UNIVERSITI PUTRA MALAYSIA

PREVALENCE AND ANTIBIOGRAM OF Staphylococcus aureus ISOLATED FROM A RESEARCH LABORATORY, ITS TRANSMISSION AND CROSS CONTAMINATION TO FRUITS AND KITCHEN UTENSILS

VITALIS RONALD EDEN

FSTM 2018 33

PREVALENCE AND ANTIBIOGRAM OF *Staphylococcus aureus* ISOLATED FROM A RESEARCH LABORATORY, ITS TRANSMISSION AND CROSS CONTAMINATION TO FRUITS AND KITCHEN UTENSILS

By

VITALIS RONALD EDEN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

June 2018

DEDICATION

Dedicated to my beloved parents, family members, and friends for their endless love and support

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

PREVALENCE AND ANTIBIOGRAM OF *Staphylococcus aureus* ISOLATED FROM A RESEARCH LABORATORY, ITS TRANSMISSION AND CROSS CONTAMINATION TO FRUITS AND KITCHEN UTENSILS

By

VITALIS RONALD EDEN

June 2018

Chairman : Professor Son Radu, PhD
Faculty : Food Science and Technology

Staphylococcus aureus is an important foodborne pathogen found on the skin and in the nose of a healthy person as normal flora. *S. aureus* can be acquired and transmitted from contaminated hands to fruits and kitchen utensils. The objectives of this research were to determine the prevalence and antibiogram of *S. aureus* in microbiology research laboratory, transmission and its cross contamination to fruits and kitchen utensils. A total of 320 isolates from nose=80; hands=80; door knobs=80 and table surface=80 were taken from microbiology research laboratory in Petaling Jaya, Selangor were examined for the presence of *S. aureus* using Most Probable Number method. The strain of *S. aureus* obtained were used in simulation test using cutting board=15; knife=15; fork=15; table cloth=15; and watermelon=15. The prevalence of *S. aureus* estimated in microbiology research laboratory was 81.56% whereby 75% before work and 88.12% after work ranged from 3.6 MPN/mL to 140 MPN/mL. In simulation test, it was identified that *S. aureus* can be transmitted via contaminated hands to fruits and kitchen utensils during food preparation whereby about 65.3% of *S. aureus* obtained from 75 isolates and watermelon recorded the highest load of *S. aureus* about 86.6%. Meanwhile in antibiogram test, *S. aureus* were found resistant to oxacillin (85.4%) and gentamicin (74.3%). The Actor Network Theory applied in this study identified that the strains of *S. aureus* obtained in microbiology research laboratory were able to contaminate the fruits and kitchen utensils during food preparation. Furthermore, Risk Ranger estimated that the risk of acquiring *S. aureus* were moderate with 4 illnesses predicted per annum scoring about 83/100. Hence, contemporary healthcare strategies must be taken immediately to prevent the transmission of *S. aureus* in microbiology research laboratory and its cross contamination to fruits and kitchen utensils

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PREVALEN DAN KECENDERUNGAN ANTIBIOTIK *Staphylococcus aureus* DALAM MAKMAL, PENYEBARAN DAN PENCEMARAN SILANG KEPADA BUAH-BUAHAN DAN PERALATAN DAPUR

By

VITALIS RONALD EDEN

Jun 2018

Pengerusi : Profesor Son Radu, PhD
Fakulti : Sains dan Teknologi Makanan

Staphylococcus aureus adalah sejenis patogen yang terdapat pada kulit dan hidung manusia yang sihat seperti flora biasa. *S. aureus* boleh diperoleh dan disebarkan dari tangan yang tercemar ke buah-buahan dan peralatan dapur. Objektif kajian ini adalah untuk menentukan kelaziman dan antibiogram *S. aureus* dalam makmal penyelidikan mikrobiologi, penghantaran dan pencemaran silang kepada buah-buahan dan perkakas dapur. Sejumlah 320 isolat dari hidung=80; tangan=80; tombol pintu=80 dan permukaan meja=80 diambil dari makmal penyelidikan mikrobiologi di Petaling Jaya, Selangor diperiksa untuk mengetahui kehadiran *S. aureus* menggunakan kaedah Most Probable Number. Ketegangan *S. aureus* yang diperolehi digunakan dalam ujian simulasi menggunakan papan pemotong=15; pisau=15; garfu=15; kain meja=15; dan tembikai=15. Lazimnya, *S. aureus* yang dianggarkan dalam makmal penyelidikan mikrobiologi adalah 81.56% di mana 75% diperoleh sebelum berkerja dan 88.12% selepas berkerja adalah dari 3.6 MPN/mL hingga 140 MPN/mL. Dalam ujian simulasi, *S. aureus* boleh dihantar melalui tangan yang tercemar ke buah-buahan dan perkakas dapur semasa penyediaan makanan di mana kira-kira 65.3% *S. aureus* yang diperoleh dari 75 isolat manakala buah tembikai mencatatkan beban tertinggi mengandungi *S. aureus* kira-kira 86.6%. Sementara itu dalam ujian antibiogram, *S. aureus* didapati tahan terhadap oxacillin (85.4%) dan gentamicin (74.3%). Actor Network Theory yang digunakan dalam kajian ini mengenal pasti bahawa ketegangan *S. aureus* yang diperolehi dalam makmal penyelidikan mikrobiologi dapat mencemari buah-buahan dan perkakas dapur semasa penyediaan makanan. Tambahan pula, Risk Ranger menganggarkan bahawa risiko memperoleh *S. aureus* adalah sederhana dengan 4 penyakit yang diramalkan setiap tahun yang mencatat skor kira-kira 83/100. Oleh itu, strategi penjagaan kesihatan kontemporari perlu diambil dengan serta-merta untuk

