices. It was concluded that there was a sufficient gap between food safety knowledge and practices to justify a food safety education program to be initiated and repeated at specific intervals for Saudi women.

Hayajneh (2015) developed a pretested anonymous self-administered questionnaire on foodborne disease to elicit the general knowledge, attitude about "food poisoning", and causes of "food poisoning" among 100 representatives in Taif, KSA, July to September, 2014. Over 70% of the respondents thought they have been affected by "food poisoning" at some time, and 70% thought that they should seek medical help when they have had one or more symptoms of the following: abdominal pain, diarrhea (bloody or not), vomiting, mild fever, weakness, nausea \pm 4.9 h, headaches, and males were more likely than females to visit a doctor (82% vs. 47%). The respondents thought that restaurants are the main cause of foodborne disease (36%), but 27% stated carelessness, 11% thought it was contaminated food, and only 3% considered bacteria. The educational level did not seem to be a big factor in this knowledge, e.g., those only with primary schooling (10) selected restaurants (8) or bacteria (2); and those with high school or university levels (85) had no idea (22), selected restaurants (28) or contaminated food (24), or carelessness (10), but only 1 selected bacteria. Interestingly, although 23% claimed they had no idea what was the cause of "food poisoning", many men and women had heard of *Bacillus* (31%), *Campylobacter* (16%), *Clostridium* (26%), *E. coli* O157 (22%), hepatitis (27%), *Listeria* (26%), *Salmonella* (49%), and *Staphylococcus aureus* (32%). When asked about checking the status of meals from restaurants, most either had no idea (45%), considered the smell or color (45%) or the general look of the restaurant or wanted to check the "instruments used" (5% each). Most (95%) thought that canned foods with expired dates could cause "food poisoning", but only 81% checked the expiry dates on cans in their homes. The author did not discuss these results, and some of the data derived are hard to interpret. For instance, it was a small sampling (100), mainly of men, but women in KSA typically do the shopping and food preparation (Alsayeq, 2015). To sum up, educational level did not seem to be a big factor as might be expected (compared with the study of Farahat et al. (2015) who surveyed Saudi women); most had no idea or thought restaurants were the cause of foodborne illness, yet, over 20% had heard of many foodborne disease pathogens, including *Listeria* and *E. coli* O157. The actual question asked was: Have you ever heard of (specific pathogen added here) as a problem in food? Self-administered surveys are not the most accurate and respondents may give the impression of more knowledge than they really have compared with observational studies (Redmond & Griffith, 2003). A similar slightly earlier but larger survey on attitudes to the risk of foodborne disease in Riyadh, but only addressed to women from March to July, 2013, was conducted by Alsayeq, (2015). Out of 1020

questionnaires distributed, a total of 785 were obtained; most respondents were under 34 years of age, had an undergraduate degree, and were not married. This survey indicated that the majority of participants shopped from chain supermarkets with possible risk factors increasing the chance of microbial growth in foods through keeping perishable foods at higher temperatures for longer times than desirable. Also, some participants did not check on food expiry dates or recommended storage conditions, as in the Hayajneh (2015) survey. Respondents claimed that they became sick after consuming food ordered from a restaurant in the previous year (28.2% if they had no background knowledge of foodborne disease prevention, and 48.0% if they had such knowledge). Risk factors for contracting foodborne disease included improper food-holding temperature (45.3%), inadequate cooking (35.5%), cross-contamination (32.2%), and food from unsafe sources (22.4%). There was a disconnect between prior knowledge of foodborne disease prevention and the responses of participants who claimed to have read such information, an observation previously recognized where reported food handling practices do not reflect the consumers' claim of food safety knowledge (Gettings & Kiernan, 2003). The author claims this was the first study to identify the gap in food safety knowledge among women in Riyadh (who do the majority of food shopping and meal preparation) which needs to be addressed by the concerned authorities in the country by engaging women more effectively in food safety educational campaigns (Alsayeq, 2015). Particularly, the Saudi Food and Drug Authority and the Ministry of Health need to design a food safety educational program engaging consumers, especially women, and advise them on how to prevent foodborne diseases, and establish an effective foodborne disease surveillance system providing sufficient epidemiological data sources to measure the burden of such diseases in the country.

Although it is not surprising that *Campylobacter* spp. is present in retail chicken in Saudi Arabia, a study of wholesale poultry market in the northern part of Riyadh showed that there was a gradual increase in the number of positive samples during storage at 4 °C with about half the carcasses positive (Yehia & Al-Dagal, 2014). On days 1, 3, and 7, the number of positive samples were 10 (30.3%), 15 (45.5%), and 27 (81.8%), respectively, for a total of 52.3% were positive for *Campylobacter jejuni*. The authors argued that this means long-term storage of poultry carcasses at refrigeration temperatures increases the risks for cross-contamination in the kitchen and thus exposure of preparers and consumers to *Campylobacter* infections. Research has shown that low temperatures do not support the growth of *Campylobacter* (Solow, Cloak, & Fratamico, 2003), which the authors admit, but *C. jejuni* is much less sensitive to oxidative stress at 4 °C compared with 42 °C, which is its optimal growth temperature (Garénaux et al., 2008). It is possible that the carcasses were stored at temperatures higher than 4 °C, or more likely, more dormant but viable *Campylobacter* cells were released for culture from the carcasses along with nutrient juices, as storage progressed. As these are viable, the increased risks from long-term refrigerated for carcass handler infections or cross-contamination within the kitchen stressed by the authors seem to be justified.

