



UNIVERSITI PUTRA MALAYSIA

***ELEMENTAL COMPOSITION OF FRUITS AND
VEGETABLES USING INAA, AAS, AND ICP-MS***

MOHAMMAD ALI SHAF AEI

FS 2012 54

**ELEMENTAL COMPOSITION OF FRUITS AND
VEGETABLES USING INAA, AAS, AND ICP-MS,**

MOHAMMAD ALI SHAFAEI

**DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA**

2012

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfillment of the Requirements for the Degree of Doctor of philosophy.**

May 2012.

The logo of Universiti Putra Malaysia (UPM) is centered in the background. It features a shield with a red and white design, including a book and a torch. The letters 'UPM' are prominently displayed at the top of the shield.

**ELEMENTAL COMPOSITION OF FRUITS AND
VEGETABLES USING INAA, AAS, AND ICP-MS**

By

MOHAMMAD ALI SHAFAEI

May 2012

This thesis dedicates to

My Family



© COPYRIGHT UPM

Abstract of thesis presented to the Senate of Universiti Putra Malaysia, in fulfillment
of the requirement for the degree of Doctor of Philosophy

ELEMENTAL COMPOSITION OF FRUITS AND VEGETABLES USING INAA, AAS, AND ICP-MS

By

Mohammad Ali Shafaei

May 2012

Chairman : Professor Elias Bin Saion, PhD

Faculty : Science

Industrial growth has provided peerless progress in living standards and comforts for mankind, but it has been the cause of menace of environmental pollution. The issues like chemical toxicology, acid rain, greenhouse effect, ozone depletion, industrial effluents, and marine pollution are universal in nature. Man is being unceasingly divulged to a large number of inorganic elements in a great variety of chemical forms and when they enter the human body they can cause toxicity effects resulting in deterioration of man general health. Knowledge of base line data of elemental compositions in fruits and vegetables is important to manage dietary adequacy of the population. In Malaysia, no systematic study on the dietary adequacy of essential heavy elements through fruits and vegetables has been published. The purpose of the present study is to determine the concentration of essential elements in fruits and

vegetables and to extrapolate the data for the dietary adequacy and regional dietary standards.

Instrumental Neutron Activation Analysis (INAA), Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) were employed in this study to determine the major elements (K, Mg, Ca) and heavy metals (Fe, Zn, Cu, Mn, Al, Co, Se, Ni, As, Hg, Pb, Cd, Cs, Th, Cr, La) of 14 types of fruits and 11 types of vegetables planted in Malaysia. Neutron irradiation and counting were performed using 500 kW of 1.1 MW TRIGA Mark at the Malaysian Nuclear Agency's research reactor. Sample powder was irradiated with thermal neutrons at flux average of $\phi = 2.03 \times 10^{12} \text{ n.cm}^{-2}.\text{s}^{-1}$ and the analysis was carried out using a hyper-pure germanium (HPGe) detector, multichannel analyzer module and Gamma Vision software. Biological standard materials (NIST-Tomato Leaves 1537a) and soil standard materials (IAEA-SOIL-7) were used as reference materials in the INAA technique. In ICP-MS, the elements of solution sample were identified by their mass-to-charge ratio (m/e) and the intensity of a specific peak in the mass spectrum is proportional to the amount of that element in the sample. In AAS, the solution sample was atomized before allowing light to pass and produced a line absorption spectrum, characteristics of the particular elements in the fruits and vegetables. No biological standard materials are needed in ICP-MS and AAS techniques. Samples were collected from a number of fresh markets at the centre of Kuala Lumpur, the capital of Malaysia and transported to the laboratory within one day to prepare the final samples for INAA, ICP-MS and AAS techniques.

The results of INAA, ICP-MS and AAS analyses, we found that there is a variation in the amount of each element for Malaysian fruits and vegetables. For the major

elements (K, Mg, Ca), K concentrations in fruits were from $10,615 \pm 500$ ppm (Jasopine pineapple) to $33,353 \pm 600$ ppm (melon) and from $9,749 \pm 1000$ ppm (egg-plant) to $51,196 \pm 900$ ppm (red spinach) in vegetables. Mg concentrations in fruits were from 680 ± 30 ppm (Morise pineapple) to $5,543 \pm 400$ ppm (red banana) and from 690 ± 140 ppm (carrot) to $3,852 \pm 500$ ppm (cucumber) in vegetables. Ca concentrations were from $1,064 \pm 127$ ppm (baby banana) to $6,888 \pm 800$ ppm (durian) in fruits and from 1100 ± 130 ppm (chili) to $8,000 \pm 900$ ppm (green bean) in vegetables.

