UNIVERSITI PUTRA MALAYSIA

MICROBIOLOGICAL RISK ASSESSMENT OF MICROWAVE HEATING ON READY-TO-EAT FOODS

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By

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MICROBIOLOGICAL RISK ASSESSMENT OF MICROWAVE HEATING ON READY-TO-EAT FOODS

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The microwave oven is an inexpensive multifunctional device commonly used for reheating purpose during meal preparation. The safety level of microwave heated foods remains in vague due to consumers' lack of awareness and knowledge on microwave heating the food safely. This research study aimed to scientifically address the microbiological safety of microwave heated ready-to-eat (RTE) foods. To initiate the study, a consumer survey study was conducted to measure the Malaysian's consumers' knowledge and practice microwave oven safety. Next, the survivability of *Salmonella enterica* and Shiga-toxigenic *Escherichia coli* (STEC) O157 in microwave heated RTE foods was studied to identify the risk factors and subsequently evaluate the risk factors. The prevalence of the foodborne pathogens' survivability in microwave heated RTE foods was investigated using the Most Probable Number coupled Polymerase Chain Reaction (MPN-PCR) method. The highest possibility of the foodborne pathogens' survival was due to factors affecting the microwave heating in particular presence of cold spots, microwave heating time and consumers' knowledge; all identified as risk factors. In the food safety context, microwave heating time and consumers' knowledge was given more attention. The microwave heating time on the influence of different food composition in relation to bacteria inactivation was then studied and the data was used to model the bacterial inactivation using the Weibull model. These studied risk factors were then incorporated into a retail and consumer phase exposure assessment model to estimate the risk of consumption of contaminated RTE food reheated at different microwaving times using @risk. The outcome of the study showed that the respondents demonstrated low level of knowledge and safety practice of the microwave oven, although they had neutral attitude on food safety. Out of the 329 samples of various convenience meals collected around Wilayah Persekutuan Kuala Lumpur and Selangor regions, 20.1% were tested positive with *Salmonella* spp. and 5.2% with STEC O157. Fats were observed to have the highest influence to the microwave heating time compared to proteins and carbohydrates. Based on the overall food composition, the results indicated that the foodborne pathogens were fully inactivated by microwave heating at 60 seconds as no viable growth was observed. However, the risk assessment model estimated probable foodborne illness cases for RTE food microwave heated less than 90 seconds for *S. enterica* serovar Enteritidis and STEC O157 exposure assessment models. The outcome indicated that RTE food should be microwave heated up to 90s and more to ensure the safety of the food and other interventions such as controlling the holding temperature and having a fixed display holding time. The current risk research study provided comparative information on the evaluation of microwave technology in terms of food safety. Notably, foodborne pathogens can survive the microwave heating which put the consumers at risk when improper safety practice and usage of the microwave oven is taken. The implementation of microwave heating guidelines, involving the safe microwave heating time and safety practice, into food safety educational programs should be established as risk interventions and further to conserve the public health.

Keywords: microwave oven, safe microwave heating time, safety practice, risk assessment, *Salmonella enterica*, Shiga-toxigenic *Escherichia coli* (STEC) O157

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PENILAIAN RISIKO MIKROBIOLOGI PEMANASAN MICROWAVE PADA MAKANAN READY-TO-EAT