mencegah pencemaran *S. aureus* dalam makmal penyelidikan mikrobiologi dan pencemaran silang ke buah-buahan dan perkakas dapur.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank God for the spirit and strength given to me throughout my study. Though I had encountered numerous challenges and difficulties, You never leave me out of your sight. Without Your blessing, I would not be able to go this far. I would also like to extend my heartiest thanks and gratitude to my main supervisor, Prof. Dr. Son Radu for his guidance and encouragement throughout my study. My warmest gratitude also goes to my co-supervisors, Dr. Nor Khaizura Mahmud@Ab Rashid for her extremely valuable advice, assistance, and support. Moreover, I would like to take this opportunity to thank all my laboratory members including Vivian and Ubong for their kind support and for sharing their priceless experiences and knowledge. I would also like to thank to Chang Wei San for helping me in many ways in completion of my study. Most importantly, a special thank goes to my family in Sabah for their sacrifices in terms of time, financial support, endless love and encouragement which had brought me one step closer to my goals in life. Thank you for trusting me and made me who I am today. I would also like to present a token of appreciation to the chairman of examination committee Assoc. Prof. Dr. Yaya Rukayadi, internal examiner Assoc. Prof. Dr. Anis Shobirin binti Meor Hussin, external examiner Y. Bhg. Prof. Dr. Clemente Micheal Wong Vui Ling, all staff in Food Science Department, technical staff of School of Graduate Studies and my fellow friends who had helped me during my study.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Son Radu, PhD
Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

Nor Khaizura Mahmud @ Ab Rashid, PhD
Senior Lecturer
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: _____

Name of Chairman of Supervisory Committee: Professor Dr. Son Radu

Signature: _____

Name of Member of Supervisory Committee: Dr. Nor Khaizura Mahmud @ Ab Rashid

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANT	Actor Network Theory
AST	Antimicrobial susceptibility testing
ATCC	American Type Culture Collection
BAM	Bacteriological Analytical Manual
BHI	Brain-heart Infusion Broth
CDC	Centre for Disease Control and Prevention
CFSAN	Centre for Food Safety and Applied Nutrition
CFU	Colony forming unit
CLSI	Clinical and Laboratory Standard Institute
DNA	Deoxyribonucleic acid
EDTA	Ethylenediaminetetraacetic acid
EPS	Extracellular Polymeric Substance
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
FRAT	Falls Risk Assessment Tool
FSIS	Food Safety and Inspection Service
H_2O_2	Hydrogen Peroxide
h	hour
HACCP	Hazard Analysis Critical Control Points
MAR	Multiple antibiotic resistance
MH	Mueller Hinton
min	minute
MPN	Most probable number
MRSA	Methicillin-resistant *Staphylococcus aureus*
MSA	Mannitol Salt Agar
NCCLS	National Committee for Clinical Laboratory Standards
NCRA	National Committee on Risk Analysis
PBP2A	Penicillin Binding Protein 2A
PRR	Probabilistic Risk Ranger
RNA	Ribonucleic acid
RR	Risk Ranger
SCCmec	*Staphylococcal* Cassette Chromosome Mec
SFD	*Staphylococcal* Foodborne Disease
TSA	Trypticase soy agar
TSB	Tryptic soy broth
U	Unit
UPM	Universiti Putra Malaysia
USA	United States of America
USDA	United States Department of Agriculture
UV	Ultraviolet
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Staphylococcus aureus (*S. aureus*) is one of the leading causes of bacterial infection in community and hospital setting producing mortality rate between 65-70% in the pre-antibiotic era and about 20-40% currently (Melzer *et al.,* 2013). Approximately, one-third of the human population become long-term carrier of *S. aureus* as it can live on waterless area in an extended period (Tadayuki *et al.,* 2010). Meanwhile, it is estimated that in 600 million peoples, 1 in 10 suffers from foodborne disease caused by contaminated food with *S. aureus* and about 420,000 dies every year (World Health Organization., 2015). *S. aureus* is described as a bacterium that capable of producing heat-resistant enterotoxin such as enterotoxin A, enterotoxin B, enterotoxin C1, enterotoxin C2, enterotoxin C3, and enterotoxin D affecting the intestine leading to food poisoning (Reiser *et al.,* 1984; Shimizu *et al.,* 2000).

S. aureus can cause a various type of illnesses ranging from minor to life-threatening including endocarditis, bacteraemia, osteomyelitis, pneumonia, meningitis, sepsis and toxic shock syndrome (Devapriya *et al.,* 2013). Moreover, it is found that the cross contamination of *S. aureus* occurs in a workplace whereby food handlers are identified to be one of the contributors through unhygienic practices including not washing hands properly, exposing food items at room temperature in extended period and neglecting the cleanliness of working area (Mutalib *et al.,* 2012). Furthermore, it is stated that lack of self-hygiene, unclean water supply and dirty environment contributing to the *Staphylococcal* food poisoning as it is easily transferred between workers due to poor hand washing techniques (Carboneau *et al.,* 2010). On the other hand, the emergence of antibiotics has resulted in major clinical cases and signification worldwide problem. Evidence of this, *S. aureus* is identified to cause resistant to many commonly used antibiotics therefore it is used as the key selective force driving to the resistance (Golzari *et al.,* 2013). In this case, β-lactam penicillinase is the best-known mechanism of bacterial resistance which may be plasmid-mediated or chromosomally and be constitutive to protects *S. aureus* against antibiotic group called Penicillins (Ali *et al.,* 2004).

Methicillin-resistant *Staphylococcus aureus* (MRSA) is one example of antibiotic resistance which is infrequently identified from patients in the community whereby it is reported that community-acquired Methicillin-resistant *Staphylococcus aureus* has increased leading to a change in epidemiology (Ghojazadeh *et al.,* 2014). The cases of foodborne illness among industrialized food production continue to prevail as people often blame the nature rather

than exploring the connection between humans and non-humans which classified as actors involved in their surroundings. Therefore, the framework of Actor Network Theory (ANT) is developed to enable researchers to explore the connection between human and non-human entities which involved in a vast quantity of food preparation (Stuart *et al.,* 2011).

