

**UNIVERSITI TEKNOLOGI MARA**

**ENHANCEMENT OF SEAWEED  
BIOAVAILABILITY FOR PHENOL  
PRODUCTION THROUGH  
FERMENTATION PROCESS USING  
*Aspergillus oryzae***

**NORAKMA BINTI MOHD NOR**

Thesis submitted in fulfillment  
of the requirements for the degree of  
**Doctor of Philosophy**  
**(Science)**

**Faculty of Applied Sciences**

**September 2021**

## CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 21 May 2021 to conduct the final examination of Norakma bt Mohd Nor on her **Doctor of Philosophy** thesis entitled “Enhancement of Seaweed Bioavailability for Phenol Production Through Fermentation Process using *Aspergillus oryzae*” in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiner recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

Professor Dr. Noorlaila Ahmad, PhD  
Professor  
Faculty of Applied Sciences  
Universiti Teknologi MARA  
(Chairman)

Associate Professor Dr Khalilah Abd  
Khalil, PhD  
Associate Professor  
Faculty of Applied Sciences  
Universiti Teknologi MARA  
(Internal Examiner)

Prof Wan Aida Wan Mustapha, PhD  
Professor  
Faculty of Sciences & Technology  
Universiti Kebangsaan Malaysia  
(External Examiner)

Dr Ir. Misnawi, PhD  
Senior Researcher  
Indonesian Coffee and Cocoa Research  
(ICCRI)  
(External Examiner)

**PROF IR. DR ZUHAINA HAJI  
ZAKARIA**

Dean  
Institute of Graduates Studies  
Universiti Teknologi MARA  
Date: 22 September 2021

## ABSTRACT

Edible seaweeds are a good source of antioxidants, dietary fibers, essential amino acids, vitamins, phytochemical and minerals. Phenolic compounds are usually extracted using hot water and organic solvent extraction. The disadvantage of these techniques is its low yield of bound phenolics. The ability of microbial fermentation to improve the yield and change the phenolic profiles was mainly due to the release of bound phenolic compounds by microbial enzymes produced during fermentation. The specific objectives of this study were to screen the fermentation method for better total phenolic content (TPC) production, to optimize the parameters (inoculum level, initial moisture content, temperature and fermentation days) during fermentation through Response Surface Methodology (RSM), to investigate the relationship between TPC and antioxidant activity with enzymes produced during fermentation, to study the effects of fermentation on the profiling, antimicrobial activity and characteristics of fermented seaweed extracts obtained and to determine the antioxidant activity, physico-chemical and sensory characteristics of chilli sauce incorporated with fermented seaweed extract. Results obtained indicated that solid state fermentation (SSF) was able to extract the highest TPC compared to submerged fermentation (SmF). The optimum SSF conditions using RSM was found at 4 days, 30 °C, 70% initial moisture content and 10% (v/v) inoculum level, respectively with desirability value 0.979. TPC, DPPH radical scavenging activity, total flavonoid content (TFC) and ferric-reducing antioxidant power (FRAP) showed positive correlation with cellulase,  $\beta$ -glucosidase and xylanase activity at  $p < 0.05$ . Total amino acid was also increased after SSF. However, phenolics profiles and volatile compounds showed some compounds were increased while some other compounds were decreased by SSF. Caffeic acid was found to present in all samples and also enhanced through SSF. The TPC and antioxidant activity of chilli sauce incorporated with fermented seaweed extracts were enhanced compared to raw fermented seaweed extracts and were superior compared to control chilli sauce. Physico-chemical characterisation of chilli sauce incorporated with fermented seaweed extracts showed that there was no serum separation observed after two months of storage. The results suggested that chilli sauce incorporated with fermented seaweed extract could be an alternative choice to corn starch in high acid foods. Therefore, the application of SSF in the seaweed processing industry can contribute to the development of value-added food ingredients with enhanced bioactivity.

## ACKNOWLEDGEMENT

In The Name of Allah, The Most Gracious and Merciful.

Alhamdulillah, praise to The Almighty Allah SWT who gave me the strength to complete this research project. First and foremost, I would like to express my deepest gratitude to my supervisor, Assoc. Prof. Dr Zaibunnisa Abdul Haiyee and my co-supervisor, Dr. Wan Razarinah Wan Abdul Razak for their support, guidance and constructive comments towards this thesis. May the precious knowledge that I gain from them will be rewarded by Allah SWT.

I would also like to express my sincere thanks to all lecturers at the Food Technology Division for their opinions and constructive comments during proposal defense and progress monitoring. My sincere thanks also go to non-academic staff especially Mr Ahmad Kambali and Mrs Norahiza for their invaluable assistance in various aspects.

I would also extend my appreciation to my workplace, Universiti Selangor for part-time study leave given during my study in UiTM, my colleagues in Department of Sciences and Biotechnology, Faculty of Engineering and Life Sciences who always support me in various aspects. Special thanks also go to non-academic staff especially Syawal and Fairuz for their help during my lab work in Unisel.

Thank you and best wishes to all my friends in UiTM especially Raihan, Asma, Hafsa, Ceah, Yan, Wan and Oyien for always there to share the problems and opinions throughout the journey. Their understanding and readiness to lend their helping hands throughout the completion of this project are very much appreciated.

Last but not least, I would like to express my endless gratitude to my late father and mother for their uncountable sacrifices, loves and affection. My special thanks goes to my beloved husband, Mr Muhamat Ude bin Eddy for always being by my side to give me support, attention and love, my children Faris, Arissa, Imran, Khadijah and Ammar and all my family members for their continuous support and understanding.

# TABLE OF CONTENTS

	<b>Page</b>
<b>CONFIRMATION BY PANEL OF EXAMINERS</b>	<b>ii</b>
<b>AUTHOR'S DECLARATION</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>iv</b>
<b>ACKNOWLEDGEMENT</b>	<b>v</b>
<b>TABLE OF CONTENTS</b>	<b>vi</b>
<b>LIST OF TABLES</b>	<b>xii</b>
<b>LIST OF FIGURES</b>	<b>xv</b>
<b>LIST OF PLATES</b>	<b>xvii</b>
<b>LIST OF SYMBOLS</b>	<b>xviii</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xix</b>
<b>LIST OF NOMENCLATURE</b>	<b>xx</b>
<b>CHAPTER ONE: INTRODUCTION</b>	<b>21</b>
1.1 Research Background	21
1.2 Problem Statement	23
1.3 Research Objectives	24
1.4 Thesis Outline	25
1.5 Significance of Study	26
<b>CHAPTER TWO: LITERATURE REVIEW</b>	<b>28</b>
2.1 Seaweed	28
2.1.1 <i>Kappaphycus alvarezii</i>	29
2.1.2 <i>Kappaphycus striatum</i>	31
2.2 Applications of Seaweed	32
2.3 Bioactive Compounds	33
2.3.1 Phenolic Compounds	34
2.3.2 Role of Phenolic Compounds in Seaweed	36
2.3.3 The Importance of Marine Algae as a Source of Antioxidants	37
2.3.4 The Chemical Structure of Phenolic Compounds in Seaweeds	38