For the heavy metal elements in fruits Mn concentration ranged from 12.0 ± 0.5 ppm (Morise pineapple) to 69 ± 1 ppm (Max banana), Fe concentration from 23.4 ± 2.8 (papaya) to 126 ± 15 ppm (watermelon), and Zn concentration from 19 ± 2 ppm (max banana) to 168 ± 20 ppm (pisang banana). While for the heavy metal elements in vegetables, Mn concentration ranged from 32.0 ± 0.9 ppm (carrot) to 316 ± 16 ppm (spinach), Fe concentration from 58 ± 3 (pumpkin) to 470 ± 56 ppm (spinach), and Zn concentration from 26 ± 3 ppm (pumpkin) to 312 ± 37 ppm (spinach).

The percentage intake of all elements was calculated for the Recommended Dietary Allowance (RDA) values for Malaysian fruits and vegetables per 100 g of eatable section. The highest percentage intakes of elements are for K, Mg, Ca, Mn, Zn, Cu, Ni, Al, and Fe, which can be achieved from eating Malaysian fruits and vegetables.

Co in spinach and star fruit were found to be the highest percentage intake of vegetables and fruits. Based on this result, spinach and star fruit can be a good source of Co, respectively each vegetable and fruit with 35% and 5% supply of this element to the recommended value of Co in the form of vitamin B₁₂.

An interesting point is that; the mean range of Pb, Hg, and Cd is lower than the tolerable upper intake level (UL), and some of the other elements such as Cr, Cs, and Se, showed near the range of UL for Malaysian fruits and vegetables, for example, Cr in durian, guava, papaya, cabbage, chili, chili padi, spinach, and red spinach, and Cs and Se, in durian and carrot respectively.

The statistical dependence between concentrations of element presents in fruits and vegetables and between types of fruits and vegetables were determined using the cluster analysis. According to the cluster analysis, the results revealed similarity in two or more than two of different fruits or vegetables, dose not mean the same affection on nutrition health.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KOMPOSISI UNSUR BUAH-BUAHAN DAN SAYUR OLEH INAA, AAS, DAN ICP-MS

Oleh

Mohammad Ali Shafaei

Mei 2012

Pengerusi : Profesor Elias Bin Saion, PhD

Faculti: Sains

Pertumbuhan perindustrian telah memberi kemajuan pesat kepada taraf hidup dan kesejahteraan umat manusia, tetapi telah menyebabkan ancaman pencemaran alam sekitar. Isu-isu seperti toksikologi kimia, hujan asid, kesan rumah hijau, penipisan ozon, efluen industri dan pencemaran hidupan laut adalah bersifat universal sekarang ini. Manusia sentiasa terdedah kepada sejumlah besar unsur-unsur tak organik dalam pelbagai bentuk kimia dan apabila bahan ini memasuki tubuh manusia boleh menyebabkan kesan toksik dan menjejaskan kesihatan manusia.

Pengetahuan tentang data garis asas komposisi unsur dalam buah-buahan dan sayur-sayuran adalah penting untuk mengurus kecukupan diet kepada populasi rakyat Malaysia. Sehingga ini tiada kajian sistematik terhadap kecukupan diet unsur-unsur berat yang penting terdapat dalam buah-buahan dan sayur-sayuran telah diterbitkan. Tujuan kajian ini adalah untuk menentukan kepekatan unsur-unsur penting dalam

buah-buahan dan sayur-sayuran dan membuat penentuan data untuk kecukupan diet dan piawai pemakanan.