Correspondingly, researchers identified *S. aureus* as one of the leading bacteria which cause food intoxication therefore prevention steps should be taken to combat its occurrence. In the same study, it is mentioned that the emergence of MRSA could be from various reasons which can be referred to the practice of infection control, antimicrobial pressures and host factors (Naghavi-Behzad *et al.,* 2015). Various factors contribute to foodborne illness such as population growth and agriculture, socioeconomic status, and culture. Hence, these might lead to improper food handling practices and insanitary procedures of a certain population leading to foodborne illness (Kau *et al.,* 2012). Meanwhile, a person with low immune system are vurnerable to the infection of *S. aureus* regardless of their age. Therefore, it is suggested that the law regarding self hgyiene of food handlers in preparation of food should be tightened including closing down the dirty food premises (Gorman *et al.,* 2005). Different types of risk factors lead to *Staphylococcal* food poisoning such as the interaction between *S. aureus* and the food as well as between other microorganism contaminating the food, humidity, the composition of gas and different storage temperature (Abdul-Mutalib *et al.,* 2015).

1.2 Problem Statement

A study conducted at Liberty University in United States of America found that *S. aureus* and Methicillin resistant *Staphylococcus aureus* (MRSA) strain can be isolated from students and healthcare workers in microbiology laboratory (Gillen *et al.,* 2014). This indicated that human can be the carrier of *S. aureus* and MRSA therefore, the chances of acquiring *S. aureus* infection and transmission to food is possible. Furthermore, the Ministry of Health Malaysia (MOH) state that, the rate of *Staphylococcal* food poisoning cases has increased from 2005-2008 and death cases have also been reported even though numerous control strategies have been implemented (Ministry of Health Malaysia., 2009).

Several studies reported that *S. aureus* found in healthcare workers which constitute an important reservoir and estimated that the rate of colonization of *S. aureus* is high among the healthcare workers especially in laboratory (Kluytmans *et al.,* 1997). Unfortunately, the major reservoir for *S. aureus* are humans where it often colonizes the anterior nares and known to be a potentially lethal opportunistic pathogen. Apart from human, *S. aureus* can survive on inanimate objects and various dry surfaces such as door knob, mattress, blanket, and garments (Brown *et al.,* 2013). The occurrence of

widespread of foodborne illness persists to highlight problems with industrialized food production and the consumption of contaminated food product with *S. aureus* or non-infectious agents like toxin and chemicals may produce symptoms like nausea and vomiting leading to diarrhoea product contaminated (Linscott *et al.,* 2011).

Foodborne illness not only affecting the economic massively in healthcare cost, but also quality of life of a person and responsible for loss of productivity (Scharff *et al.,* 2012). Most of foodborne illness cases Malaysia is associated with unhygienic food handling practices including not washing hands properly, using unclean kitchen utensils and working in dirty working surfaces. Thus, the burden of foodborne illness identified in Malaysia is lower compared as most of the cases are not well-defined compare to other countries (Soon *et al.,* (2011). Prior to that, a suitable condition and temperature for bacterial growth contributes in increase of foodborne illness cases (Bezirtzoglou *et al.,* 2011). Thus, the factors affecting food contamination from work place to domestic kitchen can be the location, water supply, pest control, ventilation and temperature of food storage, self-hygiene of food handlers including clothing and their health condition while preparing food (Ministry of Health, 2009). *S. aureus* found to be the highest contributing agent of cross contamination in households compare to other pathogenic bacteria whereby poor self and environmental hygiene is the contributing factors of cross contamination of *S. aureus* in the meals prepared by consumers in domestic kitchen (Gorman *et al.,* (2005).

1.3 Objectives

The objectives of this study are:

1. To determine the prevalence and antibiogram of *Staphylococcus aureus* in laboratory.
2. To determine the transmission of *Staphylococcus aureus* by using Actor Network Theory.
3. To determine the cross contamination of *Staphylococcus aureus* by using simulation test.
4. To estimate the risk of acquiring *Staphylococcus aureus* by using Risk Ranger.

REFERENCES

Abdul-Mutalib, N. A., Syafinaz, A. N., Sakai, K., Shirai, Y. (2015). An overview of foodborne illness and food safety in Malaysia. *International Food Research Journal* 22(3): 896-901.

Acar, J. F., Goldstein, F. W., Kitzis, M. D. (1993). Susceptibility survey of piperacillin alone and in the presence of tazobactam. *Journal of Antimicrobial Chemotherapy* 31: 23–8.

Aletkruse, S. F., Street, D. A., Fein, S. B., Levy, S. (1996). Consumer knowledge of foodborne microbial hazards and food handling practices. *Journal of Food Protection* 59: 287–294.

Ali, A. M., Rafi, S., Qureshi, A. H. (2004). Frequency of extended spectrum beta-lactamase producing gram negative *bacilli* among clinical isolates at clinical laboratories of Army Medical College. *Journal of Ayub Medical College Abottabad* 16: 357-417.

Anne, W., Maria, P., Joseph, K. and May, A. 2004. Consumer attidutes, knowledge and behaiour: a review of food safety issues. *Trends in Food Science and Technology* 15: 56-66.

Argudin, M. A., Mendoza, M. C., Rodicio, M. R. (2010). Food poisoning and *Staphylococcus aureus* enterotoxins. *Toxins* 2(7): 1751-1773.

Ataee, R. A., Ataee, M. H., Alishiri, G. H., Esmaeili, D. (2012). *Staphylococcal* enterotoxin C in synovial fluid of patients with rheumatoid arthritis. *Iranian Red Crescent Medical Journal* 16(10):16075-16075.

Ateba, C. N., Mbewe, M., Moneoang, M. S., Bezuidenhout, C. C. (2010). Antibiotic resistant *Staphylococcus aureus* isolated from milk in the Mafikeng Area, North West province, South Africa. *South African Journal of Science* 106(11-12): 1-6.

Aycicek, H., Aydogan, H., Kucukkaraaslan, A., Baysallar M., CelalBasustaoglu, A. (2004). Assessment of the bacterial contamination on hands of hospital food handlers. *Food Control* 15: 253-259.

Baird, M., Sfeir, G., Slade-Pacini, C. (1987). Lack of inhibition of mouse catalase activity by cimetidine: an argument against a relevant general effect of cimetidine upon heme metabolic pathways. *Biochemical Pharmacology* 36: 4366

Balaban, N., Rasooly, A. (2000). *Staphylococcal* enterotoxins. *International Journal of Food Microbiology* 61: 1-10.

Bartlett, J. G., Auwaerter, P. G., Pham, P. A. (2011). Johns Hopkins POC-IT Center ABX Guide: Diagnosis & Treatment of Infectious Diseases. *Jones & Bartlett Publishers* 9: 24-26.