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Microwave oven yang digunakan untuk memanaskan makanan, adalah sebuah peranti yang murah dan mempunyai pelbagai fungsi. Walau demikian, tahap keselamatan makanan yang dipanaskan dengan microwave oven masih berada di tahap ketidakpastian disebabkan oleh kekurangan ilmu dan kesedaran oleh para pengguna. Penyelidikan ini bertujuan untuk melaporkan keselamatan mikrobiologi makanan yang dipanaskan dengan microwave oven secara saintifik. Kajian ini dimulakan dengan menilai tahap ilmu para pengguna mengenai microwave oven dan praktik keselamatan menggunakan soal kaji selidik. Seterusnya, kebertahanan *Salmonella enterica* dan Shiga-toxigenic *Escherichia coli* (STEC) O157 dalam makanan ready-to-eat (RTE) yang dipanaskan menggunakan microwave oven dikaji menggunkan teknik Most Probable Number-Polymerase Chain Reaction (MPN-PCR) untuk mengenalpasti faktor-faktor risiko. Faktor-faktor yang dikenalpasti adaalah penghasilan ‘cold spots’ ketika pemanasan microwave, masa pemanasan gelombang dan tahap ilmu para pengguna. Dari segi konteks keselamatan makanan, masa pemanasan gelombang dan tahap ilmu para pengguna diberi lebih perhatian. Pengaruh komposisi makanan terhadap masa pemanasan microwave dan kematian bakteria juga dikaji dan data tersebut digunakan untuk membina model kematian bakteria dengan Weibull model. Kesemua faktor risko yang dikaji akan dimasukkan ke dalam model exposure assessment fasa runcit dan pengguna untuk menganggar risiko pengambilan makanan RTE yang dicemar dengan *S. enterica* serovar Enteritidis dan STEC O157 menggunakan @risk. Keputusannya menunjukkan para responden mempunyai ilmu yang rendah mengenai microwave oven dan praktik keselamatan walaupun mereka menunjukkan sikap neutral terhadap keselamatan makanan. Daripada 329 makanan RTE sampel yang dikumpul sekitar kawasan Wilayah Persekutan Kuala Lumpur dan Selangor, didapati patogen makanan dapat menahan pemanasan microwave di mana 20.1% positif dengan *Salmonella* spp. and 5.2% positif dengan STEC O157. Berdasarkan semua komposisi makanan, didapati patogen makanan tidak boleh bertahan sehingga 60 saat pemanasan microwave. Tetapi, model penilaian risiko

mikrobiologi tersebut telah menganggarkan kes keracunan makanan akan berlaku jika makanan RTE dipanaskan menggunakan microwave oven selama 90 saat atau kurang. Oleh demikian, ia adalah selamat untuk memanaskan makanan RTE lebih daripada 90 saat serta mengawal suhu dan masa pameran makanan. Kajian penilaian risiko ini telah memberi maklumat mengenai penilaian teknologi microwave dari segi keselamatan makanan. Para pengguna akan berhadapan dengan risiko keracunan makanan kerana patogen masih boleh wujud setelah makanan dipanaskan dengan microwave oven ditambah pula dengan praktik keselamatan penggunan microwave oven yang tidak dijalankan dengan sepatutnya. Standard penggunaan microwave oven perlu ditubuhkan dan masa pemanasan yang dikira selamat dan praktik keselamatan perlu dimasukkan sebagai langkah pengawalan risiko untuk memastikan kesejahteraan ramai.

Kata-kata Kunci: Microwave oven, masa pemanasan microwave selamat, praktik keselamatan, risk assessment, *Salmonella enterica*, Shiga-toxigenic *Escherichia coli* (STEC) O157

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

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LIST OF ABBREVIATIONS

CAC	CODEX Alimentarius Commission
CDC	Center for Control Disease and Prevention
CSIRO	Commonwealth Scientific and Industrial Research Organization
ECDC	European Centre for Disease Prevention and Control
EPA	United States Environmental Protection Agency
FAO	Food Agriculture Organization
FSAI	Food Safety Authority of Ireland
FSANZ	Food Standards Australia New Zealand
FSIS	Food Safety and Inspection Service
IFT	Institute of Food Technologist
MPN-PCR	Most Probable Number-Polymerase Chain Reaction
MRA	Microbiological Risk Assessment
NRC	National Research Council
NTS	Non-typhoidal *Salmonella*
QMRA	Quantitative Microbiological Risk Assessment
STEC	Shiga-toxigenic *Escherichia coli*
US FDA	United States Food and Drug Administration
USA	United States of America
USDA	United States Department of Agriculture
WHO	World Health Organization
FoSIM	Malaysian's Food Safety and Quality Division

CHAPTER 1

INTRODUCTION

1.1 Background

The microwave oven is now an indispensable and popular item in every household as it reheats food quickly than conventional heating. Based on dielectric heating, the interaction between the microwaves and the food, particularly the water molecules produce volumetric heating which heats the food from inside out in a short period. When exposed to microwaves, the molecules will either re-orientate themselves according to the electromagnetic field or do not react. At a certain period, the re-orientating molecules lag behind which is then converted to heat energy used to heat up the food. Ionic conduction also occurs with the presence of charged molecules in the food whereby the charged molecules will vibrate and generate heat from friction.