Analisis Pengaktifan Neutron Instrumen (INAA), Spektroskopi Penyerapan Atom (AAS) dan Spektroskopi Jisim Induktif Gandingan Plasma (ICP-MS) telah digunakan dalam kajian ini untuk menentukan unsur-unsur utama (K, Mg, dan Ca) dan logam berat (Fe, Zn, Cu, Mn, Al, Co, Se, Ni, As, Hg, Pb, Cd, Th, Cr dan La) dalam 14 jenis buah-buahan dan 11 jenis sayur-sayuran yang ditanam di Malaysia. Penyinaran neutron dan pengiraan dilakukan menggunakan 500 kW daripada reactor penyelidikan 1.1 MW TRIGA Mark di Agensi Nuklear Malaysia. Serbuk sampel didedahkan kepada fluks neutron purata keratan rentas $G = 2.03 \times 10^{12} \text{ n/cm}^2 \cdot \text{s}$ dan analisis telah dijalankan dalam menggunakan pengesan hiper-tulin germanium (HPGe), penganalisis modul berbilang saluran dan perisian Gamma Vision. Bahan biologi standard (NIST-Daun Tomato 1537a) dan bahan tanah standard (IAEA-Tanah 7) telah digunakan sebagai bahan rujukan dalam teknik INAA. Dalam kaedah ICP-MS unsur-unsur dikenal pasti dengan cara nisbah (e/m) dan keamatan puncak spectrum jisim adalah berkisar kepada jumlah unsur yang terdapat dalam sampel. Dalam kaedah AAS sampel larutan dijadikan atom terlebih dahulu sebelum membenarkan cahaya menembusi dan menghasilkan spektrum penyerapan garis cirikan unsur tertentu dalam buah-buahan dan sayur-sayuran. Tiada bahan biologi piawai diperlukan dalam teknik ICP-MS dan AAS. Semua sampel buah-buahan dan sayur-sayuran dikumpulkan daripada beberapa pasaraya di tengah-tengah Kuala Lumpur, ibukota Malaysia dan dibawa ke makmal dalam tempoh satu hari untuk penyediaan sampel teknik INAA, ICP-MS dan AAS.

Daripada keputusan analisis, kami mendapati bahawa terdapat perubahan dalam jumlah kepekatan setiap unsur untuk semua buah-buahan dan sayur-sayuran. Bagi kepekatan unsur-unsur utama (K, Mg dan Ca), kepekatan K dalam buah-buahan adalah $10,615 \pm 500$ ppm (nanas Jasopine) kepada $33,353 \pm 600$ ppm (tembikai) dan dalam sayur-sayuran adalah daripada $9,749 \pm 1,000$ (terung) kepada $51,196 \pm 900$ ppm (bayam merah). Kepekatan Mg dalam buah-buahan adalah daripada 680 ± 30 ppm (nanas Morise) kepada $5,543 \pm 400$ ppm dan daripada 690 ± 140 ppm (lobak merah) kepada $3,852 \pm 500$ ppm (timun) dalam sayuran-sayuran. Kepekatan Ca daripada $1,064 \pm 127$ ppm (pisang) kepada $6,888 \pm 800$ ppm (durian) dalam buah-buahan dan daripada 1100 ± 130 ppm (cili) kepada $8,000 \pm 900$ ppm (kacang hijau) dalam sayur-sayuran.

Sebaliknya kepekatan unsur-unsur logam berat dalam buah-buahan adalah antara 12.0 ± 0.5 ppm (nanas Morise) dan 69 ± 1 ppm (pisang) untuk Mn, antara 23.4 ± 2.8 ppm (kepaya) dan 126 ± 15 (tembikai) untuk Fe dan antara 19 ± 2 ppm (pisang) dan 168 ± 20 ppm (pisang) untuk Zn. Kepekatan unsur-unsur logam berat dalam sayur-sayuran adalah antara 32.0 ± 0.9 ppm (lobak merah) dan 316 ± 16 ppm (bayam) untuk Mn, antara 58 ± 3 ppm (labu) dan 470 ± 56 ppm (bayam) untuk Fe dan antara 26 ± 1 ppm (labu) dan 312 ± 37 ppm (bayam) untuk Zn.

Pengambilan puratus semua unsur telah dikira bagi elaun permakanan yang disyorkan untuk buah-buahan dan sayur-sayoran Malaysia bagi setiap 100 g bahagian yang dapat dimakan. Pengambilan puratus tertinggi adalah untuk

elemen K, Mg, Ca, Mn, Zn, Cu, Ni, Al, dan Fe yang boleh dicapai dengan memakan buah-buahan dan sayur-sayuran Malaysia. Kepekatan Co dalam bayam dan belimbing merupakan peratusan tertinggi pengambilan buah-buahan dan sayur-sayuran Malaysia. Berdasarkan keputusan ini bayam dan belimbing boleh menjadi satu sumber Co yang baik dengan masing-masing membekalkan 35% dan 5% nilai Co yang disyorkan dalam bentuk vitamin B₁₂.