Batalha, J. E. N., Cunha, M. L. R. S., Montelli, A. C., Barreti, P., Caramori, J. C. T. (2010). Identification and antimicrobial susceptibility of *Staphylococcus* from home-treated peritoneal dialysis patients. *Journal of Venomous Animals and Toxins including Tropical Diseases* 16(2): 212-222.

Bennett, S. D., Walsh, K. A., Gould, L. H. (2013). Foodborne disease outbreaks caused by *Bacillus cereus*, *Clostridium perfringens*, and *Staphylococcus aureus*—United States, 1998–2008. *Clinical Infectious Diseases* 57(3): 425-433.

Bezirtzoglou, E., Stavropoulou, E. (2011). Immunology and probiotic impact of the newborn and young children intestinal microflora. *Anaerobe* 17: 369-374.

Bhat, M., Dumortier, C., Taylor, B. S., Miller, M., Vasquez, G., Yunen, J., Leon, P. (2009). *Staphylococcus aureus* ST398, New York City and Dominican Republic. *Emerging Infectious Diseases* 15(2): 285.

Bhatia, A., Zahoor, S. (2007). *Staphylococcus aureus* enterotoxins: a review. *Journal of Clinical Diagnosis Research* 3(1): 188-197.

Bondi, M., Messi, P., Halami, P. M., Papadopoulou, C., de Niederhausern, S. (2014). Emerging microbial concerns in food safety and new control measures. *BioMed Research International* 1-3.

Borrusso, P., Quinlan, J. J. (2013). Development and piloting of a food safety audit tool for the domestic environment. *Foods* 2(4): 572-584.

Brooks, J. D., Flint, S. H. (2008). Biofilms in the food industry: problems and potential solutions. *International Journal of Food Science and Technology*, 43, 2163–2176.

Brown, A. F., Leech, J. M., Rogers, T. R., McLoughlin, R. M. (2013). *Staphylococcus aureus* colonization: modulation of host immune response and impact on human vaccine design. *Frontiers in Immunology* 4: 507.

Byrd-Bredbenner, J., Berning, J., Martin-Biggers, V. Q. (2013). Food safety in home kitchens: a synthesis of the literature. *International Journal of Environmental Research and Public Health* 10: 4060–4085.

Carboneau, C., Benge, E., Jaco, M. T., Robinson, M. (2010). A lean six sigma team increases hand hygiene compliance and reduces hospital-acquired methicillin-resistant *Staphylococcus aureus* infections by 51%. *Journal for Healthcare Quality* 32: 61-70.

Centers for Disease Control and Prevention. (2014) Methicillin-Resistant *Staphylococcus aureus* (MRSA) Infections. http://www.cdc.gov/mrsa/

Chadha, T., Kulsum, S. N., Adlekha, S., Mailapur, P. C. (2014). Comparison of antibiotic susceptibility pattern of community-and hospital-acquired methicillin-resistant *Staphylococcus aureus* with special reference to inducible clindamycin resistance in a tertiary care hospital in southern India. *Medical Journal of Dr. DY Patil Vidyapeeth* 7(4): 439.

Chambers, H. F., DeLeo, F. R. (2009). Waves of resistance: *Staphylococcus aureus* in the antibiotic era. *Nature Reviews Microbiology* 7(9): 629-641.

Chen, Y.H., Jackson, K.M., Chea, F.P., Schaffner, D.W. (2001). Quantification and variability analysis of bacterial cross-contamination rates in common food service tasks. *Journal of Food Protection* 64: 72–80.

Cimolai, N. (2008). MRSA and the environment: implications for comprehensive control measures. *European Journal of Clinical Microbiology and Infectious Diseases* 27(7): 481-93.

Clinical and Laboratory Standard Institute. (2006). Performance standards for antimicrobial susceptibility testing; seventeenth informational supplement. MS100-S17 27: 1.

Cody, M. M., Hogue, M. A. (2003). Result of the home food safety—it's in your hands 2002 survey: comparison to the 1999 benchmark survey and healthy people 2010 food safety behaviours objective. *Journal of American Diet Association* 103: 1115–1125.

Cogan, T.A., Slader, J., Bloomfield, S.F., Humphrey, T.J. (2002). Achieving hygiene in the domestic kitchen: the effectiveness of commonly used cleaning procedures. *Journal of Applied Microbiology* 92: 885– 892.

Cole, A. M., Tahk, S., Oren, A., Yoshioka, D., Kim, Y. H., Park, A., Ganz, T. (2001). Determinants of *Staphylococcus aureus* nasal carriage. *Clinical and Diagnostic Laboratory Immunology* 8(6): 1064-1069.

Daka, D. (2014). Antibiotic-resistant *Staphylococcus aureus* isolated from mobile phone and hands of Health care workers in the Hawassa referral Hospital, South Ethiopia. *Journal of Microbiology and Antimicrobials* 6(4): 72-78.

David, M. Z. and Daum, R. S. (2010). Community-associated methicillin-resistant *Staphylococcus aureus*: Epidemiology and clinical consequences of an emerging epidemic. *Clinical Microbiology Reviews* 23(3): 616–687.

De Alwis, W. R., Pakirisamy, P., Wai San, L., Xiaofen, E. C. (2012). A study on hand contamination and hand washing practices among medical students. *International Scholarly Research Notices* 12:1.

Deurenberg, R. H., Vink, C., Kalenic, S., Friedrich, A. W., Bruggeman, C. A., Stobberingh, E. E. (2007). The molecular evolution of methicillin-resistant *Staphylococcus aureus*. *Clinical Microbiology and Infection* 3: 222-235.

Devapriya, F., Ramesh, R., Khan, A. K. S., Shanmugam, J. (2013). β-lactamase production of *Staphylococcus aureus*: A comparison study of different iodometric methods. *Gulf Medical Journal* 2: 16-21.

Dharod, J. M., Pérez-Escamilla, R., Paciello, S., Bermúdez-Millán, A., Venkitanarayanan, K., Damio, G. (2007). Comparison between self-reported and observed food handling behaviours among Latinas. *Journal of Food Protection* 70: 1927–1932.

