PROFILING OF MINERAL CONTENTS OF TYPICAL MALAYSIAN MUSLIM FOODS

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To

1. *My beloved wife Mrs Simiat Olaide Adedeji-Salau*
2. *My Children: Zainab,Sherifdeen, Sururah, Barakah and Ridwan*
3. *The struggle for the emancipation of the opressed and the deprived*

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ABSTRACT

Mineral malnutrition is said to account for 11 per cent of the global burden of disease. It is a disease condition in which the amount or concentration of one or more mineral elements known to be essential to human health is found to be low and detrimental to health. Mineral deficiency diseases (MDD) are worth looking into as they could be very drastic, sometimes leading to death or permanent disabilities. The current approaches in tackling the problem of micronutrient malnutrition are based on four options: fortification, supplementation, education and control. This study offers the need to approach the solution to the mineral malnutrition by sourcing the micronutrients from a natural and less cumbersome source like the commonly eaten foods which are accessible, cheaper, needs no expertise and above all, meet the conditions of green health concept. The mineral load of five essential major elements (Ca, Mg, P, K and Na), and nine trace elements (Cr, Co, Cu, Fe, Mn, Mo, Ni, Se and Zn) and three toxic trace elements (As, Cd, and Pb) were quantified in 41 types of Malaysian food dishes samples. The samples were oven dried, homogenised and wet ashed with nitric acid and hydrogen peroxide. The elements were determined using flame photometry, flame atomic absorption spectrometry and inductively coupled plasma mass spectrometry. All of the studied elements were present in the samples. They have good food quality ratios of Ca:P (0.1-2.5) and K:Na (0.9-2.9). When compared with the dietary allowance benchmarks, minimum 40% to maximum 180% of values as in K and Se can be met by the foods. Some of the studied foods have self-sufficient and self-supplementing tendency to be relevant in the maintenance of health and management of MDD. The foods are also within safe level. The essential elements were 0.5-63.0% of Upper Tolerable Limit (UL), while, the trace elements were 0.2-77.3% of Provisional Tolerable Daily Intake (PTDI). The score/loading biplot of the Principal Component Analysis (PCA) facilitated the discovery of foods which are mineral rich as well as those prone to toxic elements toxicity. The Hierarchical Cluster Analysis (HCA) dendrogram identified close substitute foods which facilitate wider food choices to the consumers. Finally, a simple food informatics software (MDD-FG) was developed to provide information about MDD, implicated mineral elements as well as the relevant Malaysian food dishes. The software was adjudged simple, user friendly and effective by over 80% end user respondents. In the future, the research could be extended as national project covering more foods and wider geographical regions. Further study on mineral elements bioavabilty in food intakes is also crucial.