Apart from microbiological contamination of food, sometimes chemical contamination should not be ignored. Al-Jassir, Shaker, and Khaliq (2005) assessed the deposition of heavy metals on green leafy vegetables sold on roadsides of Riyadh, and found that unwashed leafy vegetables had higher levels of heavy metals (lead, cadmium, copper and zinc) compared with washed leafy vegetables, but that the intake would not represent a health hazard for consumers.

6.5. Government oversight

In KSA, food safety legislation that is promulgated by the state has to be consistent with the provisions of the Qur'an and Sunnah, but generally there is no conflict with safe food production. Al-Mutairi et al. (2015) has reviewed the current state of government oversight in KSA. Several governmental and non-governmental organizations are responsible for ensuring the safety of local and imported food. The governmental departments include the Ministries of Health (MOH), Commerce & Industry, Municipal and Rural Affairs (MMRA), and Agriculture, and the non-governmental organizations include Saudi Society of Food and Nutrition, Consumer Protection Association, and the National Standing Advisory Committee on Food Irradiation. With these bodies, many regulations, guidelines and administrative circulars had been issued, confusing food law enforcers and creating difficulties for effective enforcement. This has resulted in ineffective management with limited official communication, overlapping duties, and a lack of coordination mechanisms among organizations, all leading to poor engagement with citizens and food businesses. The Saudi Food and Drug Authority (SFDA) was established under the Council of Ministers resolution no (1) dated January 1, 2003, as an independent body that directly reports to the Prime Minister (El Sheikh, 2015). The SFDA is responsible to regulate, oversee, and control food, drug, medical devices, as well as set mandatory standard specifications, whether they are imported or locally manufactured. The control and/or testing activities can be conducted at the SFDA or any other agency's laboratories. Since its formation, the SFDA has been developing as a new central agency, intended to provide better coordination and assure the safety and quality of both local and imported food. Traditionally, the MOH has been responsible for regulating foodborne disease outbreaks at both the administrative and field levels, educating society about food safety issues, training those investigating foodborne disease outbreaks to recommend appropriate sanctions in accordance with Saudi law (Al-Mutairi et al., 2015). There is some overlap with the MMRA which has a more legislative and enforcement role in food safety. It has a significant role in setting food legislation (health conditions), regulating food and health inspection, commercial adulteration control, supervision of slaughterhouses, participating in reaction to foodborne disease outbreaks, conducting food and water sampling and the registration of food and health premises. Unfortunately, most government employees involved in food inspection have had limited education with most training being on the job, but it is improving today with recent graduates having knowledge in food safety and environmental protection. Rapid expansion of food inspection has resulted in the creation of women's departments for food and health inspection, starting with the opening of a women's department at the Riyadh Municipality. The Tripartite Committee on Food Poisoning Outbreaks involves members from the Ministries of Interior, Health, and Municipalities. The work of members starts during an outbreak of "food poisoning" linked to two or more patients exhibiting similar symptoms after ingestion of the same food from the same source where investigations implicate food as the source of the disease. Today, the Committee includes SFDA and seeks to achieve a coordinated approach across the various agencies, although the main reporting line is through the MOH. However, the structure of the Committee is such that there is still a lack of analysis, interpretation, and recommendations from the outbreak investigations that could be used to prevent further illnesses. This reflects the limited integration between different disciplines, such as epidemiology, food microbiology, chemistry, management and risk communication, in the investigations. Apart from its role on the Committee, the SFDA ensures that both imported and locally-produced foods

conform to national and internationally recognized standards, contributes to food safety education, notifies consumers when there is a product recall, and maintains laboratories to inspect imported food. It also approves policies and legislation related to food and drugs, and reviews regulations and rules, similar to the U. S. Food and Drug Administration (USFDA) (Al-Mutairi et al., 2015). The SFDA brings together experts and advisors from various government and educational bodies in food safety and other disciplines. Although total consolidation of food safety oversight has not yet been established through the SFDA, current progress has helped promote food safety by building public confidence, regulating organizational interactions and preventing inconsistencies between the various public agencies. The eventual goal will be to have a centralized food control system similar to those in Canada, Denmark, Germany, Ireland, the Netherlands, New Zealand, the United Kingdom, and the European Food Safety Authority (Al-Kandari & Jukes, 2012).