Suatu yang menarik adalah julat min bagi Pb, Hg, dan Cd adalah lebih rendah daripada pengambilan tahap atas (UL) dan beberapa unsur lain seperti Cr, Cs, dan Se memunjukkan menghampiri julat UL buah-buahan dan sayur-sayuran, contohnya durian, kepaya, kobis, lada, cili padi, bayam dan bayam merah, dan Cs dan Se masing-masing dalam durian dan lobak merah.

Pergantungan statistik antara kepekatan unsur yang hadir dalam buah-buahan dan sayur-sayuran dan antara jenis buah-buahan dan sayur-sayuran telah ditentukan dengan menggunakan kaedah klompok. Menurut analisis kluster, keputusan menunjukkan bahawa kesamaan antara dua atau lebih buah-buahan atau sayur-sayuran tidak menunjukkan kecenderungan yang sama terhadap nutrasi pemakanan kesihatan.

ACKNOWLEDGEMENTS

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

In the name of God, the Most Gracious, the Merciful

First of all, all praises due Allah, Lord of universe. Only by His grace and mercy this thesis has been completed.

I would like to take this opportunity to express my most grateful and deep appreciation to my supervisor and Chairman of the Supervisory Committee Professor Dr. Elias Saion for his sincere and invaluable guidance, honestly encouragement, and patience throughout my research.

I would like to extend my heartfelt gratitude to the members of my supervisory Committee, Dr Abdul Khalik Wood, Dr Halimah Mohamed Kamari, Prof. Dr. W. Mahmood Mat Yunus, and Dr Kok Sinong Khoo for their constructive comments and criticisms.

Thanks are expressed to the Malaysian Nuclear Agency (MNA) for their continuous supporting and the usage of their facilities. I am very much thankful and especial thanks to Mr. Md Suhaimi Elias, Mr. Ariffin Talib, Mr. Lim, Mrs. Jammiliy and Mrs. Irean for their help in collection of data in the laboratories.

I would like to extend my great thanks the staff of the Department of Physics, Universiti Putra Malaysia.

I would like to express my deepest gratitude to my father, mother, and mother in law. Especial thanks to my father in law, Haj Mohammad Safizadeh with material and moral help.

Finally, I would like to express my sincere gratitude to my wife, Zohreh Safaizadeh and my daughter Delaram and my son Danial for their patience and prayers.

APPROVAL SHEETS

This thesis was submitted to the Senate of University 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:

Elias B Saion, PhD

Professor

Faculty of Science

University Putra Malaysia

(Chairman)

Wan Mahmood B Mat Yunus, PhD

Professor

Faculty of Science

University Putra Malaysia

(Member)

Halimah Bt Mohamed Kamari, PhD

Associate Professor

Faculty of Science

University Putra Malaysia

(Member)

Kok Siong Khoo, PhD

Faculty of Science and Technology, Universiti Kebangsaan Malaysia

(Member)

BUJANG BIM KIM HUAT, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia
Date:09.08.2012

I certify that a Thesis Examination Committee has met on 7th May 2012 to conduct the final examination of MOHAMMAD ALI SHAFAEI on his thesis entitled “**Elemental composition of fruits and vegetables using INAA, ICP-MS, and AAS**” in accordance with the Universities and University colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the examination Committee are as follows:

Prof. Dr. Azmi B Zakaria
PhD
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Prof. Dr. Abdul Halim B Shaari
PhD
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Prof. Dr. Zainal Abidin B Sulaiman
PhD
Pusat Asasi Pertanian
Universiti Putra Malaysia
(Internal Examiner)

Prof. Dr Pawel Pohl
PhD
Faculty of Chemistry
Wroclaw Univeristy of Technology
Faculty of Chemistry, DiVision of Analytical Chemistry 50-370 Wroclaw Wybrzeze
Stanistawa Wyspianskiego 27
Poland
(External Examiner)

SEOW HENG FONG, PhD

Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:09.08.2012

DECLARATION

I declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or other institutions.