ABSTRAK

Kekurangan zat mineral dikatakan menyumbang sebanyak 11 peratus daripada beban global penyakit. Ia adalah keadaan di mana amaun atau kepekatan satu atau lebih daripada unsur mineral yang dikenalpasti penting untuk kesihatan manusia didapati rendah dan memudaratkan kesihatan. Penyakit kekurangan mineral (MDD) wajar dikaji kerana ia boleh menjadi sangat drastik, kadang-kadang membawa kepada kematian atau kehilangan upaya yang kekal. Pendekatan semasa dalam menangani masalah kekurangan zat makanan mikronutrien adalah berdasarkan kepada empat komponen pilihan: pengayaan, suplemen, pendidikan dan kawalan. Kajian ini menawarkan pendekatan dalam menyelesaikan masalah kekurangan zat mineral dengan mengambil mikronutrien daripada punca sumber semula jadi dan kurang membebankan, misalnya makanan yang biasa dimakan yang senang didapati, murah, tidak memerlukan kepakaran dan lebih penting, memenuhi syarat konsep kesihatan hijau. Muatan mineral lima unsur penting yang utama (Ca, Mg, P, K dan Na), dan sembilan unsur surih (Cr, Co, Cu, Fe, Mn, Mo, Ni, Se dan Zn) dan tiga unsur surih toksik (As, Cd, dan Pb) telah ditentukan secara kuantitatif dalam 41 jenis sampel hidangan makanan Malaysia. Sampel telah dikeringkan menggunakan ketuhar, dihomogenkan dan melalui proses pengabuan basah menggunakan asid nitrik dan hidrogen peroksida. Unsur telah tentukan menggunakan fotometeri nyala, spektrometri serapan atom nyala dan spektrometri jisim-plasma aruhan berganding. Semua unsur yang dikaji terdapat dalam sampel makanan yang dianalisis. Sampel makanan tersebut mempunyai nisbah kualiti makanan Ca:P (0.1-2.5) dan K:Na (0.9-2.9) yang baik. Apabila dibandingkan dengan penanda aras diet dibenarkan, minimum 40% sehingga maksimum 180% daripada nilai seperti dalam K dan Se dapat dipenuhi oleh makanan tersebut. Sebahagian daripada makanan yang dikaji mempunyai sifat keupayaan kendiri dan suplemen kendiri yang didapati relevan dalam penyelenggaraan kesihatan dan pengurusan MDD. Makanan tersebut juga adalah dalam julat selamat. Unsur penting adalah 0.5-63.0% daripada had atas toleransi maksimum (UL), manakala, unsur surih adalah 0.2-77.3% daripada Toleransi Pengambilan Harian Sementara (PTDI). Biplot skor/muatan bagi Analisis Komponen Utama (PCA), memudahkan penemuan makanan yang kaya dengan sumber mineral dan juga makanan yang mudah terdedah kepada unsur toksik. Dendogram Analisis Kluster Hierarki (HCA) mengenalpasti makanan pengganti hampir yang membantu pengguna membuat pemilihan makanan yang lebih luas. Akhir sekali, suatu perisian informatik makanan (MDD-FG) telah dibangunkan untuk menyediakan maklumat mengenai MDD, unsur mineral yang terlibat serta hidangan makanan Malaysia yang berkaitan. Sebanyak 80% daripada responden pengguna akhir mengklasifikasikan perisian tersebut sebagai mudah, mesra pengguna dan efektif. Pada masa akan datang, kajian ini boleh dijadikan projek nasional dengan mempelbagaikan jenis makanan dan memperluaskan lagi liputan geografi pengambilan sampel. Kajian lanjutan mengenai keterbiosediaan unsur mineral dalam pengambilan makanan juga penting untuk dilakukan.

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LIST OF ABBREVIATIONS

AAS	-	Atomic Absorption Spectrometry
AES	-	Atomic Emission Spectrometry
AI	-	Adequate Intake
AMDR	-	Acceptable Macronutrient Distribution Range
ANOVA	-	Analysis of Variance
AOAC	-	Association of Official Analytical Chemists
ASP.NET	-	Active Server Page . Network Enabled Technology
AXICP-AES	-	Inductively Coupled Plasma Atomic Emission Spectrometry
C & RT	-	Classification and Regression Tree
Cor A	-	Correlation Analysis
CRM	-	Certified Reference Materials
DIICPMS	-	Dry Injection Inductively Coupled Plasma Mass Spectrometry
FA	-	Factor Analysis
GFAAS	-	Graphite Furnace Atomic Absorption Spectrometry
HCA	-	Hierarchal Cluster Analysis
ICP-AES	-	Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-DRC-MS	-	Inductively Coupled Plasma Dynamic Reaction Cell Mass Spectrometry
ICP-MS	-	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	-	Inductively Coupled Plasma Optical Emission Spectrometry
ID-ICPMS	-	Isotopic Dilution Inductively Coupled Plasma Mass Spectrometry
IDE	-	Integrated Drive Electronics
INAA	-	Instrumental Neutron Activation Analysis
IUPAC	-	International Union of pure and Applied Chemistry
KNN	-	K-nearest neighbour
LDA	-	Linear Discriminate Analysis