Local oversight agencies do the brunt of food safety oversight, and can also respond to public concerns, as illustrated by an issue of foul-tasting produce sold at a well-known grocery store in the Eastern Province. In February, 2014, consumers had complained of vegetables sold from this store had tasted of sewage. As a result, the General Administration of Agricultural Affairs in that province found that the vegetables had been harvested from crops irrigated with sewage water, and the implicated farm was stopped from selling its produce (Al-Sughair, 2014). In addition, the farm owner was fined SR50,000 (about \$13,000) and 14 greenhouses on the farm were dismantled for an estimated loss of SR300,000 (about \$80,000) to the owner. Although the shoppers had rightly demanded more intensive health control and supervision of fruits and vegetables sold in the province, the action by the General Administration was mainly punitive. A second example shows that perhaps the local authority struggled in maintaining control in its oversight of establishments. In early 2015, samples of food items and drinks taken from more than 2000 restaurants in Jeddah were found to be contaminated with 11 types of pathogenic bacteria and molds and their indicator organisms after being tested in municipal laboratories (Anonymous, 2015d). From the limited information available reported on the inspections, it appears that coliforms and intestinal bacteria were isolated including *Bacillus cereus*, *Staphylococcus* species, *Listeria monocytogenes*, and *Salmonella*. Factors contributing to the contamination were listed as molds and yeasts in expired food and poor storage. The bacteria were found in old sweets, juices, salad blends, grains and their products, pickles and nuts. These results forced the authorities to close down 2745 Jeddah restaurants in a four-month period. Some of the restaurants, however, defied the decision by opening their doors again, and several owners also tried to attack inspectors, requiring the intervention of police to help close down their businesses (Anonymous, 2015e). They also received fines for violating the municipality's ruling. Publicly denouncing offending restaurants is part of the municipality's accountability to citizens with regard to their health and safety. An official statement claimed that only when the names of the offending establishments are published, do the rulings have a real impact. Previously, business owners would simply pay the fines and continue breaking the law.

In KSA, there are still major obstacles to improving food safety, especially for implementing HACCP at the SME (small and medium enterprises) level (Al-Mutairi et al., 2015). These include: 1) commercial adulteration/food fraud and the risks of foodborne illnesses, reflecting traditional networks of patronage, self-interest and social obligation within Saudi society; 2) the food sector being heavily dependent on undocumented migrant (typically illegal) workers who are not easily accessible to

enforcement efforts; 3) inadequate material resources for safe production of food; 4) poor technical knowledge among food manufacturers, retailers and food control personnel; 5) high summer temperatures impacting the transportation, distribution and storing of food as well as the execution of duties by law enforcement officials.

7. United Arab Emirates

7.1. Overview

In 1972, out of the Trucial States a federation of seven emirates, Abu Dhabi, Dubai, Sharjah (Sharjah), Ras Al Khaymah, Fujayrah, Umm Al Qaywayn, and Ajman became the United Arab Emirates (UAE) extending for some 1200 km (746 mi.) along the southern coast of the Persian Gulf and another 250 km (155 mi.) on the Gulf of Oman (Anthony & Hearty, 1980, chap. 7). The emirates are run from six principal tribal groups, and by far the largest emirate is Abu Dhabi with Abu Dhabi City the capital of both the emirate and the whole country (Aquastat-UAE, 2009). Dubai, because of its long-standing position as the major trading center of the lower Gulf, and the commitment of its ruler to developing the maritime sector of its economy, has by far the largest port facilities in the region. The UAE's constitution provides for federal legislative, executive, and judicial bodies. The legislature, called the Federal National Council (FNC), is more of a consultative assembly in keeping with the norms of traditional tribal and Islamic rule in this part of Arabia (Anthony & Hearty, 1980, chap. 7). The seven-member FNC is charged with formulating and supervising all federal policies, ratifying UAE laws, approving the union's annual budget, ratifying international treaties, and approving the prime minister, the president and the members of the supreme court. In procedural matters, a simple majority vote is sufficient for passage of any resolution. However, in substantive concerns, Abu Dhabi and Dubai have a veto power.

The total area of the UAE is about 83,600 km², which can be divided into three ecological areas: the northeastern mountain areas, sandy/desert areas, and marine coastal areas; 80% of UAE is desert, especially the western area. The coastal area, where the bulk of the population lives, has a hot and humid climate in the summer with temperatures and relative humidity reaching 46 °C and 100%, respectively. Winters are generally mild with temperatures 14–23 °C. The interior desert region has hot summers with temperatures rising to about 50 °C and cool winters during which the lowest temperature can fall to around 4 °C. The country is arid with annual rainfall from <40 mm in the southern desert to 160 mm in the northeastern mountains. The population was almost 4.5 million in 2005, of which 14.5% was rural. By 2015 the population had doubled to 9.5 million of which the majority were foreign workers from many countries but mostly the Indian subcontinent; the UAE native citizens were only 11.3% of the population with 1.1 million (Snoj, 2015a,b). Abu Dhabi has the largest population numerically, but it also has the lowest population density among the emirates. Dubai, which has the highest population density, is considered the business capital and the most important port in the country. Over two-thirds of the total population is concentrated in these two emirates. UAE residents come from different Arabian groups, some of which had a traditional nomadic lifestyle, breeding camels and goats. Most of the nomad group settled in the Liwa Oasis to work in simple agriculture and palm plantations (Aquastat-UAE, 2009). In the coastal area, groups used to work in fishing and pearl hunting. In the Al Ain Oasis, other groups work in agriculture, especially in date plantations using underground water and aflaj irrigation (shared community resource from channeled underground sources or springs to support agriculture and domestic use). In the northern

emirates where there is more rainfall, people can work in agriculture all year-round. In the Hajar Mountains of Al Fujayrah, terrace farming is practiced, while in Dubai, Sharjah and Ras Al Khaymah people trade with boats and modern ships. For water use, aquifers are tapped, but some are saline, and to increase the groundwater recharge, a number of dams have been built at various locations in the country, both for recharging purposes and for protection against flash flood damage. Desalination plants provide most of the municipal supply, and wastewater is treated for reuse to irrigate vegetables and fruit trees. The amount of sewage water increases according to the size of the town and its population and the UAE pioneered in this field in the Gulf Area with sewage water subjected to tertiary treatment and then used in landscaping in and around the cities and towns.

