Development of a Rapid and Accurate System To Differentiate Malaysian Honey Samples Using UV and Colour Image

by

Abd Alazeez Almaleeh
(1430611499)

A thesis submitted in fulfillment of the requirements for the degree of Master of Science in Mechatronic Engineering

School of Mechatronic Engineering
UNIVERSITY MLAYSIA PERLIS

2016

ACKNOWLEDGMENT

In the name of ALLAH, the most gracious and the most merciful

Alhamdulillah, all praises to Allah for the strengths and his blessing in completing this thesis.

Foremost, I would like to express my sincere gratitude to my supervisor Prof. Dr. Abdul Hamid Adom for his invaluable guidance, continuous encouragement and constant support in making this research possible. I really appreciate his guidance to develop an understanding of this research thoroughly.

Also, I would like to thanks Dr. Fathinul Syahir Ahmad Sa'ad and Dr. Ammar Zakaria for his continuous encouragement, advices, comments and his guidance to develop of this research.

I also would like to express very special thanks go to all lecturers and members of the staff of the School of Mechatronic Engineering Department, UniMAP, who helped me in many ways.

My sincere indebtedness and gratitude thanks to my parents and my brothers, dream and sacrifice throughout my life. I am really thankful for their sacrifice, patience and understanding that inevitable to make this work possible done. Their sacrifice had inspired me to finish my study with successful life.

TABLE OF CONTENTS

		PAGE
DECLARATION		
ACKNOWLEDGMENT		i
TABLE OF CONTENTS		ii
LIST OF FIGURES		vi
LIST OF TABLES		viii
LIST OF ABBREVIATION		x
ABSTRAK		xi
ABSTRACT		xii
CHAPTER 1 INTRODUCTION		
1.1	Background and Research Motivation	1
1.2	Problem Statements	3
1.3	Research Objectives	4
1.4	Scope of this Research	4
1.5	Motivation of The Work	5
1.6	Thesis Outline	6
CHAPTER 2 LITERATURE REVIEW		
2.1	Overview of Honey	7
2.2	Types of Honey	8
2.2.1	Tualang Honey	11
2.2.2	Acacia Honey	11
2.2.3	Kelulut Honey	12
2.3	Colour of Honey	13
2.3.1	RGB Colour Space	14
2.3.2	HSV Colour Space	15

2.3.3 CIE-LAB Colour Space 17
2.3.4 YCbCr Colour Space 19
2.3.5 Pfund Scale 19
2.4 Data Processing 22
2.4.1 Pre-processing 22
2.4.2 Normality Test 22
2.4.3 Parametric and Non-Parametic Test 23
2.5 Data Reduction 24
2.5.1 Principal Component Analysis (PCA) 24
2.5.2 Linear Discriminant Analysis (LDA) 25
2.5.3 Other Methods 25
2.6 Pattern Recognition and Classification (PARC) 26
2.6.1 k-Nearest Neighbors (k-NN) 27
2.6.2 Linear Discriminant Analysis (LDA) 27
2.6.3 Support Vector Machine (SVM) 28
2.7 The Review of Data Fusion and Its Application 33
2.8 The Review of Honey Classification 39
2.9 Summary 45

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction 46
3.2 Honey Sample Selection 51
3.3 UV–Vis Spectroscopy 53
3.3.1 Sample Preparation 53
3.3.2 Data Acquisition 55
3.4 RGB Digital Camera 59

3.4.1 Apparatus and Software 60
3.4.2 Sample Preparation 61
3.4.3 Color Space Transformations 62
3.4.3.1 CIE-LAB 62
3.4.3.2 YCbCr 65
3.4.3.3 HSV 66
3.4.4 Hue Histograms 67
3.4.5 Data Acquisition 69
3.5 Data Analysis and Feature Extraction 71
3.5.1 Multivariate Analysis of Variance (MANOVA) 72
3.5.2 Normality Test 72
3.5.3 Principal Components Analysis (PCA) 73
3.5.4 Linear Discriminate Analysis (LDA) 75
3.6 Classification 76
3.6.1 k-Nearest Neighbors (k-NN) 76
3.6.2 Support Vector Machine (SVM) 77
3.6.3 Data Fusion 79