Dinges, M. M., Orwin, P. M., Schlievert, P. M. (2000). Exotoxins of *Staphylococcus aureus*. *Clinical Microbiology* 13: 16-34.

Fritz, S. A., Hogan, P. G., Singh, L. N., Thompson, R. M., Wallace, M. A., Whitney, K., Fraser, V. J. (2014). Contamination of environmental surfaces with *Staphylococcus aureus* in households with children infected with methicillin-resistant *Staphylococcus aureus*. *Journal of American Medical Association Pediatrics* 168(11): 1030-1038.

Furuno, J. P., Shurland, S. M., Zhan, M., Johnson, J. K., Venezia, R. A., Harris, A. D., Roghmann, M. C. (2011). Comparison of the methicillin-resistant *Staphylococcus aureus* acquisition among rehabilitation and nursing home residents. *Infection Control and Hospital Epidemiology* 32(3): 244-249.

Gheiti, A. J. C., Mulhall, K. J. (2013). Peri-prosthetic joint infection: prevention, diagnosis and management. InTechOpen. DOI: 10.5772/53247

Ghojazadeh, M., Naghavi-Behzad, M., Nasrolah-Zadeh, R., Bayat-Khajeh, P., Piri, R., Mirnia, K. (2014). Knowledge production status of Iranian researchers in the gastric cancer area: based on the medline database. *Asian Pacific Journal of Cancer Prevention* 15(12): 5083-8.

Gillen, A. L., Daycock, W. O., Serafin, A. (2014). High MRSA Carriage Rate among Nursing Microbiology Students. *Advances in Microbiology* 4(13): 871.

Golzari, S. E., Ghabili, K., Aslanabadi, A., Khanli, H. M., Bazzazi, A. M., Sabermarouf, B. (2013). Infectious threats after Iran's Bushehr earthquake. *Clinical Infectious Disease* 57(4): 619.

Gorman, R., Bloomfield, S., Adley, C. C. (2005). A study of cross-contamination of food-borne pathogens in the domestic kitchen in the Republic of Ireland. *International Journal of Food Microbiology* 76: 143–150.

Gorwitz, R. J., Jernigan, D. B., Powers, J. H., Jernigan, J. A. (2009). Participants in the Centers for Disease Control and Prevention-Convened Experts' Meeting on Management of MRSA in the Community. Strategies for clinical management of MRSA in the community: summary of an experts' meeting convened by the Centers for Disease Control and Prevention. *The Pediatric Infectious Disease Journal* 25(2): 178-180.

Goto, H., Shimada, K., Ikemoto, H., Oguri, T. (2009). Study group on antimicrobial susceptibility of pathogens isolated from respiratory infections. *Journal of Infection and Chemotherapy* 15: 347-360.

Götz, F. (2002). *Staphylococcus* and biofilms. *Molecular Microbiology* 43:1367–1378.

Greenwood, D. (2008). Antimicrobial drugs: chronicle of a twentieth century medical triumph. *New York Oxford University Press* 85-139.

Griffith, C., Worsfold, D., Mitchell, R. (1998). Food preparation, risk communication and the consumer. *Food Control* 9: 225–232.

Gustafson, R. H., Bowen, R. E. (1997). Antibiotic use in animal agriculture. *Journal of Applied Microbiology* 83(5): 531-541.

Gutiérrez, D., Delgado, S., Vázquez-Sánchez, D., Martínez, B., Cabo, M. L., Rodríguez, A., García, P. (2012). Incidence of *Staphylococcus aureus* and analysis of associated bacterial communities on food industry surfaces. *Applied and environmental microbiology* 78(24): 8547-8554.

Haberberger, R. L., Kallen, A. J., Driscoll, T. J., Wallace, M. R. (2015). Microbiology: Oxacillin-Resistant Phenotypes of *Staphylococcus aureus*. *Laboratory Medicine* 29(5): 302-305.

Hakuno, H., Oie, S., Furukawa, H. (2013). Contamination of wheelchairs by *Staphylococcus aureus*. *Journal of Hospital Administration* 2(2): 55.

Hardy, D. J., Hensey, D. M., Beyer, J. M., Vojtko, C., McDonald, E. J., Fernandes, P. B. (1988). Comparative in vitro activities of new 14-, 15-, and 16-membered macrolides. *Antimicrobial Agents Chemotherapy* 32: 1710–19.

Hassanzadeh, P., Hassanzadeh, Y., Mardaneh, J., Rezai, E., Motamedifar, M. (2015). Isolation of Methicillin-Resistant *Staphylococcus aureus* (MRSA) from HIV Patients Referring to HIV Referral Center, Shiraz, Iran, 2011-2012. *Iranian Journal of Medical Sciences* 40(6): 526–530.

Hiramatsu, K., Ito, T., Tsubakishita, S., Sasaki, T., Takeuchi, F., Morimoto, Y., Baba, T. (2013). Genomic Basis for Methicillin Resistance in *Staphylococcus aureus*. *Infection Chemotherapy 45*(2): 117–136.

Ho, J., Boost, M. V., O'donoghue, M. M. (2015). Tracking sources of *Staphylococcus aureus* hand contamination in food handlers by spa typing. *American Journal of Infection Control* 43(7): 759-761.

Hong, J., Lim, S. Y. (2015). Microbial Contamination in Kitchens and Refrigerators of Korea Households. *Journal of Food Hygiene and Safety* 30(4): 303-308.

Houghton, J.R., Rowe, G., Frewer, L.J., Van Kleef, E., Chryssochoidis, G. and Kehagia, O. 2008. The quality of food risk management in Europe: Perspectives and priorities. *Food Policy* 33(1): 13-26.

Jeyaletchumi, P., Tunung, R., Margaret, S.P., Chai, L.C., Son, R., Farinazleen, M.G., Cheah, Y.K., Nishibuchi, M., Nakaguchi, Y. and Pradeep, K.M. (2010). Assessing the risk of acquiring listeriosis from consumption of minimally processed vegetables using a step-wise risk assessment. *Asian Journal of Food and Agro-Industry* 3(06): 587-596.