Water used for agriculture is free of charge while water for municipal use, which is mostly desalinated water, is subsidized by the state. Prior to the introduction of modern irrigation systems (sprinkler and localized irrigation), all agricultural land was irrigated by traditional flood and furrow methods but that has changed today with savings of water use up to 60%. Most farms are privately owned and they are typically 2–3 ha in size and each has two drilled wells at opposite corners of the plot. Through subsidies, agricultural expansion up to about 3000 new farms each year is promoted, although expansion is currently restricted due to exhaustion of groundwater supplies. All crops in the UAE are irrigated, consisting mostly of palm trees, green fodder and vegetables (mainly tomatoes and onions). Unfortunately, groundwater levels have declined rapidly because of increased irrigation use and less precipitation today to replenish the supplies, and in many aquifers there are increased salinity levels. Desalination plants will increase but energy costs are high, and particularly affects Dubai which has no oil resources compared with Abu Dhabi. Most food is imported, and the economy is much driven by foreign commerce and is sensitive to financial downturns, as in 2009.

7.2. Gastrointestinal diseases

Typhoid fever is believed to be transient in UAE because many expatriates who work there come from developing countries where the disease is endemic, and regularly go back to visit family or renew their work visas, sometimes bringing *Salmonella* Typhi back with them. This was confirmed in a study by Al Abro et al. (2011) who examined blood cultures of 118 typhoid patients from April 2007–May 2009 at Rashid Hospital, Dubai. They showed symptoms and signs mainly of fever, vomiting, diarrhea, abdominal pain, relative bradycardia, and splenomegaly. Of these, 118 patients, 86.4% were males and 13.5% females, and most of the patients were expatriates from developing countries (94.9%); 79.6% had a history of travel within a month to endemic areas. The sensitivity pattern showed that the resistance rate was highest for nalidixic acid (71.5%), followed by chloramphenicol (37.5%), ampicillin (34.8%), co-trimazole (30.7%), augmentin (14%) and ciprofloxacin (6%). The authors found that a significant percentage of *S. Typhi* strains were resistant to the primary drugs, but the quinolones and third generation cephalosporins were considered potentially more effective drugs against *S. Typhi*. However, they considered that the increasing resistance to the quinolones was a matter for concern. There is always a similar risk for cholera to be brought into Gulf states. Following a case of an Omani woman who was diagnosed with cholera after a recent visit to Iraq in November 2015, UAE health officials confirmed that the nation is cholera-free (Staff, 2015b). Cholera has spread in some countries, such as Iraq and Tanzania, but no cases in the UAE have been reported, and the spread of the disease is negligible in the countries with good public health infrastructure like UAE and other Gulf states.

Campylobacteriosis seems to one of the more common enteric diseases in the world in both developing and developed countries, including the Middle East. Senok and Botta (2009) reviewed *Campylobacter* enteritis in the Arabian Gulf states and indicated that recent data for the Arabian Gulf region has enhanced our understanding of the epidemiology of *Campylobacter* both in humans and poultry in the region, and also contributed to the overall understanding of the mechanism of campylobacteriosis, antibiotic resistance, and improved diagnostic approaches. In a more specific study, Sonnevend et al. (2006) investigated the antibiotic sensitivity and the serotype and molecular type (MT) distribution of 41 *Campylobacter jejuni* strains isolated from diarrheal patients in a hospital in Al Ain, one of the UAE emirates. While all strains were sensitive to erythromycin, 35 isolates (85.4%) exhibited resistance to ciprofloxacin. These results show that the local incidence of fluoroquinolone resistance among *C. jejuni* was one of the highest reported worldwide. It was also demonstrated that stable MTs could persist for a relatively long time among the clonally unrelated antibiotic-resistant isolates of *C. jejuni*. The data also emphasize the need to replace fluoroquinolones as empirical therapy for diarrhea of undiagnosed etiology.

Sewage water is important to be recycled in an arid country for use in landscaping. There are recent concerns about treated sewage water used to irrigate grass, flowers and trees in parks, however. In samples taken from 30 parks in Sharjah and Dubai municipalities, >80% in one test were found to contain *E. coli*, while 60% of samples failed UAE and international standards for coliforms in 60% of the reclaimed wastewater samples which exceeded 1000 cfu/100 ml for unrestricted irrigation (Al Amimi, Khan, & Dghaim, 2014; Sean, 2014). Overall, the study showed that 97% of the samples contained unidentified bacteria, while 63% contained *Shigella*, 30% had *E. coli* and 10% had *Salmonella*. Using a different sampling method, 83% of the water samples contained *E. coli* and 76% had unknown bacteria, while the other bacterial contaminants were also found in lower numbers. Although the overall risk to persons in the parks or runoff to neighboring communities was not measured, such sewage-treated water should be free of fecal contaminants. Other concerns such as *Legionella* and environmentally-resistant enteric viruses were not determined.