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 Separate Analysis 80
4.1.1 Exploratory Data Analysis Using PCA 80
4.1.2 Evaluation and Performance Analysis of Different Classifier 85
4.1.2.1 Selection of Component in Colour Space 85
4.1.2.2 Selection of UV Wavelength Range 85
4.1.2.3 Selection of Classification Method 86
4.2 Evaluation and Performance of a Support Vector Machine (SVM) based Fusion Classifier 88

4.2.1 SVM Kernel Optimization 88

4.2.2 Classification Performance 89

CHAPTER 5 CONCLUSION

5.1. Conclusions 92

5.2. Future Work 93

REFERENCES 94

APPENDIX 105

LIST OF FIGURES

NO.		PAGE
2.1	Hue value of the angle colour	16
2.2	Framework of the CIELAB colour model	18
2.3	Pfund colour scale	20
2.4	Pfund colour grader and wedge of amber-coloured glass and wedge-shaped cell filled with the honey sample	21
2.5	Division in classification or pattern recognition	26
2.6	Hyperplane through two linearly separable classes	31
2.7	Overview of multi-modality sensor fusion concept	35
2.8	Implementation of low level data fusion	36
2.9	Single data combined in low level sensor fusion	36
2.10	Implementation of Intermediate level data fusion	37
2.11	Data combined in intermediate Level sensor fusion	37
2.12	Implementation of high level data fusion	38
2.13	Data combined in high level sensor fusion	38
3.1	Research methodology overview	48
3.2	Framework of the intermediate level data fusion	49
3.3	Framework for the selection of (a) colour space and (b) classifier	50
3.4	Certified Honey samples collected from Malaysian local market	51
3.5	Lambda 35 UV-Vis	55
3.6	Cuvettes of samples of honey and blank	55
3.7	Schematic for a UV-Vis spectroscopy	56

3.8	Absorbance spectra of 81 honey samples	57
3.9	Chemical structures of Naringenin and Pinocembrin	59
3.10	Digital images obtained from three different type of honey having distinctive colour	60
3.11	USB Phillips RGB Digital Camera	60
3.12	Honey image capturing device without the external light shield	61
3.13	The three circular region selected in the center of the image	68
3.14	Process to capture honey sample and display Hue Histogram	69
3.15	The histogram scans of (a) Acacia, (b) Kelulut and (c) Tualang honey	70
3.16	The histogram scans of three types honey	71
3.17	Framework of the dimension reduction using PCA	74
3.18	The process of calculate the extracted features for Principal Component	75
3.19	Framework of the SVM classification with (a) separate and (b) combined the data	78
3.20	The summary of SVM training and classification	78
4.1	Scree plot of UV spectroscopy for the first 10 components	82
4.2	Scree plot of Digital Image for the first 10 components	82
4.3	PCA plot of 81 samples of honey from three different type using UV-Vis spectroscopy	83
4.4	PCA plot of 81 samples of honey from three different types using Digital Camera	84
4.5	PCA plot using data fusion technique for three different types of honey	88

LIST OF TABLES

NO.		PAGE
2.1	Differences in composition and physicochemical parameters of nectar honey and honeydew honey; Values (g/100g)	10
2.2	Differences in composition and physicochemical parameters of three honey types	13
2.3	Colour classifications of honey, according to the Pfund scale	20
2.4	Summary of studies which involves Ultraviolet Visible, Near Infrared, E-Nose, E-Tongue and Digital camera, with the analysis methods	42
3.1	Description of different sample varieties of honey and used in the experiments	52
3.2	The table shows the number of samples prepared for the data acquisition for both methods. The table also show the samples being aged to four (4) and eight (8) months for the data collection	53
3.3	Wavelength range and corresponding first three PCs variance based on PCA	58
3.4	Raw Data Analysis using MANOVA for UV Spectroscopy and Digital Image	72
4.1	The amount of variance (%) of the first three principal components for two different Method	81
4.2	Image classification accuracy for different colour space using SVM	85
4.3	UV Wavelength range and corresponding SVM classification	86
4.4	The cross performance between different classifier (LDA, SVM and k-NN)	87
4.5	Classification accuracy for different ages using SVM	87