Kadariya, J., Smith, T. C., Thapaliya, D. (2014). *Staphylococcus aureus* and *Staphylococcal* foodborne disease: an ongoing challenge in public health. *BioMed Research International* 827965-827965.

Kagan, L. J., Aiello, A. E., Larson, E. (2002). The role of the home environment in the transmission of infectious diseases. *Journal of Community Health* 27: 247-68.

Kau, A. L., Ahern, P. P., Griffin, N. W., Goodman, A. L., Gordon, J. I. (2012). Human nutrition, the gut microbiome, and immune system: envisioning the future. *Nature* 474 (7351): 327-336.

Kennedy, J., Nolan, A., Gibney, S., O'Brien, S., McMahon, M. A. S., McKenzie, K., Wall, P. G. (2011). Deteminants of cross-contamination during home food preparation. *British Food Journal* 113(2): 280-297.

Kishimoto, M., Hioki, Y., Okano, T., Konuma, H., Takamizawa, K., Kashio, H., Kasuga, F. (2004). Ribotyping and a study of transmission of *Staphylococcus aureus* collected from food preparation facilities. *Journal of Food Protection* 67(6): 1116-1122.

Kloos, W. E., Bannerman, T. L. (1994). Update on clinical significance of coagulase negative S*taphylococci*. *Clinical Microbiology* 7: 117-140.

Kloos, W. E., Lambe, D. W. (1991). *Staphylococcus*. *Manual of Clinical Microbiology* 5: 222-237.

Kloos, W. E., Musselwhite, M. S. (1975). Distribution and persistence of *Staphylococcus* and *Micrococcus* species and other aerobic bacteria on human skin. *Applied Microbiology* 30: 381-385.

Kloos, W. E., Schleifer, K. H. (1986). Genus IV. *Staphylococcus* in Rosenbach 1884. *Bergey's Manual of Systemic Bacteriology* 2.

Kluytmans, J. A., Wertheim, H. F. L. (2005). Nasal carriage of *Staphylococcus aureus* and prevention of nosocomial infections. *Infection* 33 (1): 3-8.

Kluytmans, J., van-Belkum, A., Verbrugh, H. (1997). Nasal carriage of *Staphylococcus aureus* epidemiology, underlying mechanisms, and associated risks. *Clinical Microbiology Reviews* 10(3): 505–20.

Krishna, B. V. S., Patil, A., Chandrasekhar, M. R. (2007). Methicillin-resistant *Staphylococcus aureus* infections-Implications in hospital infection control. *Editorial Board* 51: 1.

Kusumaningrum, H. D., Riboldi, G., Hazeleger, W. C., & Beumer, R. R. (2003). Survival of foodborne pathogens on stainless steel surfaces and cross-contamination to foods. *International journal of food microbiology* 85(3): 227-236.

Lando, A., Verill, L (2006). Trends in US consumers' safe handling and consumption of food and their risk perceptions, 1988 through 2010. *Journal of food protection* 74(9): 1513-1523.

Larsen, H. D., Sloth, K. H., Elsberg, C. (2000). The dynamics of *Staphylococcus aureus* intramammary infections in nine Danish dairy herds. *Veterinary Microbiology* 71: 89-101.

Lawley, R., Laurie, C., Judy, D. (2008). The food safety hazard guidebook. *The Royal Society of Chemistry*. http://dx.doi.org/10.1039/9781849734813

Lilenbaum, W., Nunes, E. and Azeredo, M. (1998). Prevalence and antimicrobial susceptibility of Staphylococci isolated from the skin surface of clinically normal cat. *The Society for Applied Microbiology* 27: 224-228.

Linscott, Andrea J. (2011). Food-Borne Illnesses. *Clinical Microbiology Newsletter* 33(6): 41-45.

Loir, Y. L., F. Baron, M. Gautier. 2003. *Staphylococcus aureu*s and Food poisoning*. Genetics and Molecular Research* 2:63-76*.*

Lues, J. F. R., Van Tonder, I. (2007). The occurrence of indicator bacteria on hands and aprons of food handlers in the delicatessen sections of a retail group. *Food Control* 18(4): 326-332.

Lynch, M., Painter, J., Woodruff, R., Braden, C. (2006). Surveillance for foodborne disease outbreaks-United States. *Morbidity and Mortality Weekly Report* 55: 1-34.

Mataragas, M., Bellio, A., Rovetto, F., Astegiano, S., Decastelli, L., Cocolin, L. (2015). Risk-based control of food-borne pathogens *Listeria monocytogenes* and *Salmonella enterica* in the Italian fermented sausages *Cacciatore* and *Felino*. *Meat Science* 103: 39-45.

Melzer, M., Welch, C. (2013). Thirty-day mortality in UK patients with community onset and hospital-acquired methicillin-susceptible *Staphylococcus aureus* bacteraemia. *Journal of Hospital Infection* 84(2): 143–50.

Ministry of Health Malaysia. (2009). Statistik Fakta Kesihatan. http://www. moh.gov.my/v/stats_si.

Miranda, R. C., Schaffner, D. W. (2016). Longer contact times increase cross-contamination of Enterobacter aerogenes from surfaces to food. *Applied and Environmental Microbiology* 82(21): 6490-6496.

Murray, P. R., Baron, E. J., Jorgensen, J. H., Pfaller, M. A. Yolken, R. H. (2003). Manual of Clinical Microbiology. *American Society for Microbiology* 125: 2334-2336.

Murray, R. J. (2005). Recognition and management of *Staphylococcus aureus* toxin-mediated disease. *Internal Medicine Journal* 35: 2.

Mutalib, A., Azira, N., Abdul-Rashid, M. F., Mustafa, S., Nordin, A., S., Hamat, R. A., Osman, M. (2012). *Staphylococcus aureus* in food and nares of food handlers in Kuala Pilah, Malaysia. *Pertanika Journal of Tropical Agricultural Science* 35(4): 853-862.

Naghavi-Behzad, M., Akhi, M. T., Alizadeh, M., Saleh, P., Jafarzadeh, S., Sohrab-Navi, Z., Piri, R. (2015). *Staphylococcus aureus*: resistance pattern and risk factors. *Journal of Analytical Research in Clinical Medicine* 3(1): 43-50.