Mohammad Ali Shafaei

TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	v
ACKNOWLEDGEMENTS	ix
APPROVAL SHEETS	x
DECLARATION	xii
LIST OF TABLES	xxi
LIST OF FIGURES	xxiv
LIST OF ABBREVIATIONS	xxxi

CHAPTER

1 INTRODUCTION

1.1	General introduction	1
1.2	Significance of study	2
1.3	Problem statement	2
1.4	The scope of the present study	3
1.5	Objectives of the study	4
1.6	Outline of the thesis	5

2 LITERATURE REVIEW

2.1	Introduction	6
2.1.1	Instrumental Neutron Activation Analysis (INAA)	6
2.1.2	Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	7
2.2	Determination of element concentrations by INAA	8
2.3	Determination of concentration elements using AAS and ICP-MS	11
2.4	Studies of elemental concentrations of fruits and vegetables	12
2.5	Nutritional in human	14
2.5.1	Minerals	16
2.5.2	Major Elements	16
2.5.3	Heavy metal Elements	19

3 THEORETICAL

3.1	Introduction	25
3.2	Simply of describing about Neutron Activation Analysis	25

3.3	Principle of NAA	27
3.4	Neutron Energy Classification	29
3.5	Interaction of Neutron with Matter	32
3.5.1	Elastic Scattering	33
3.5.2	Inelastic scattering	34
3.5.3	Transmutation	35
3.5.4	Radioactive Capture Reaction	36
3.6	Neutron Cross Sections	36
3.6.1	Dependence of Neutron Interaction cross section into energy	38
3.7	Neutron Sources	40
3.7.1	Theory of Neutron Activation Analysis	42
3.8	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	44
3.8.1	ICP-MS—The Quadrupole Mass Analyzer	47
3.8.2	ICP-MS—The High-Resolution Mass Analyzer	48
3.9	Atomic Absorption Spectrometry (AAS)	50
4	MATERIAL AND METHODS	
4.1	Introduction	54
4.1.1	INAA Technique	54
4.2	Gammy-Ray spectrometry system	61
4.2.1	Energy calibration of gamma-ray Spectroscopy system	66
4.2.2	Absolute Efficiency Calibration of HPGe Detectors	68

4.2.3	Efficiency Calibration of Gamma-Ray Spectroscopy	
	System (ξ_p)	72
4.2.3.1	Full energy peak detection efficiency	73
4.2.3.2	Lower limited of detection	80
4.3	Irradiation Facility	80
4.3.1	Triga Mark II Nuclear Research Reactor	82
4.3.2	INAA-Comparative Method	85
4.4	Samples Preparation	89
4.4.1	INAA: Sample Preparation	91
4.4.2	Preparation of Standard Solutions Used For Calculation the Elemental Concentrations	93
4.5	Atomic Absorption Spectrometry (AAS)	96
4.6	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	97
4.7	AAS, and ICP-MS; Sample Preparation	98
4.8	Cluster analysis	99
5	RESULTS AND DISCUSSION	
5.1	Introduction	100
5.2	Applicability of the INAA, AAS and ICP-MS, Technique for Analysis of concentration of elements in Malaysian fruits and vegetables	101
5.3	Data analysis of concentration of elements of fruits and vegetables	107
5.3.1	Evaluation of element concentration in Malaysian banana (<i>Musa acuminata</i>)	108
5.3.2	Equation of element concentrations in bananas	112

5.3.2.1	Dietary intake Level of Elemental Malaysian banana	114
5.3.2.2	Comparison of the result with previous researchers	116
5.3.2.3	Potassium (K) concentration in Malaysian bananas other results.	117
5.3.2.4	Magnesium (Mg) concentration in Malaysian bananas other results.	118
5.3.2.5	Calcium (Ca) element concentration in Malaysian banana	119
5.3.2.6	Zinc (Zn) concentration in Malaysian bananas other results	119
5.3.2.7	Manganese (Mn) element concentration in Malaysian banana	121
5.3.2.8	Iron (Fe) element concentration in Malaysian banana	121
5.4	Evaluation of element concentration in watermelon (<i>citrullus lanadtus</i>)	122
5.4.1	Equation of element concentrations in watermelon	125
5.4.2	Dietary intake level of elemental Watermelon	126
5.4.3	Compare the result with other researchers for Watermelon	128
5.5	Evaluation of element concentrations in Malaysian pineapple (<i>Ananascomosus</i>)	131
5.5.1	Equation of element concentrations in Pineapple	134
5.5.2	Dietary intake level of elemental Pineapple.	135
5.5.3	Comparison of the result with other researchers on Pineapple	137
5.6	Evaluation of element concentration in Malaysian guava (<i>Psidium guajava</i>)	139