4.6	Results of SVM classification experiments with multi kernel function	89
4.7	Classification result on fused UV-Vis and Digital Image using SVM for three different honey types	90
4.8	Confusion matrix of SVM tested	91

LIST OF ABBREVIATIONS

SVM	Support Vector Machine
PCA	Principal Component Analysis
DPPH	1,1-Diphenyl-2-picryl-hydrazyl
PFund	Colour Scale of honey
LDA	Linear Discriminant Analysis
E-NOSE	Electronic Nose
E-Tongue	Electronic Tongue
FIR	Fourier Infrared Spectroscopy
MIR	Mid Infrared Spectroscopy
NIR	Near Infrared Spectroscopy
HLF	High Level Fusion
LLF	Low Level Fusion
ILF	Intermediate Level Fusion
BPNN	Back Propagation Neural Network
PLS	Partial Least Squares
DPLS	Discriminant Partial Least Squares
ANN	Artificial Neural Network
SVR	Support Vector Regression
UV	Ultraviolet
SIMCA	Soft Independent Modeling of Class Analogy

Pembangunan Kaedah yang Pantas dan Tepat Bagi Membezakan Sampel-Sampel Madu Malaysia Menggunakan UV dan Imej Warna

Abstrak

Malaysia adalah sebuah negara yang kaya dengan hasil hutan termasuk rempah-ratus, herba dan madu. Madu serta produk berasaskan madu semakin popular di Malaysia kerana berkait rapat dengan pemakanan sihat yang dipromosi oleh pelbagai agensi termasuklah kerajaan sebagai salah satu sumber permakanan yang sihat. Ini seterusnya membuka peluang perniagaan untuk menyediakan produk madu serta produk sampingan yang berasaskan madu ke pasaran. Namun, fenomena ini juga menimbulkan permasalahan menentukan kualiti serta jenis madu yag ditawarkan di pasaran. Ini kerana jenis madu yang berlainan, sebagai contoh, mempunyai nilai khasiat yang berbeza, dan mungkin sesuai untuk sesuatu produk serta jenis pasaran. Pada waktu ini, kaedah menentukan jenis atau asal madu adalah melalui proses yang dilakukan di dalam makmal, yang kebanyakannya remeh, tidak mudah-alih, melibatkan penggunaan bahan kimia serta memerlukan kepakaran. Penyelidikan ini menampilkan kaedah yang lebih cekap menggunakan UV untuk pengkelasan madu. Penyelidikan ini juga menunjukkan bahawa penggunaan kamera digital RGB kos rendah juga boleh digunakan untuk tujuan yang sama. Selain dari itu, kerja yang dilaksanakan memperkenalkan fusion kedua-dua kaedah ini dan menunjukkan hasil pengkelasan yang lebih baik. Kerja ini mempamerkan pengkelasan madu berdasarkan dua ciri-ciri dari tiga (3) jenis madu tempatan yang berlainan, iaitu kandungan antioksidan serta warnanya. Kandungan antioksidan dibezakan dengan menggunakan gelombang spektroskopi UV pilihan, dan warna dibezakan menggunakan kamera RGB. Principal Component Analysis (PCA) digunakan di dalam kedua-dua kaedah untuk mengurangkan dimensi data yang terhasil. Support Vector Machine (SVM) pula digunakan bagi pengkelasan madu. Penilaian berasingan dilaksanakan bagi kedua-dua kaedah serta ke atas '*data fusion'*, setelah terlaksana pengekstrakan ciri. Hasil pengkelasan menggunakan kaedah fusion meningkat sehingga 94% berbanding dengan dua kaedah tunggal yang dinyatakan. Ini menunjukkan kaedah yang disyorkan mampu menghasilkan pengkelasan madu yang tepat dan cepat mengikuti asalnya. Kaedah yang disyorkan boleh diaplikasikan ke atas industri madu di Malaysia dan meningkatkan kualiti penilaian serta membolehkan penilai terhadap jenis-jenis madu.