LOD	-	Limit of Detection
LOQ	-	Limit of Quantitation
MATLAB	-	Mathematical Laboratory
MDD	-	Mineral Deficiency Diseases
MDD-FG	-	Mineral Deficiency Diseases-Food Guide
ML		Maximum Level
MSSQL	-	Microsoft Structured Query Language
MVA	-	Multivariate Analysis
NIST	-	National Institute of Standard and Technology
OES	-	Optical Emission Spectrometry
PC	-	Principal Component
PCA	-	Principal Component Analysis
PCR	-	Principal Component Regression
PLS	-	Partial Least Square
Ppb	-	Part per billion
PTDI		Provisional Tolerable Daily Intake
PTWI		Provisional Tolerable Weekly Intake
QA	-	Quality Assurance
QC	-	Quality Control
QCS	-	QCS Quality Control Sample
RAM	-	Random Acess Memory
RDA	-	Recommended Dietary Allowance
RNI	-	Recommended Nutrient Intake
RSD	-	Relative Standard Deviations
SIMCA	-	Soft Independent Modelling Class Analog
SPSS	-	Statistical Package for Social Science
SQL	-	Structured Query Language
SRM	-	Standard Reference Materials
TXRF	-	Total Reflection X- Ray Fluorescence
UTC Format	-	Universal Time Coordinated Format
XAML	-	Extensible Application Markup Language
XRF	-	X- Ray Fluorescence

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Foods are consumed for their nutritive and nourishment values. The quest to consume foods that confer nourishment to the body, qualitatively, quantitatively and yet affordable, has been the ultimate goal of food researchers. The chemists' roles in food research are enormous. These roles range from determination, characterization to analysis of food nutritional values and their chemical compositions. Usually, foods are eaten either in raw form, processed or in cooked form. Naturally, people eat or drink to respond to hunger and thirst respectively. However, most of the times choice of food is more based on affordability. The challenge of modern research is therefore to initiate a nutritional awareness of quality foods that are locally available and also affordable.

Determination of the mineral content of food, which is the focus of this study, is all about chemical and physical techniques in quantifying the mineral elements contained in foods. Minerals are the inorganic chemical elements present in foods and which are needed to assist in various body functions, particularly, to regulate body fluids and main body interaction. Mineral elements are essentially needed in small quantities (major elements) and minute or smaller quantities (trace elements). Mineral elements work hand in hand with other food classes like vitamins as co-

factors and also promote the functioning of the macronutrients like carbohydrate, fats and protein.

Chemical nature and composition of food that an individual eats have great role on his or her well-being. When data is generated about a diet one is able to discuss the adequacy or otherwise of the dietary consumption of people in a particular locality. The nature of the mineral elements consumed by the individual can also enable us to quantify the toxicity, health risk and safety of foods as well as the individuals eating them.

Malaysia as a developing nation with a good score card on effort to combat hunger among its citizens, ranked 81 among 185 selected countries across the world (WHO, 2009) with health expenditure per capita of USD 336.44 compared to China (USD 177.15) and Thailand (167.70). This is a measure of concern and Government intervention into health and nutritional matters. Similarly, corollary statistics by UNO (2000) and Somsiah (2000) put percentage of child malnutrition level in Malaysia at 16.7 in 1999 reducing to 10.7 in 2010 (Eunice *et al.*, 2014 and Ministry of Health, 2011). These are good records that need to be improved. What is therefore of major concern now to Malaysia is to tilt research focus towards the studies of quality and quantity of the nutritional entities in food.

The United Nation perspective forum called 'The Copenhagen Consensus', produced a challenge paper (Horton *et al.*, 2008) which focused on hunger and malnutrition, an adjustment of the earlier slogan of poverty and hunger. This is in realization of not just satisfying hunger, but also to focus on the qualitative and quantitative aspects of nutrition. Some essential minerals (iodine, iron and zinc) were figured out as global nutritional deficits which require immediate interventions in terms of supplementation. Iodine, iron and zinc supplementations were key priorities. In addition, earlier WHO/FAO reports (1996, 2001, 2005 and 2008) have identified Selenium, Copper as other essential elements of priorities. WHO/FAO joint expert

consultation in Bangkok, 1998, also identified Calcium and Magnesium in the major elements category to be considered for supplementation and fortification.