5.6.1	Equation of element concentrations in Malaysian guava	142
5.6.2	Dietary intake level of elemental Guava	143
5.7	Determination of element concentration in Malaysian star fruit (<i>Averrhoa carambola</i>)	145
5.7.1	Equation of element concentrations in Malaysian Star fruit	147
5.7.2	Dietary intake level of elemental Star fruit	148
5.8	Evaluation of element concentration in Malaysian papaya (<i>Carica Papaya</i>)	149
5.8.1	Equation of element concentrations in Malaysian papaya	152
5.8.2	Dietary intake level of elemental Papaya	152
5.9	Determination of element concentration in Malaysian dragon fruit (<i>Hylocereus undatus</i>).	153
5.9.1	Equation of element concentrations in Malaysian dragon fruit	155
5.9.2	Dietary intake level of elemental Dragon fruit	156
5.10	Determination of element concentration in Malaysian durian (<i>Durio zibethinus</i>).	157
5.10.1	Equation of element concentrations in Malaysian durian	159
5.10.2	Dietary intake level of elemental Durian	160
5.11	Determination of element concentration in Green Bean (<i>Phaseolus vulgaris</i>).	161
5.11.1	Equation of element concentrations in Malaysian green bean	164
5.11.2	Dietary intake level of elemental Green bean	165
5.12	Evaluation of element concentration in Chili (<i>Capsicum</i>)	167
5.12.1	Equation of element concentrations in Chili	170
5.12.2	Dietary intake level of elemental Chili	170

5.13	Determination of element concentration in Spinach (<i>Spinaciaoleracea</i>)	172
5.13.1	Equation of element concentrations in Malaysian spinach	175
5.13.2	Dietary intake level of elemental Spinach	176
5.14	Evaluation of element concentration in Malaysian Cabbage (<i>Brassica oleracea var. capitata L.</i>)	178
5.14.1	Equation of element concentrations in Malaysian cabbage	180
5.14.2	Dietary intake level of elemental Cabbage	181
5.15	Evaluation of element concentration in Malaysian cucumber (<i>Cucumis sativus</i>)	183
5.15.1	Equation of element concentrations in Malaysian cucumber	186
5.15.2	Dietary intake level of elemental Cucumber	186
5.16	Determination of element concentration in Egg-Plant (<i>Solanum melongena L</i>)	188
5.16.1	Equation of element concentrations in egg-plant	190
5.16.2	Dietary intake level of elemental Egg-plant	191
5.17	Determination of element concentration in Carrot (<i>Daucas carota L</i>)	193
5.17.1	Equation of element concentrations in Malaysian carrot	195
5.17.2	Dietary intake level of elemental Carrot	196
5.18	Determination of element concentration in Pumpkin (<i>Disambiguation pumion</i>)	198
5.18.1	Equation of element concentrations in Malaysian pumpkin	200
5.18.2	Dietary intake level of elemental Pumpkin	201

5.19	Clustering Analysis of fruits and vegetables	202
5.19.1	Statistical dependence of Elements concentration in Malaysian fruits and vegetables	203
5.19.2	Cluster analysis of K concentration in Malaysian fruit	204
5.19.3	Cluster analysis of K concentration in Malaysian vegetables	205
5.19.4	Cluster analysis of Mg concentration in Malaysian fruit	207
5.19.5	Cluster analysis of Mg concentration in Malaysian vegetables	209
5.19.6	Cluster analysis of Ca concentration in Malaysian fruits	210
5.19.7	Cluster analysis of Ca concentration in Malaysian vegetables	212
5.19.8	Similarity of Malaysian fruits	213
5.19.9	Similarity of Malaysian vegetables	214
5.20	Element concentrations compared to other countries	216
5.20.1	Comparison of Potassium (K) with other results	216
5.20.2	Comparison of Magnesium (Mg) with other results	221
5.20.3	Comparison of Calcium (Ca) with other results	225
5.20.4	Comparison of Manganese (Mn) with other results	229
5.20.5	Comparison of Iron (Fe) with other results	233

6 CONCLUSION AND FUTURE WORK

6.1	Conclusion	238
6-2	Future work and recommendations	242

REFERENCES	243
-------------------	-----

BIODATA OF STUDENT	252
---------------------------	-----