Development of a Rapid and Accurate System to Differentiate Malaysian Honey Samples Using UV and Colour Image

Abstract

Malaysia is a country rich with natural forest resources such as spices, herbs and honey. Honey and honey-based products in Malaysia is gaining popularity as a result to the healthy lifestyle promotions by various groups including the government. This leads to the business opportunities to provide honey and its derivatives into the market. However, this also creates another problem in determining the quality, and types of honey offered by the market. This is because different honey types, for example, have different properties, which may be desirable for different purposes, and market segments. At the moment, the methods in determining the botanical origins of honey are all laboratory-based, which may be tedious, not portable, involve chemical synthesis, time consuming and required expert personal. This research introduces a more efficient approach using UV for honey classification. This research work also shows that a low-cost approach using RGB digital camera, can also be used for the same purpose. In addition to that, the work introduces the idea of fusion using the two approaches and shows an improvement in classification. The work presented the classification of the honey based on two characteristics from three (3) types of local honey, namely the antioxidant contents and colour variations. The former uses the UV spectroscopy of selected wavelength range, and the latter using RGB digital camera. Principal Component Analysis (PCA) was used for both methods to reduce the dimension of extracted data. Support Vector Machine (SVM) was used for the classification of honey. The assessment was done separately for each of the methods, and also on the fusion of both data after features extraction. The overall classification of the fusion method improved significantly compared to single modality. Honey classification based on the fusion method was able to achieve 94% accuracy. Hence, the proposed methods have the ability to provide accurate and rapid classification of honey products in terms of its origin. The proposed system can be applied to the Malaysian honey industry and further improve the quality assessment and provide tracebility.

CHAPTER 1

INTRODUCTION

1.1 Background and Research Motivation

Malaysia is a tropical country rich in natural forest resources such as herbs, medicinal plants, spices and honey. These traditional foods are one of the main sources of income for the Malaysian agricultural industry. This opens up more demand and hence creates the need for a better classification methods, which can provide an accurate dan dependable verification for these products. This will help the local industry such as honey which is gaining popularity day by day. At present, consumers usually classify honey in terms of its geographical distribution and different floral sources, smell, taste and their colour. As there are many different types of honey available in Malaysia, the identification of the botanical origin is important to classify it accurately.

There are few existing methods to classify type of honey. Sensory evaluation is one of the methods that currently being used, unfortunately it is not easy to set up and the subjective experiences among the panelist are often biased and inconsistent. Chemical test methods in laboratory (Serrano, Villarejo, Espejo, & Jodral, 2004), is more accurate than the sensory evolution method. However, it is quite time consuming and costly. In addition to that, this method does not guarantee the safety of consumers and hinders further development of apiculture.

This researchers have suggested to use sensory systems that make use of electronic nose and electronic tongue to discriminate bee honey (Zakaria et al., 2011), along with the application of physicochemical criteria such as: enzymatic activity, sugar content, pH, water content, electrical conductivity and so on to analyze different types

of Uni-floral honey (Conti, Stripeikis, Campanella, Cucina, & Tudino, 2007). Furthermore, identification of pollen counts for authentication has been used, although there are difficulties to provide guarantee a precise assignment of the origin (Corbella & Cozzolino, 2008; Ramsay, 2005).

There are also some researchers use Pfund colour scale (Bertoncelj, Doberšek, Jamnik, & Golob, 2007) to classify honey for commercial purposes. The Pfund colourimeter is a simple tool which is used to compare the colour of the honey sample with a standard coloured glass. The reference unit is on the Pfund scale (0 to 140 mm), starts with very light-coloured honey and rising up to the darkest honey. However, this method requires very large amounts of sample and depends on the person performing the analysis since different observers lead to different measurements. However, these drawbacks are still remained in these researches. Thus, it is essential to find out a rapid and accurate way of honey discrimination.