The main communicable disease concern today in KSA and other Gulf states are the infections and deaths arising from exposure to the Middle Respiratory Syndrome East Corona virus (MERS-CoV), which has reservoirs in camels and bats (Todd & Greig, 2015). A food source such as unpasteurized camel milk has yet to be eliminated as camel farmers drink the milk as well as being exposed through other aspects of camel contact. However, camel milk is being promoted as an export product (see under Research).

7.3. Foodborne disease outbreaks

In June, 2009, two children and their mother were brought to a hospital in Dubai with suspected “food poisoning” (vomiting) after they ate take-away food (the father was out of town). Although the mother eventually recovered, the two young children (5 and 7 years old) died, one on arrival and the other the next day. The cause was not determined (Saberi & Scott, 2009). It is not known if the family or restaurant was primarily responsible for the deadly gastrointestinal attack as bacteria can multiply quickly in the hot summer months, and the public had been recently warned to minimize eating out at this time of year, especially at smaller eateries where hygiene levels are often of lower standard. A toxin was likely involved to cause fatalities so rapidly, but it could have been an accidental contamination of the food with a chemical such as a pesticide (see below), as much as it could have been with an enterotoxin produced by *Staphylococcus aureus* or *Bacillus cereus*

through careless ambient temperature food storage. Unfortunately, this was one episode in a string of them in the county, most of them with fatalities. In April, 2007, a three-year-old died of suspected “food poisoning” in Sharjah, and in August, a 10-year-old girl died of “food poisoning” in Abu Dhabi. In March, 2008, six people fell ill after eating buffet food at a restaurant in the large Ibn Battuta Mall, Dubai; in November of the same year, 14 employees at a cement factory were hospitalized after consuming what was considered rotten food prepared at the factory kitchen in another Emirate, Ras Al Khaimah. In May, 2009, a four-year-old girl died of suspected “food poisoning” in Sharjah. The Indian family of four rushed to the hospital after series of vomiting but were too late to save the girl. Apparently, pesticide use is rampant for households to use on pests like bedbugs, and severe illnesses and deaths through improper use has resulted in misdiagnosis of pesticide poisoning as food poisoning in some recent cases in the UAE that has prompted the Dubai Municipality to release public statements on the risks of pesticide poisoning (Staff, 2013). Normally the last meal that was eaten is the suspected vehicle of a foodborne agent following a complaint of illness, especially as vomiting is a typical symptom involving fumigant exposure. It is hard to prove such chemicals are the cause of illnesses or deaths because by the time inspectors arrive at a residence, any trace of it has been flushed away. However, in rare situations fumigants can be determined to be the cause. For instance, the Municipality determined that pesticide poisoning was the cause of illness among a group of men in March 2012 when 20 cans of aluminum phosphide were found in the apartment of their neighbors. These neighbors had vacated their apartment for a day after having used the chemical that was illegally procured. In July 2013, a 11-year old girl died and her brother and the mother only just survived from pesticide poisoning in Sharjah. The 11-year-old girl was the latest victim in a spate of pesticide poisoning deaths that have plagued the country in the recent summers. Fatalities occur when neighbors are unaware of such fumigation and they stay in the toxin-filled rooms. Such exposures cause severe vomiting, chest burns, severe abdominal cramps, possibly leading to death, especially among children who cannot tolerate even small levels of such fumigants. Eight pesticide companies were shut down in 2013 by the Municipality after they were found to be using pesticides banned for domestic use. An unusual follow-up to pesticide poisoning occurred when six members of a Sharjah family were admitted to a hospital in February 2016 with symptoms of “food poisoning” with abdominal pain and vomiting (Al Ramahi, 2016a). Whereas the parents were quickly released, the children were in an unstable condition for some time. The father suspected that their maid had deliberately put pesticide into their food, but this was unconfirmed. Although this statement may seem farfetched, there are sometimes conflicts between maids and their hiring families in the Middle East. On March 31, 2016, an Indonesian maid jailed for pouring drain cleaner on a young boy’s face (which she denied) and leaving him scarred for life, had her sentence increased from 3 to 15 years (Al Ramahi, 2016b). The 25-year-old domestic worker was also ordered to pay Dhs270,000 (\$73,000) in compensation and would be deported on her eventual release. The housemaid had worked for the Sharjah family for almost four years and was due to leave in February, when the incident took place.

In recent years, surveillance has improved with at least some etiologies were being determined. In Abu Dhabi, the Abu Dhabi Food Control Authority (ADFCA) reported there were 561 “food-poisoning” cases in 2010, 667 in 2011 and 627 cases in the first six months of 2012 (compared with 420 in the same period in 2011 and 288 in 2010), meaning that the six-month figure was almost the total for 2011 (Malek, 2012). Rotavirus, which causes severe diarrhea, fever and vomiting among children, accounted for more than

half the cases, a total of 330. There were 66 cases of *Salmonella*. It was claimed that many of the *Salmonella* (typhoid and non-typhoid) cases originated abroad since many in the UAE go on vacation to less-developed countries in the early summer when the peak of these cases was recorded. It was argued that the water supply there is not safe, and vegetables irrigated with such water can be contaminated. Although the UAE health authorities are unable to prevent illnesses in travelers abroad, monitoring of hygiene in labor-camp kitchens patronized by many expatriates from endemic countries is carried out in the UAE. Lack of good hygienic practices has been identified in these camps with the ADFCA working on improving the quality of food there. In 2014, children were started to be inoculated against rotavirus, and also an on-line reporting system was being developed to help identify foodborne disease outbreaks more quickly. The Municipality stated that the reasons for investigating foodborne disease outbreaks were mainly to identify the source of the outbreak to take interventions or corrective actions, to learn more about the public health implications of foodborne pathogens, and to develop better food control and other prevention strategies. As can be seen from this report, less than half were confirmed as foodborne and of these factors contributing to outbreaks are not mentioned. One reason was that most of these cases of foodborne illnesses were sporadic which means they are difficult to investigate and trace to source. It is interesting that the more common foodborne pathogens are not listed as etiological agents, such as *Salmonella*, *Clostridium perfringens*, *Staphylococcus aureus* and *Bacillus cereus*.