In the current food technology, microwave heating is expanding into the food industry with many applications such as drying, bread baking, tempering, thawing and precooking. The potential of microwave heating is expected to be widely applied in the food industries in the future as it has emerged as a viable alternative for thermal processing by providing flexibility of usage in most operation units and a time-saving process.

1.2 Problem Statement

The popularity of using a microwave oven to prepare food continues to increase as shorter time of meal preparation is only required. Despite the added advantage, much research is still being conducted on microwave heating due to its major drawback of uneven heating distribution. This had led to a major food safety concern of the food being reheated in a microwave oven, in particular microbiological hazard. Insufficient heating of the food will allow the pathogens and spoilage microorganisms to survive through the thermal treatment and cause infection or intoxication. Outbreak cases concerning the consumption of food reheated with the microwave oven have been reported mostly in the United States of America (USA) with the most recent case in 2013. The safety of the food being reheated using a microwave oven is evidently an issue neglected by today's society. The risk of one suffering from foodborne illness via the consumption of microwave heated food is present.

1.3 Objectives

Generally, this study conducted aimed to scientifically address the microbiological safety of microwave heated ready-to-eat foods. The study contained five specific chapters with the following objectives:

(a) To measure the Malaysian consumers' knowledge and practice and to understand their perspective of microwave oven safety
(b) To study the prevalence of the survivability of *Salmonella enterica* and Shiga-toxigenic *Escherichia coli* (STEC) O157 in microwave heated ready-to-eat food and the risk factors associated
(c) To investigate the influence of food composition to the microwave heating time in relation to the inactivation of *S. enterica* serovar Enteritidis and STEC O157
(d) To model the microwave heating inactivation of *S. enterica* serovar Enteritidis and STEC O157 using the Weibull model
(e) To perform the exposure assessment of *S. enterica* serovar Enteritidis and STEC O157 on microwave heated RTE food.

Microwave ovens can be seen in most convenience stores now and, even restaurants are using the microwave oven frequently. Consumers' knowledge on the microwave oven is relatively important to determine the safety of the food product. Therefore, the first study's objective was to measure their knowledge and practice of microwave oven emphasizing on food safety. Consumers' food safety attitude and concerns about microwave heated foods were also addressed.

The survivability of the naturally contaminated pathogens, particularly *Salmonella enterica* and Shiga-toxigenic *Escherichia coli* O157, in microwave heated ready-to-eat (RTE) food were evaluated. The survived pathogens were enumerated using the Most Probable Number-Polymerase Chain Reaction (MPN-PCR) technique and modelled through a simple exposure assessment to estimate the risk of consumption. The surviving factors of the pathogen were then studied extensively in the second study to identify the possible risk factors.

Based on the surviving factors, it was identified that the microwave heating time and the consumers' knowledge were essentially part of the main contributing factors of the pathogen survival apart from the uneven heating distribution. Hence, the third study focused more on the microwave heating time and explored the influence of food composition on microwave heating time in relation to the inactivation of the pathogens. The data collected was then subjected to model the microwave inactivation of the pathogens using the Weibull model in the third study.

To complete the study, a retail and consumer phase exposure assessment was conducted on *S. enterica* serovar Enteritidis and STEC O157 on microwave heated RTE foods. The retail and consumer phase exposure assessment model will incorporate the data and information from the previous studies to quantitatively assess the risk. Based on the characterized risk, interventions will be designed and evaluated to estimate the level of risk reductions.

All in all, it is hoped that this study will scientifically address the safety of microwave heated food and educate the public of the appropriate measures to be taken while microwave heating food to preserve the public health.

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