Recently, UV-Visible spectroscopy has received wide range of attention of the researchers as it is suitable for non-destructive analysis of biological and biomedical materials. For example, the UV-Vis spectroscopy can be used for discriminating tea beverages (Chen, Zhao, Liu, & Cai, 2008), milk (Balabin & Smirnov, 2011), coffee (Lv, 2011), and other materials (Sinelli, Cerretani, Di Egidio, Bendini, & Casiraghi, 2010; H Yang, Kuang, & Mouazen, 2012; Haiqing Yang, Kuang, & Mouazen, 2011). Some researchers used this technique such as (Gallardo-Velázquez, Osorio-Revilla, Zuñiga-de Loa, & Rivera-Espinoza, 2009; Zhu et al., 2010) to classify adulterants in some local origins of honey. Although these researches achieved high accuracy for honey discrimination, the calibration models were developed using full range of wavelengths, which brought about high complexity in computation and cause difficulty in practical applications.

This thesis presents two methods for the classification of honey in terms of Botanical origin. Based on UV-Vis spectroscopy and Digital Camera, the difference in antioxidants and their hue colour were measured and later classified by the developed SVM classifier.

1.2 Problem Statements

Generally honey is classified in terms of taste, aroma, flavour and can also be distinguished by its colour (Lammertyn, Veraverbeke, & Irudayaraj, 2004). Due to these facts, human panelist has been the method of choice and often sought to provide quality assessment of honey. However, sensory evaluation is often inconsistence and varies from person to person (Massimiliano Magli, 2012). This is also due to personal experiences which may lead to bias and inaccurate assessment.

On the other hand, although artificial sensors, such as electronic nose and electronic tongue, are accurate (Guiyun Chen, 2013; Ulloa et al., 2013; Zakaria et al., 2011), they suffer some drawbacks as such tedious handling, requiring scheduled calibrations, involved with pattern recognition and may be sensitive to minute inconsistencies in the samples prepared.

Conventionally, chemical test is still acceptable but comes with the downside. Chemical test methods in laboratory, are accurate (Serrano et al., 2004). However, they are time consuming and costly. For example, UV-Vis spectroscopy is able to differentiate and classify honey with high accuracy (Chen et al., 2008). More than often, the computational analysis is getting complex as they use the full wavelength spectrum.

Hence, the improvement to the honey classification in terms of simpler procedures, more consistent results and portability is favorable. Therefore in this

research, two methods for honey classification were proposed and discussed separately. Also, the fusion of the two methods is presented.

1.3 Research Objectives

The main goal of this project is to provide an alternative method to allow the different types of honey to be classified. Also, it presents a fusion of the two methods implemented to improve the classification accuracy. The objectives of this project are as follow:

- To classify the origin of honey using antioxidant level by measuring the wavelengths from UV-Vis Spectroscopy.
- To classify the origin of honey based on the colour of honey images captured by Digital Camera.
- To implement data fusion technique by combining both UV and Digital Image for honey classification.
- To evaluate the performance of the fusion and compared with single method

1.4 Scope of This Research

The major contributions of this research are as follows:

- Develop procedure to prepare honey samples for the UV-Vis and Colour Image, also to cover the different age of the samples
- Perform data conditioning to allow the classification using SVM, k-NN and LDA to be performed.
- Implement classifications of honey samples using single methods, and implement fusion approach and the results were compared.

1.5 Motivation of The Work

The work highlights a new way of classification of honey product. The classification of honey products are no longer based only on the sensory evaluation and subjective human experience such as: taste, aroma and colour. As the discriminating factors. Instead, highly accurate techniques to classify honey products in terms of its botanical origin and level of colour have been utilised and demonstrated in this work.