To improve prevention and control strategies in Dubai, a foodborne disease investigation and surveillance system was established as a joint venture of the Municipality and the Dubai Health Authority under the guidance of the World Health Organization and the US Centers for Disease Control and Prevention.

In 2011, The Municipality released data showing there were 1663 enteric disease cases in the first 9 months, but less than half of these were confirmed as foodborne (Anonymous, 2014a; Saseendran, 2014). In 2013, the number had decreased slightly with 1123 suspected cases of enteric illnesses, including “food poisoning”, of which 518 were confirmed; there were 214 cases of amebic dysentery, 137 of typhoid/paratyphoid, 43 of hepatitis A, 20 of giardiasis, 10 of shigellosis, 5 of dysentery, 3 of campylobacteriosis, and 1 each of *E. coli* and other *Campylobacter* enteritis. It was speculated that these diseases, particularly amebiasis, mainly occurred in people with a history of travel to endemic areas. The report indicated that there were five known foodborne disease outbreaks but no deaths. Salmonellosis was confirmed in 84 cases linked mainly to consumption of contaminated egg and meat products. Although the reasons for investigating foodborne disease outbreaks were mainly to identify the source of the outbreak to take interventions or corrective actions, there is no indication stated for specific food links to these pathogens apart from *Salmonella*. Many of the pathogens recorded in 2013 could have had non-food sources, such as water or person-to-person transmission.

Expatriate laborers may not only be a source of enteric pathogens like *S. Typhi*, but they may also be at the greatest risk of foodborne illness from food eaten within the UAE. The Al Jaber Group, one of the country’s largest construction conglomerates, serves 150,000 meals a day all over the UAE. However, in March, 2011, it was charged with food safety violations after more than 200 laborers fell ill with suspected “food poisoning”, and 40 of them were hospitalized (Davids, 2011). They had consumed rice from an on-site catering unit described by the Abu Dhabi Food Control Authority as “functioning in utterly squalid conditions, violating all norms of hygiene and disregarding the health consequences for the labourers.” Inspectors found cockroach-infested drinking water, the mixing of raw meat, fish and vegetables and cooked food housed

next to open dustbins. The catering unit, which was unlicensed, was supplying food to around 2200 workers. In a similar situation more than 100 workers in Abu Dhabi suffered from apparent foodborne disease in May, 2014, after being served “bad” food at their accommodation camp in Mussafah in the UAE’s capital (Staff, 2014). The victims from different Asian countries complained of stomach pains, loose stools, headaches and exhaustion and were admitted at the emergency department; some remained at the hospital for further treatment. There was no official statement from the company where the victims worked, and the health authorities in Abu Dhabi investigating the incident did not reveal the causative agent, but stated that severity could have been worse if the victims had not been immediately rushed to the hospital. More than 250 reported cases of foodborne disease in Abu Dhabi camps in 2011 were attributed to “wrong raw material, wrong raw handling and wrong transportation”. One of the reasons given for an unacceptable number of “food-poisoning” cases in the UAE is that there is insufficient care when transporting food under hot ambient temperatures to keep it cool enough to prevent bacterial growth (Lyon, 2012). Hot catered meals at 60 °C can fall to 30–40 °C after these are collected from distribution centers and driven around for a few hours, unless they are sealed in temperature-controlled boxes; this problem is most apparent in catering for labor camps. There is much food wastage and spoilage from production to delivery through many current practices.

7.4. Research

As indicated above, there is little information available about incidences and causes of foodborne illnesses in the UAE that can help the emirate governments develop policies to prevent them in the future. Afifi and Abushelaibi (2012) studied a group of multinational subjects (males and females), residing in Al Ain, UAE, and of an age ranging between 15 and 55 years. A questionnaire designed to assess “Knowledge” and “Practice” of public hygiene measures was piloted in a group of subjects from the public. Data shows that 100% of highly educated subjects with postgraduate degrees (Master and PhD) have the proper information about food safety. However, only 70% of them always washed their hands before and after eating, while 80% always washed their hands after using the toilet, frequently using warm water and soap. About 29% of the participants claimed to have suffered from foodborne illness, and 85% read articles about food safety and personal hygiene. A point to note is that most of the study subjects were Muslims, and their hygienic attitude may depend on their degree of religious practice they have to wash before praying. In addition, self-reported behaviors may overestimate actual safe hygienic practices. The authors state that awareness programs or training is needed, even for the highly educated members of the public.