Mineral deficiency disease is a condition in which the amount or concentration of one or more mineral elements known to be essential to human health is found to be low and detrimental to health. Mineral deficiency diseases could be very drastic sometimes leading to death or permanent disabilities. Table 1.1 highlights various deficiency diseases associated with the mineral elements earmarked for study. Information is sourced from Acu-Cell-Nutrition (2014), FAO/WHO (2004) and UNICEF (2010).

Table: 1.1: Mineral elements and deficiency diseases

Elements	**Deficiency diseases and their characteristics**
Calcium	Hypocalcaemia characterised by Osteomalacia (bone matrix not mineralised), Osteoporosis (fragile bones), Arthritis (joint pain).
Magnesium	Hypomagnesemia characterized by Metabolism and nutritional disorders, nervousness, convulsion, menstrual difficulties and cardiac (heart) disorder.
Phosphorus	Hypophosphatemia characterised by bone pain, fatigue, weakness and weight loss.
Potassium	Hypokalaemia characterised by acne, glucose intolerance, cognitive impairment, constipation, tachycardia (rapid heart rate).
Sodium	Hyponatremia characterised by imbalance body fluid electrolytes, dehydration
Arsenic	Arsenic deficiency disease is characterised by liver impairment
Cadmium	Cadmium deficiency disease is characterised by poor protein synthesis

Chromium	Chromium deficiency disease is characterised by diabetes, elevated blood cholesterol and triglycerides, coronary blood vessel disease, low blood sugar, infertility and decreased sperm count
Cobalt	Cobalt deficiency disease is characterised by emaciation, listless, anaemia and starved look.
Copper	Copper deficiency disease characterised by Alopecia (hair loss), white or grey hair, hernias, criminal or violent behaviour, high blood cholesterol and respiratory disease.
Iron	Anaemia (blood loss), characterised by weakness, heart palpations, dizziness and fatigue
Manganese	Manganese deficiency disease is characterised by hearing loss, loss of sex drive, poor cartilage formation, infertility failure to ovulate and testicle atrophy, convulsions.
Molybdenum	Molybdenum deficiency disease is characterised by impaired or deactivated enzyme activities.
Nickel	Nickel deficiency disease is characterised by delayed puberty, high new born mortality and dermatitis.
Selenium	Selenium deficiency disease is characterised by cataracts, low birth weight, sterility in males, sudden infant dead syndrome (SIDS), cancer risk, deadly cancer associated with high vegetable oil intake and impaired immunity.
Zinc	Zinc deficiency disease is characterised by congenital birth defects such as small or absent eyes, webbed toes or fingers and urogenital defects. Other effects include alopecia (hair loss), bad body odour, eczema, sexual immaturity, small and/or poor ovary and testes function. Zinc deficiency is associated with nutritional dwarfism.

The pictorial illustration of some of the mieral deficiencies are presented in Appendix G.

1.2 Problem Stament

The current approaches in tackling the problem of micronutrient malnutrition are based on four options: fortification, supplementation, education and control. All these options apart from education are based on the conventional chemical method whereby micronutrients chemicals are prepared, processed or synthesized as solutions to the problem of deficiencies or total lack of the minerals. The prepared chemical substances are either directly administered in the form of tablets, capsule or injections (supplementation) or passed through commonly eaten foods like salts, flour and cooking oil (fortification).

These options of sourcing the micronutrients are rather artificial and often beset with toxicity and adverse body reactions of some non-tolerating individuals. There is a need to approach the solution to the mineral malnutrition by sourcing the micronutrients from a natural and less cumbersome source like the commonly eaten foods. Food source is more accessible, cheaper, needs no expertise and above all, meet the conditions of green health concept.

Evaluation tool of foods mineral data in previous studies were generally limited to conventional statistics. Although, the common statistical tools are able to reveal a lot of information, it is still limited in scope to reveal enough information or argument suitable to expose food mineral characteristics, maximally and especially, when needed to analyze foods as alternative source of essential micronutrients. Chemometrics approach which is able to resolve and interpret both extrinsic and intrinsically buried characteristics stands to be a better analytical tool to apply.