In this research, the discrimination of honey in terms of different floral and level of colour has been performed. The success of using high accurate techniques allow further classification made not only based on the brands, but allowing the user to group the sample based on the combination of colour and antioxidants.

The scope of the work does not include:

- To find or to propose new algorithm or compare the performance of pattern recognition.
- Work on the comparison or suggestion to persuade or to determine the accuracies of the proposed approach compared to the existing approaches. If we are trying to introduce more accurate classification system, the direct comparison will be performed.
- Comparison with human expert panels. At the moment in these research areas, there are no trained personnel that are able to provide classification for honey samples.

1.6 Thesis Outline

This thesis is organized in five chapters.

Chapter 1 discusses the background, problem statements, objectives, scope and motivation for this research.

Chapter 2 presents an overview of previous studies and researches on classification of honey. Main components of honey and the proportions of these components have been presented in this chapter. Previous methods used to classify the honey in terms of Botanical Origin and colour has been described including the methods used in this research to classify honey.

Chapter 3 presents the methods used for classifying honey, terms of antioxidant using UV-Vis spectroscopy and various of colour using digital camera, and also present the overview of the research methodology.

Chapter 4 presents the data dimention reduction using PCA and classification using SVM on single methods as well as fusion of multiple classifiers.

Chapter 5 concludes the thesis by summarizing the research findings. It ends by proposing future work.

CHAPTER 2

LITERATURE REVIEW

This chapter presents an overview of previous studies and researches on classification of honey. The main differences in composite and physicochemical parameters of honey types are presented in this chapter. Previous methods used to classify the honey in terms of Botanical Origin and colours have been described including the methods used in this research to classify honey.

2.1. Overview of Honey

Honey is a natural food produced by bees from the nectar of blossom (nectar honey) or from the secretions of living plants or excretions of plant sucking insects of the living part of plant (honeydew honey) that transform and combine with specific substances of their own, and keep this mixture in the honey comb to ripen and mature (Sanz, Gonzalez, De Lorenzo, Sanz, & Martınez-Castro, 2005). Honey is composed primarily by a mixture of sugars (85–95%) and water (16–18%) approximately, and minority components such as proteins, free amino acids, organics acids, phenolic compounds, vitamins and minerals (Castro-Vázquez, Díaz-Maroto, De Torres, & Pérez-Coello, 2010; Kahraman, Buyukunal, Vural, & Altunatmaz, 2010; Pires, Estevinho, Feás, Cantalapiedra, & Iglesias, 2009; Sanz et al., 2005). Bee foragers collect nectar and honeydew from plants and carry it by means of their honey sac and bring it to their colony. When a worker bee drinks the nectar from flowers, a maximum of about 25 mg of nectar is stored at the bottom of the esophagus in a widened region called the honey

stomach or honey sac. On their way, they already add enzymes from their two glands, salivary and the hypopharengeal, and transfer the nectar to colony bees. These nurse bees pass it over to each other and finally fill the honey into the combs. During this process the bees fan with their wings, thus lowering honey´s humidity, and when the water contents reaches 30–40% the honey is filled into the combs. However, the bees add additional enzymes to the honey. These enzymes include diastase and invertase, both of which break down to larger saccharides, especially invertase, into monosaccharide (fructose and glucose). While glucoseoxidase oxidants the glucose to gluconic acid and hydrogen peroxide; the latter acting as an agent against bacterial spoilage. Thus, chemical transformation of the nectar into honey begins almost immediately. The warm colony temperature (35 ºC), and further fanning lowers further the honey humidity. Bees also suck out the honey and deposit it back into the combs, and by this process further lower the water content of the honey. This transformation process takes place in 1 to 3 days. Generally, when the ripe honey has humidity lower than 20% the bees cap the combs, thus preventing absorption of moisture by the ripe honey. Only rarely, under very humid or tropical conditions can honey with more than 20% be capped by bees. The aim of the beekeeper is to harvest honey with less than 18% humidity (Ball, 2007).