Following dairy cattle, water buffalo, goats and sheep, camels are the fifth most important dairy animals in the world. Dubai is starting to market camel milk, called Camelicious, from 3600 camels (and increasing these to 10,000 animals in the future) from a large-scale camel dairy farm (Anonymous, 2010; EICMP, 2016). Camel milk has at least three times more vitamin C than bovine milk, and is considered an alternative for lactose-intolerant milk consumers. The UAE ensures that camels imported from other Gulf states are free from brucellosis and the Middle East respiratory syndrome coronavirus (MERS-CoV) before they can be allowed in the herd. Although camel milk is kosher and prohibited under Jewish law, the United Kingdom has started to import this product to ethnic and halal shops (Al Serkal, 2014), and it is now approved for the EU. Although it is still strictly illegal to import or sell camel milk in the United States, the National Conference on Interstate Milk Shipment (NCIMS), which is responsible for the

implementation of milk quality regulations (Grade “A” Pasteurized Milk Ordinance) set by the FDA, is considering a request from the UAE. Thus, camel milk and products made from this milk may have widespread global availability in time. Whereas camel milk is inhibitory toward both Gram-negative (*Salmonella* Typhimurium, *Escherichia coli*) and Gram-positive (*Staphylococcus aureus*, *Listeria monocytogenes*) because of its ability to inhibit these pathogens through the presence of high concentrations of antimicrobial compounds such as immunoglobulins, lactoferrin, and lysozyme, Al-Nabulsi et al. (2016), cautions complete inhibition of pathogens in camel milk products. Camel milk inoculated with 3 log₁₀ *L. monocytogenes* and *E. coli* O157:H7 cfu/mL was fermented at 43 °C for 5 h using freeze-dried lactic acid bacteria (LAB) starter cultures (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) and stored at 4 or 10 °C for 14 days. Camel milk inoculated with these pathogens without starter culture was also prepared. During fermentation, the numbers of *L. monocytogenes* and *E. coli* O157:H7 increased 0.3 and 1.6 log cfu/mL, respectively, in the presence of LAB, and by 0.3 and 2.7 log cfu/mL in the absence of LAB. During storage at 4 or 10 °C, *L. monocytogenes* increased 0.8–1.2 log cfu/mL, respectively, by 14 days in camel milk without LAB, but in the presence of LAB, the numbers of *L. monocytogenes* were reduced by 1.2–1.7 log cfu/mL by 14 d. Further, *E. coli* O157:H7 numbers in camel milk were reduced by 3.4–3.5 log cfu/mL in the absence of LAB, but *E. coli* O157:H7 was not detected (6.3 log cfu/mL reduction) by 7d in camel yogurt made with LAB and stored at either temperature. Although camel milk contains high concentrations of natural antimicrobials, *L. monocytogenes* was able to tolerate these compounds in camel yogurt stored at refrigerator temperatures unlike the *E. coli*. Therefore, appropriate care should be taken during production of yogurt from camel milk to minimize the potential for post-process contamination by this and other foodborne pathogens.

Since the UAE imports roughly 90% of its food at a cost predicted to increase 300% in the next decade, the country has been exploring ways to offset imports (Staff, 2016). To this end, the world’s first research facility to grow both food and fuel, using desert lands irrigated by seawater, started operations on a 2-ha site in Masdar City in Abu Dhabi. The research facility uses coastal seawater to raise fish and shrimp for food, whose nutrient-rich wastewater then fertilizes plants rich in oils that can be harvested for aviation biofuel production. Salt-tolerant halophyte plants thriving in arid, desert conditions and not requiring fresh water or arable land to grow will be explored for potential exploitation. In the last step of the system, wastewater is diverted into a cultivated mangrove forest, further removing nutrients and providing valuable carbon storage, before the naturally filtered and treated effluent is discharged back into the sea. In the same way as the pilot Sahara Forest Project in Qatar (Clery, 2013), if the technology proves viable in a small-scale operation, further expansion is planned to scale up to a 200-ha site. The goal of the research facility is to demonstrate the viability of an integrated bioenergy production system with respect to essential food and fuel production, suitable land use, reduced carbon emissions and wastewater clean-up.

7.5. Government oversight

Similar to other Gulf states, agriculture does not play a big role in the economy of the UAE in which the vast majority of food is imported. In 2003, the agricultural labor force was 5% which contributed 3.3% to the GDP of the nation (Technical Cooperation Department, 2003). The Abu Dhabi Food Control Authority (ADFCA) is the responsible body in the UAE to protect the health of animals and plants and deliver safe food (in collaboration with other Emirate and Federal agencies where appropriate) (FAOLEX,

2015). The authority's emirate food safety training (EFST) program, started in 2008, provides basic training in food hygiene and safety in four languages to those who work in food outlets and covers basic food hygiene issues, and in 2011, the ADFCA began checking all food handlers for safe practices. (Olarate, 2011). Those who have learning difficulty or are illiterate are given assistance through illustrations, in order to understand food safety issues and pass the examination. One of the critical elements of food safety that the ADFCA has to monitor and ensure is that food handlers need to keep food out of the Danger Zone (4 °C–60 °C). The ADFCA categorizes the food premises and carries out inspections based on their risk factors — high, medium and low. Restaurants and hypermarkets belong to the high-risk group; warehouses to the medium risk; while groceries, honey shops and vegetable and fruit outlets are considered low risk (Pennington, 2014). All independently owned restaurants, cafeterias, cafes and take-aways that can seat up to 50 patrons, employ about 10 workers and serve more than 100 meals daily are expected to take part in the Salamat Zadna, or Our Safe Food initiative, currently voluntary but eventually expected to be mandatory. The businesses will each be given a Guide to Safe Food Handling package that includes 10 picture cards depicting safe procedures for chilled storage, protective clothing, hand washing, personal hygiene, handling ready-to-eat food, washing fruit and vegetables, cleaning high risk surfaces, and cooking. Managers will also be handed food-safety diaries, which they will use to assess whether their employees are following the ten procedures every day. The response was initially positive.