Analysis of foods for mineral contents is not a new concept. However, focus has been more on individually isolated foods in both cooked and uncooked forms. The problem of this approach is the non-adequate information about mineral intake as it omits the fact that foods are traditionally eaten in combined forms (***all-serving-units-inclusive***). The ***all-serving-units-inclusive*** form in the analysis of food takes

into consideration all the serving units like sauce, soup, stew, fruits, vegetables, meat, fish and so on that goes along with the food dishes.

This traditional food preparation is often the basis for their local names. A Malaysian is able to distinguish *nasi lemak* from *nasi kerabu* based on the method and the ingredients combined in them despite the fact that they both have rice as the main ingredient. Analysis of just cooked or raw rice will not give enough mineral content information on the mentioned foods. This inadequacy makes it necessary to adopt the alternative method (***all-serving-units-inclusive*** form) of evaluating the whole and ready-to eats foods.

The late Doctor Linus Pauling, father of orthomolecular medicine and a two-time Nobel Prize winner (Chemistry & Peace), was an advocate of use of natural food in healing. Pauling (1982;1986), asserted that every sickness, disease and ailment is traceable to mineral deficiencies of one form or the other. This assertion greatly underscores how serious the mineral malnutrition can be and why there is need to attend to it.

Mineral malnutrition is said to account for 11 per cent of the global burden of disease. It is the number one risk to health worldwide (Lancet, 2008). It is also implicated in about 40 per cent of the 11 million deaths of children under age of 5 years in developing countries (UNICEF, 2010). Countries may lose an estimated 2 -3 per cent of their Gross Domestic Product (GDP) as a result of iron, iodine, and zinc deficiencies (Horton *et al.*, 2008).

Currently, in Malaysia, urgent attention is required for intakes of elements such as calcium, iron, magnesium, phosphorus and zinc in response to many recent reported critical cases of Calcium, magnesium and phosphorus deficiency (*osteoporosis* incidence), Iron deficiency (*anaemia*) disease and zinc toxicity of *Mowat-Wilson syndrome* (MWS) .This zinc toxicity could only occur in excessive

supplementation rather than from food sources. Food as a means of supplying these entire mineral nutrients can help in preventing and remedying the cases.

Norhaizan and Faizadatul (2009) reported cases of mineral deficiencies in Malaysia. The incidence of anaemia due to deficiency of iron was reported to nearly about one million cases. In the same study, the osteoporosis due to calcium, magnesium and phosphorus balance deficiencies was up to 2.5 million cases as at 2009.

In a study by Lai *et al.* (2008) in Malaysia, osteoporosis that was prevalent among the elderly was characterised by weak and easily fractured bones of the spine, hip, wrists and arms especially in the aged population. It is projected (Mafauzy, 2000) that about 3.3 million Malaysians by year 2020 will attain the age of above 65 years. This requires proper nutritional plan to avert such ugly incidence. Similarly, by year 2050, Asia will account for over 70% of the 6.26 million hip fractures (Kannus et al, 1996). In Malaysia, hip fractures as a result of osteoporosis affected 218 women and 88 men per 100,000 (Lau *et al.*, 2001).

Two Malaysian cases of *Mowat-Wilson syndrome* (MWS) were reported (Balasubramaniam, 2010). MWS is zinc related syndrome as described by Mowat (2003). *Mowat-Wilson syndrome* consists of a group of birth defects that occur together as a result of heterozygous mutations or abnormality in zinc involving genetic processes. In another study on adolescents, in the Sabah rural community, 20% of the subjects were found to be anaemic (Foo *et al.*, 2004). Similarly, in the remote interior communities in Sarawak, there was also a high prevalence of anaemia among men above 40 years, adolescents, young women and elderly women above 61 years (Sagin *et al.*, 2002).

A proactive action will be required to avert future occurrences of other mineral deficiency diseases which have little or non-prevalence now. It is far

morecost effective if commonly eaten foods can be shown to be a good source of these elements.