Nouwen, J. L., Fieren, M. W., Snijders, S., Verbrugh, H. A., & Van Belkum, A. (2005). Persistent (not intermittent) nasal carriage ofStaphylococcus aureus is the determinant of CPD-related infections. *Kidney international* 67(3): 1084-1092.

Nouwen, J., Boelens, H., van-Belkum, A., Verbrugh, H. (2004). Human factor in *Staphylococcus aureus* nasal carriage. *Infection and Immunity* 72(11): 6685-8.

Nurul Izzah, A., Aminah, A., Md Pauzi, A., Lee, Y. H., Wan Rozita, W. M., Siti Fatimah, D. (2012). Patterns of fruits and vegetables consumption among adults of different ethnics in Selangor, Malaysia. *International Food Research Journal* 19(3):1095-1107.

Oguttu, J. W., McCrindle, C. M., Makita, K., Grace, D. (2014). Investigation of the food value chain of ready-to-eat chicken and the associated risk for *Staphylococcal* food poisoning in Tshwane Metropole, South Africa. *Food Control* 45: 87-94.

Onanuga, A., Oyi, A. Onaolapo, J. (2005). Prevalence and susceptibility pattern of methicillin resistant staphylococcus aureus isolates among healthy women in Zaria, Nigeria. *African Journal of Biotechnology* 4(11): 321-1324.

Orient, A., Donko, A., Szabo, A., Leto, T. L., Geiszt, M. (2007). Novel sources of reactive oxygen species in the human body. *Oxford University Press* 1281-1288.

Othman, K. I., Karim, M. S., Karim, R., Adzhan, N. M., Halim, N. A. (2013). Consumption pattern on fruits and vegetables among adults: a case of Malaysia. *Academic Journal of Interdisciplinary Studies* 2(8): 424.

Patil, S. M., Cates, S., Morales, R. (2005). Consumer food safety knowledge, practices, and demographic differences: findings from a meta-analysis. *Journal of Food Protection* 68: 1884–1894.

Perez-Escamilla, R., Putnik, P. (2007). The role of acculturation in nutrition, lifestyle, and incidence of type 2 diabetes among Latinos. *Journal of Nursing* 137: 860–870.

Qian, Q., Eichelberger, K., Kirby, J. E. (2014). Rapid identification of Staphylococcus aureus directly from Bactec blood culture broth by the BinaxNOW *Staphylococcus aureus* test. *Journal of Clinical Microbiology* 52(1): 319-320.

Quinn, G. A., Cole, A.M. (2007). Suppression of innate immunity by a nasal carriage strain of *Staphylococcus aureus* increases its colonization on nasal epithelium. *Immunology* 122(1): 80-9.

Rajaduraipandi, K., Mani, K., Panneerselvam, K., Mani, M., Bhaskar, M. and Manikandan, P. 2006. Prevalence and Antimicrobial sensitivity pattern of methicillin resistant *Staphylococcus aureus*: a multicenter study. *Indian Journal of Medical Microbiology* 24(1): 34-38.

Rayner, C., Munckhof, W. J. (2005). Antibiotics currently used in the treatment of infections caused by *Staphylococcus aureus*. *Internal Medicine Journal* 35: 2.

Reagan, D. R., Doebbeling, B. N., Pfaller, M. A., Sheetz, C. T., Houston, A. K., Hollis, R. J., Wenzel, R. P. (1991). Elimination of coincident *Staphylococcus aureus* nasal and hand carriage with intranasal application of mupirocin calcium ointment. *Annals of Internal Medicine* 114(2): 101-106.

Redmond, E. C., Griffith, C. J. (2005). Consumer food handling in the home: a review of food safety studies. *Journal of Food Protection* 66:130–161.

Reiser, R. F., Robbins, R. N., Noleto, A. L., Khoe, G. P., Bergdoll, M. S. (1984). Identification, purification and some physiochemical properties of *Staphylococcal* enterotoxin C3. *Infection and Immunity* 45:625-630.

Rocha, L. A., Ribas, R. M., da Costa Darini, A. L., Gontijo Filho, P. P. (2013). Relationship between nasal colonization and ventilator-associated pneumonia and the role of the environment in transmission of *Staphylococcus aureus* in intensive care units. *American Journal of Infection Control* 41(12): 1236-1240.

Rolo, J., Worning, P., Boye Nielsen, J., Sobral, R., Bowden, R., Bouchami, O., Miragaia, M. (2017). Evidence for the evolutionary steps leading to *mecA*-mediated β-lactam resistance in *Staphylococci*. *Genetics* 13: 4.

Rongpharpi, S. R., Hazarika, N. K., Kalita, H. (2013). The prevalence of nasal carriage of *Staphylococcus aureus* among healthcare workers at a tertiary care hospital in assam with special reference to MRSA. *Journal of Clinical and Diagnostic Research* 7(2): 257–260.

Ross, T., Sumner, J. (2002). A semi-quantitative seafood safety risk assessment. *International Journal of Food Microbiology* 77(1-2): 55-59.

Rossi, E. M., Beilke, L., Barreto, J. F. (2018). Microbial contamination and good manufacturing practices in school kitchen. *Journal of Food Safety* 38(1).

Ryan, K. J., Ray, C.G. (2004). An introduction to infectious diseases. *Sherris Medical Microbiology* 4: 123.

Salgado, A., Cunha, J., Abreu, J., Barros, P., Pires, B., Nogueira, A. J. M., Afonso, A. (2014). Assessment of microbiological contamination in different catering units related to food handling in the district of Bragança. *3rd International Congress of Environmental Health* 485-486.

Sangvik, M., Olsen, R. S., Olsen, K., Simonsen, G. S., Furberg, A. S., Sollid, J. U. E. (2011). Age-and gender-associated Staphylococcus aureus spa types found among nasal carriers in a general population: the Tromsø Staph and Skin Study. *Journal of Clinical Microbiology* 49(12): 4213-4218.

Scharff, R. L. (2012). Economic burden from health losses due to foodborne illness in the United States. *Journal of Food Protection* 75(1): 123-31.

Schelin, J., Wallin-Carlquist, N., Thorup Cohn, M., Lindqvist, R., & Barker, G. C. (2011). The formation of *Staphylococcus aureus* enterotoxin in food environments and advances in risk assessment. *Virulence* 2(6): 580-592.