The Government plans to increase its involvement in the trade and commerce in food and to ensure controls operate across the food chain within the country (FAOLEX, 2015). Its main target is the safety of the consumer, with information to give informed choice, and work with food business operators who are responsible for food safety. The ADFCA's Integrated Risk Management Framework, based on risk analysis, is an essential tool to provide a consistent approach for making decisions on any government intervention and action in response to animal, plant and human health related issues. Necessary tools to achieve this approach are: GOPs (good operating practices); credibility and capability; transparency through deploying an efficient consultation and communication approach with consumers and stakeholders; alignment with international standards; harmonization across the UAE; traceability and proper labeling of food products.

Also within UAE, the Sharjah Municipality initiated the Sharjah Food Safety Programme (SFSP) in 2011 with 5063 managers and 3437 staff of the food service businesses operating in Sharjah being trained to adopt the Hazard Analysis and Critical Control Points (HACCP) system in which every step in the manufacture, storage, and distribution of a food product is scientifically analyzed for microbiological physical and chemical hazards (MENAFN.com, 2016). In the second phase of the SFSP launched in March 2016 the Municipality has made it compulsory to implement good hygienic practices (GHP) at all food establishments operating in Sharjah, as a prerequisite for HACCP which is being implemented in all food establishments in Sharjah. The Municipality also provides food safety information on the municipality's website to help the food service businesses join the SFSP. Specific details on the SFSP and its links to TSI are available at (TSI, 2016). Somewhat behind Abu Dhabi, Dubai and Sharjah in timing, Ajman emirate initiated its food safety program for businesses in 2014 using a similar approach of training for HACCP (Malek, 2014). All the lessons learnt from other emirates would feed into Ajman's plan which integrates training, examinations, food safety management systems and certification, all linked with municipality inspections, with input from TSI. Most training would be based on visual material. Ajman is also working with the Ministry of Environment and Water and the Food

and Agriculture Organization on a seven-year project called Promoting Food Safety in the UAE and Yemen.

8. Conclusion

In this review of food safety issues in the Gulf states, several commonalities are observed. Because of oil revenues, these are the richest states in the Middle East and much of the world. They all have by definition a sea coast (Persian Gulf) and they have arid climates, much of it desert unsuitable for traditional agriculture. However, through tapping of aquifer resources and building desalination facilities, it has been possible to irrigate certain crops and provide sufficient potable water for populous urban communities, but these aquifers are fast diminishing and have been encroached by salt water. Also, desalination plants are expensive to use depending on their finite oil or gas resources. Wisely, Gulf state governments recognize these issues and they are seeking ways to be less reliant on them. Waste water is increasingly being recycled for landscaping and some crops. Ongoing research points to better ways of minimizing water use through projects like the Sahara Forest project, but these have yet to be exploited on a large scale. Another commonality is the vast expatriate work force, much of which is employed in the food industry. Except for multinational businesses which have international standards, little food is produced in the Gulf states and these workers are mostly employed in food service such in SMEs, restaurants and hotels. Food safety government departments and agencies are aware of risks of poorly educated and illiterate food handlers from other countries, and civil servants along with external consultants have developed programs to help train them to avoid transmitting enteric diseases to patrons. This has stimulated more effort to centralize and modernize ministries of health and other departments with responsibilities for food safety to improve the countries' prevention and control strategies. However, attitudes of government oversight authorities and their inspectors to those facilities and employees that are deemed to have infractions to internal standards can be quite punitive compared with those in the West. Large fines, jail terms and deportations are not unusual in some states. The Arab cultural background to food safety may be a factor in such attitudes to comply with societal norms and behaviors, such as how and when to wash hands and ways of preparing food. Community knowledge on what is safe would be handed down through families and credible institutions. Today, our mobile society has lost much of this hands-on knowledge and practice and is replaced by our peers and the Internet. Thus, although science may be the main driver in food safety in Gulf states, culture still plays an important role in those producing, serving and inspecting food. A successful policy for safe food throughout the food chain depends on impartiality, integrity, and diligence, conditions that have tended to be taken for granted in studies of regulatory systems in developed countries as they are assumed to be the necessary preconditions for successful food safety. However, Al-Mutairi et al. (2015) argue that departures from these ideals do occur in Saudi Arabia and is assumed for other Gulf states, and oversight is often treated rather simplistically as evidence of corruption or personal weakness, requiring punitive solutions. They state that these factors should be better understood as a predictable outcome of the tensions between being a good member of a community, who exchanges favors and looks after relatives, and being a modern street-level bureaucrat, administering either rules or discretion in an impartial manner. The future challenges for Gulf states food safety regulation seem likely to be cultural rather than organizational, which will require additional strategies than in developed countries.

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