The research contribution to knowledge can be summarized in the table below:

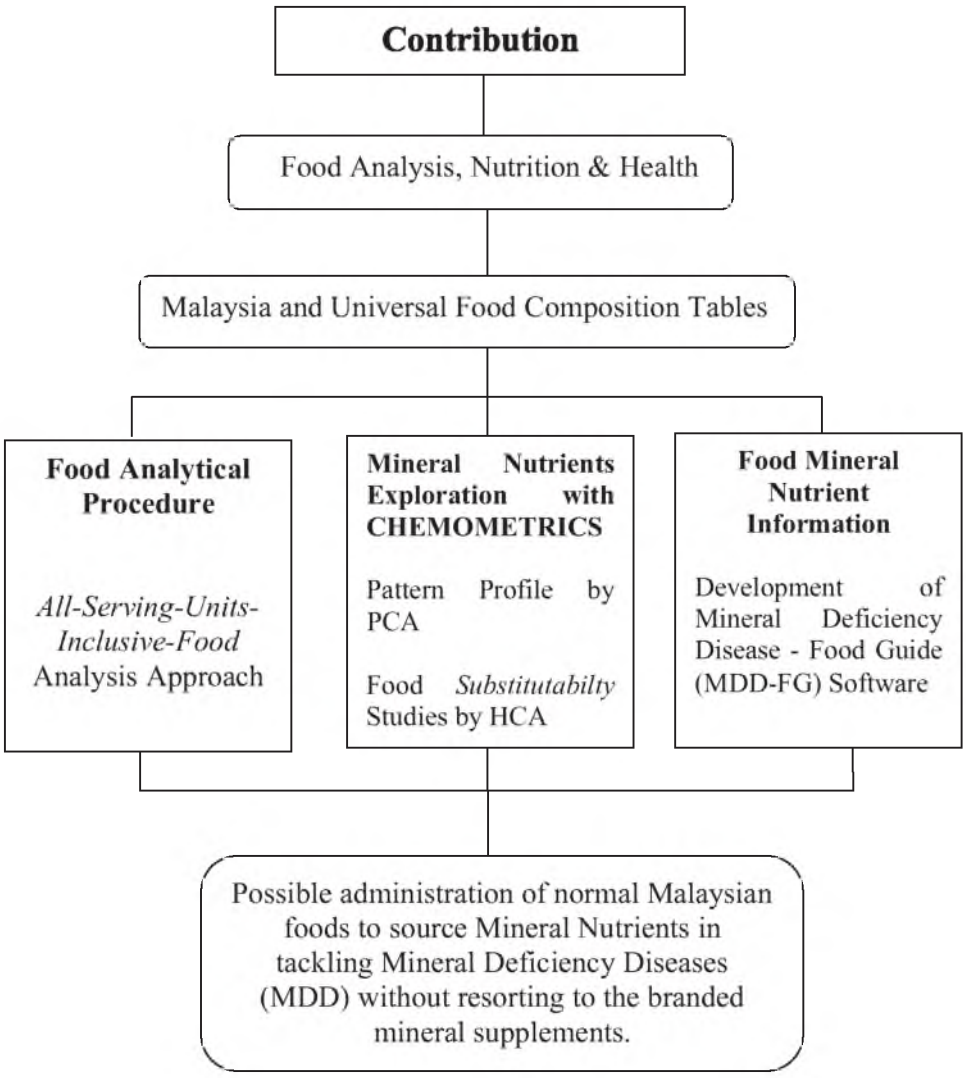

Figure 0.1 Contribution of this study to knowledge

1.3 Objectives of the Study

The objectives of the study are:

a) To quantify the major and trace element contents of selected Malaysian Muslim foods by use of Inductively Coupled Plasma-Mass spectrometer (ICP-MS), Flame Atomic Absorption Spectrophotometer (FAAS) and Flame Photometry (FP).

b) To compute the determined food data and compare with dietary allowances benchmarks.

   i. To compare the quantified food data with Standard Recommended Dietary Allowance (RDA) in order to establish the nutritional values and adequacy of the foods.
   ii. To determine the values of the essential trace elements in the foods relative to the Standard Upper Limit (UL) set by nutritional and health authorities in order to obtain information on excessiveness and toxicity.
   iii. To assess the safety and contamination level of the toxic trace elements in the foods by comparing the quantified values with Standard Provisional Tolerable Daily Intake (PTDI).

c) To apply chemometrics methods to perform exploratory pattern recognition using Principal Component Analysis (PCA), Hierarchical Cluster Analysis (HCA) and Data Matrix on the food dataset.

d) To develop an interactive software program, Mineral Deficiency Diseases - Food Guide System MDD-FG System. The constructed software will provide nutritional information about Mineral Deficiency Diseases (MDD), mineral content of Malaysian served food dishes and which of the foods are of therapeutic relevance in value as potential remedy and prevention.