Shimizu, A., Fujita, M., Igarashi, H., Takagi, M., Nagase, N., Sasaki, A., Kawano, J. (2000). Characterization of *Staphylococcus aureus* coagulase type VII isolates from *Staphylococcal* food poisoning outbreaks (1980–1995) in Tokyo, Japan, by pulsed-field gel electrophoresis. *Journal of Clinical Microbiology* 38(10): 3746- 3749.

Shittu, A. O., Johnson, L. (2006). Antimicrobial susceptibility patterns and characterization of clinical isolates of *Staphylococcus aureus* in Kwazulu Natal Province*. Infectious Dis*eases 6: 125.

Siegel, J. D, Rhinehart, E., Jackson, M. (2007). Guideline for isolation precautions: Preventing transmission of infectious agents in healthcare settings. *American Journal of Infection Control* 35(10): 65-164.

Solberg, C. O. (1965). A study of carriers of *Staphylococcus aureus* with special regard to quantitative bacterial estimations. *Journal of Internal Medicine* 178: 436.

Soon, J. M., Singh, H. and Baines, R. (2011). Foodborne diseases in Malaysia: A review. *Food Control* 22: 823- 830.

Souza, E. L. D., Silva, C. A. D., Sousa, C. P. D. (2005). Bacteriocins: molecules of fundamental impact on the microbial ecology and potential food bio preservatives. *Brazilian Archives of Biology and Technology 48*(4): 559-566.

Stella, S. A., Cervantes, L., Knepper, B. C., Sabel, A. L., Price, C. S., Burman, W. J. (2013). Targets for antibiotic and healthcare resource stewardship in inpatient community-acquired pneumonia: a comparison of management practices with National Guideline Recommendations. *Infection* 41(1): 135-144.

Stewart, G.C. (2005). *Staphylococcus aureus* in foodborne pathogens: microbiology and molecular biology. *Caister Academic Press* 273-284.

Stuart, D. 2011. “Nature” is Not Guilty: Foodborne Illness and the Industrial Bagged Salad. *Sociologia Ruralis* 51(2): 158-174.

Syne, S. M., Ramsubhag, A., Adesiyun, A. A. (2013). Microbiological hazard analysis of ready-to-eat meats processed at a food plant in Trinidad, West Indies. *Infection Ecology and Epidemiology* 3(1): 20450.

Tadayuki, I., Yoshi, U., Hitomi, S., Akiko, T., Hiromi, S., Koji, T. (2010). *Staphylococcus epidermidis* especially inhibits *Staphylococcus aureus* biofilm formation and nasal colonization. *Nature* 465.

Tamarapu, S., McKillip, J. L., Drake, M. (2001). Development of a multiplex polymerase chain reaction assay for detection and differentiation of *Staphylococcus aureus* in dairy products. *Journal of Food Protection* 64(5): 664-668.

Tan, S.L., Lee, H.Y., Abu Bakar, F., Abdul Karim, M.S., Rukayadi, Y., Mahyudin. (2013). Microbiological quality on food handlers’ hands at primary schools in Hulu Langat District, Malaysia. *International Food Research Journal* 20(5): 2973-2977.

Teixeira, P., Silva, S., Aranjo, F., Azeredo, J. O. (2007). Bacterial adhesion to food contacting surfaces. *Communicating Current Research and Educational Topics and Trends in Applied Microbiology* 8.

Tournas, V. H., Heeres, J., Burgess, L. (2006). Moulds and yeasts in fruit salads and fruit juices. *Food Microbiology* 23(7): 684-688.

Trepka, M. J., Violet, M., Syreeta, C., Fatma, G. H., Zisca, D. (2006). Food safety beliefs and barriers to safe food handling among WIC program clients, Miami, Florida. *Journal of Nutrition Education and Behaviour* 38:371–377.

Uhlemann, A. C., Knox, J., Miller, M., Hafer, C., Vasquez, G., Ryan, M., Lowy, F. D. (2011). The environment as an unrecognized reservoir for community-associated methicillin resistant *Staphylococcus aureus* USA300: a case-control study. *PLoS One* 6(7).

Varma, J. K., Greene, K. D., Ovitt, J., Barrett, T. J., Medalla, F., Angulo, F. J. (2005). Hospitalization and antimicrobial resistance in Salmonella outbreaks, 1984–2002. *Emerging Infectious Diseases* 11(6): 943.

Viswanathan, P., Kaur, R. (2001). Prevalence and growth of pathogens on salad vegetables, fruits and sprouts. *International Journal of Hygiene and Environmental Health* 203(3): 205-213.

Wertheim, H. F., Van-Kleef, M., Vos, M. C., Ott, A., Verbrugh, H. A., Fokkens, W. (2006). Nose picking and nasal carriage of *Staphylococcus aureus*. *Infection Control and Hospital Epidemiology* 27(8): 863-867.

Whitt, D. D., Salyers, A.A. (2002). Bacterial pathogenesis: a molecular approach. *American Society of Microbiology Press*, 1-55581-171.

Whyte, P., Fanning, S., O'Brien, S., Grady, L. O. (2010). Tracing pathogens in red meat and game production chains and at abattoir. *Tracing Pathogens in the Food Chain* 401-450.

Wieneke, A. A., Roberts, D., Gilbert, R. J. (1993). *Staphylococcal* food poisoning in the United Kingdom, 1969–90. *Epidemiology and Infection* 110(3): 519-531.

Wolde, T., Bacha, K. (2016). Microbiological Safety of Kitchen Sponges Used in Food Establishments. *International Journal of Food Science* 1659784.

World Health Organization. (2015). WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015.

Yang, L. (2012). Combating biofilms. *Immunology and Medical Microbiology* 65: 146-157.

Zoabi, M., Keness, Y., Titler, N., Bisharat, N. (2011). Compliance of hospital staff with guidelines for the active surveillance of methicillin-resistant *Staphylococcus aureus* and its impact on rates of nosocomial methicillin-resistant *Staphylococcus aureus* bacteraemia. *Israel Medical Association Journal* 13: 740-744.