1.4 Scope of the study

Seventeen elements having significant effects on human health and physiology were selected. This selection of widely varied elements is partly to enhance greater chance of pattern formation and also due to their health and environmental importance to human being. Their health and nutritional importance are highlighted in table 2.1 in chapter 2. The mineral elements determined were five essential major elements which include: calcium, magnesium, phosphorus, Potassium, and sodium. Nine essential trace elements quantified were: chromium cobalt, copper, iron, manganese, molybdenum, nickel, selenium, and zinc. Three toxic trace element studied were arsenic, cadmium and lead.

The selected samples were limited to foods commonly prepared and eaten in Skudai area (Universiti Teknologi Malaysia, Taman Universiti and Sri Pulai) and Johor Bahru area (Larkin and Johor Bahru). The food samples are to be analysed to reflect the way and how they are served for people to eat in restaurants. The samples were the cooked and ready-to-serve and eat food dishes.

The cooking recipe of the consulted restaurants were merged and standardized with cited recipe from some leading food websites in Malaysia. This is to obtain a consistent recipe scope on which this study analysis was based.

Western foods and junk foods as well as drinks were excluded. Foods to be studied were exclusively Malay and Indian Muslim foods commonly served in restaurants. Indian food list also included those ones also eaten by Malays. Mamak restaurants trusted to serve Halal foods are among the consulted restaurants.

1.5 Significance of the Study

This study exposed and identified the inherent capacity of some foods as sufficient source of some essential elements which are important to combat, prevent or ward off the prevalence of mineral malnutrition. The impact of this on Malaysians is that they can now identify the mineral values of their foods and save the household expenditure on mineral supplement medicines. The health situation of the populace should be able to improve because people can access nutritional information about food dishes. And also get enriched with the knowledge that some diseases are preventable or curable based on guided choice of foods. Similarly, adverse side effects of taking chemical based mineral supplement medicines can be avoided. This awareness is capable of moving Malaysia as a nation in general closer to the attainment of the set Millennium Development Goals.

The application of chemometrics approach for profiling the essential and non-essential distribution patterns in the ready-to-eat foods, based of *all-serving-units-inclusive* analysis, is novel and of great relevant contribution to mineral analysis of Malaysian food dishes. It is also a further contribution to Malaysian food composition tables as well as health information databases.

The developed Mineral Deficiency Diseases - Food Guide System MDD-FG System, an interactive software program, will further bridge the gap of information between the populace and the nutritional educators. This will be a novel computer aided contribution of analytical chemistry to nutrition and national health.

1.6 Operational Definitions

In this section, some specific terms used in this study are defined in the context of their application. The general operational terms are organized as follows:

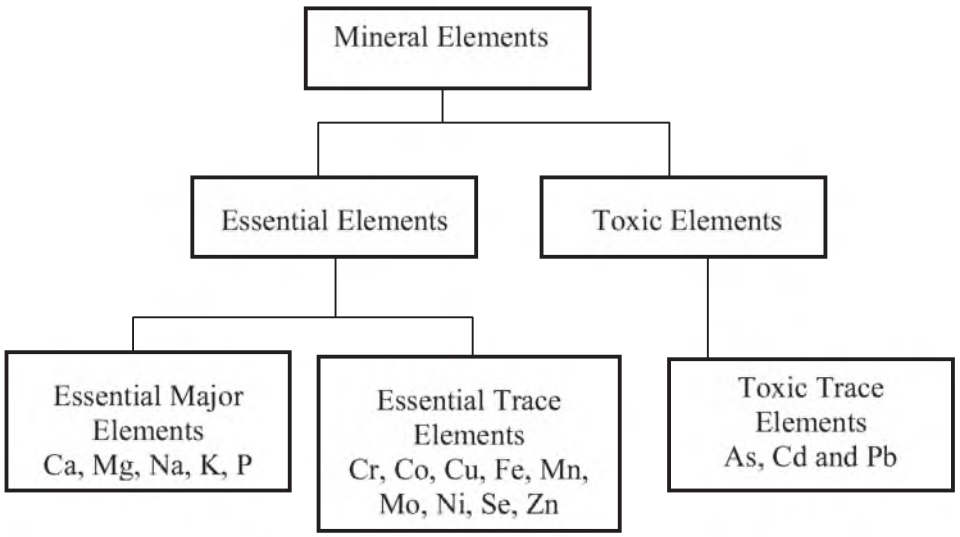

Figure 1.0.2 Flow Chart of Definitions in the Thesis

Mineral Elements

Inorganic chemical elements required by the body in specified amounts for a variety of functions. Seventeen of these elements are studied in this research.

Essential elements

Essential Elements are those elements that play vital health roles in the body. Fourteen of essential elements are studied in this research.

Essential Major Elements

The essential major elements are those elements, in fairly appreciable amount, that are needed to play vital roles in the body. The five major elements in this study are Ca, Mg, Na, K and P.

Essential Trace Elements

The essential trace elements are those elements, in relatively minute amount, that are needed to play vital roles in the body. The nine trace elements in this study are Cr, Co, Cu, Fe, Mn, Mo, Ni, Se and Zn.

Toxic Trace Elements

The trace elements are those elements whose presences in the body are highly detrimental even at a very low level of concentrations. As, Cd and Pb are the studied toxic trace elements.

All Elements-Foods Dataset

It is a collection of data involving all elements and foods in a data matrix of 41 by 17. The number of considered food samples is 41 which represent all the selected foods, while the number of the variables includes all the 17 elements.

Essential Elements-Foods Dataset

It is a collection of data involving the essential elements and foods in a data matrix of 41 by 14. The number of considered food samples is 41 which represent all the selected foods, while the number of the variables includes only the 14 essential elements.

Toxic Elements-Foods Dataset

It is a collection of data involving the toxic elements and foods in a data matrix of 41 by 3. The number of considered food samples is 41 which represent all the selected foods, while the number of the variables includes only the 3 toxic elements.

Sectioned Database

It is a portion extracted from the database structure in the software for the purpose of presentation in this thesis.

1.7 Organization of the Thesis

This thesis has seven chapters. Each of the chapter gives information about particular research area.

- **Chapter 1** discusses the background, aim and objectives, scope and significance of research.

- **Chapter 2** covers the literature survey which includes information about foods, elements, methods previously used in analysis and the current trends in the last one decade. General information about both instruments and tools for food analysis were reviewed.

- **Chapter 3** includes the description of the sampling, sample treatments, detailed laboratory procedure of digestions, materials and instrumentation techniques employed. Discussion in the chapter also includes the adopted optimum parameters and operating condition of the equipment used. The statistical and chemometric details are described in this chapter. The quality assurance procedure followed is also described.

- **Chapter 4** presents the results of the quantification of element contents of foods. It discusses various quality assurance validation methods, the calibration parameters and significant test for the results. This chapter also discusses health and nutritional quality as well as safety of the foods.

- **Chapter 5** is about the application of chemometrics method to analyse patterns and quality of the studied Malaysian foods. It gives the classification of food profile according to the food base types, richness in essential element content as well as health safety based on the mineral content of the foods by

use of PCA. The chapter also discusses the application of HCA and Correlation Matrix which further characterize the food.

- **Chapter 6** discusses the development of a simple software that gives information about mineral deficiency diseases, the implicated elements and the Malaysian food dishes capable of supplying the elements. The development, procedure and application and end user evaluation of the software are detailed.

- **Chapter 7** draws conclusion based on the four cardinal objectives of the study and makes recommendation based on the outcomes obtained from the study.

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