2.2. Types of Honey

Honeys can be classified into two types: nectar honey and honeydew. Nectar is a sugar solution of varying concentrations: from 5–80%. About 95% of the dry substances are sugars, the rest are amino acids (0.05%), minerals (0.02–0.45%), small amounts of organic acids, vitamins and aroma compounds (Al et al., 2009; Manzanares, García, Galdón, Rodríguez, & Romero, 2011). The sugar value ranges widely, from 0.0005 to 8

mg. The sugar composition is also typical for each plant species, the main component of sugar are sucrose, glucose and fructose. Most plants have nectars consisting predominantly of fructose and glucose (60–85%); but in some plants the nectar is mainly sucrose (De La Fuente, Ruiz-Matute, Valencia-Barrera, Sanz, & Castro, 2011; Lazaridou, Biliaderis, Bacandritsos, & Sabatini, 2004). The sugar concentration depends on different climatic factor such as temperature, soil humidity and weather season. When humidity is higher, the nectar quantity is greater, but the sugar concentration is smaller. Temperature also plays a very important role in the process of honey production. Optimum temperatures are 25 to 35 ºC. Strong winds reduce nectar secretion. The nectar secretion depends also on the day time. Therefore it is not possible to foresee nectar production. Maximum secretion is at early afternoon. Bees prefer nectar with higher sugar contents, e.g. around 50% and will not forage if it is below 5%, bees gather nectar for their energy needs. The higher the sugar value of a plant, the more it is visited by bees for foraging (Manzanares et al., 2011; Weryszko-Chmielewska & Chwil, 2007).

Honeydew is the secretion product of plant-sucking insects (Hemiptera, mostly aphids). These insects pierce the foliage or other covering parts of the plant and feed on the sap. The ingested sap is passed through the insect´s gut, and the surplus is excreted as droplets of honeydew, which are gathered by the bees. There are different sorts of honeydew producing insects. Most plants are trees; the coniferous trees yield worldwide the highest amounts of honeydew. However, other plants, e.g. cotton, lucerne and sunflower can also provide honeydew (Manzanares et al., 2011; Sanz et al., 2005). And in Malaysian have a few types of honeydew plants as Star fruit and honey melon. Honeydew is a solution with varying sugar concentration (5–60%), containing mainly fructose, besides higher sugars (oligosaccharides). There are also smaller amounts of

amino acids, proteins, minerals, acids and vitamins. In addition, honeydew contains cells of algae and fungi, however there are not specific for the honeydew origin. Some insects produce high amounts of the trisaccharide melezitose, which is only very slightly soluble in water, thus yielding honey, which can crystallize in the combs (Manzanares et al., 2011). Honeydew production is even less predictable than the nectar flow, as it depends on the buildup of plant sucking insects. By evaluating the populations of the plant-sucking insects, the potential for a possible honey flow can be estimated. However, the honeydew flow depends also on favorable weather conditions during the honey flow period (De La Fuente et al., 2011; Manzanares et al., 2011). Table 2.1 shows the differences in composition between nectar and honeydew honey for some physicochemical parameters these two kinds of honeys.

Table 2.1: Differences in composition and physicochemical parameters of nectar honey and honeydew honey; values (g/100 g) (Al et al., 2009; Manzanares et al., 2011).

Component	**Nectar Honey**	**Honeydew Honey**
Water	15–20	15–20
Carbohydrates	72–85	73–83
Fructose	30–45	28–40
Glucose	20–40	22.9–40.7
Sucrose	0.1–4.8	0.2–7.6
Melezitose	<0.1	0.3–22.0
Erlose	0.56	0.16–1
Threhalose	1.2–2.4	1.2–2.9
Turanose	1.0–2.1	0.7–2.2
Other Disaccharides (maltose)	28	16
Other Oligosaccharides	0.5–1.0	0.1–6.0
Total sugars	79.7	80.5
Acids	0.2–0.8	0.8–1.5
Water activity	0.56–0.61	0.57–0.61
Minerals	0.1–0.5	0.6–2
Amino acids, Proteins	0.2–0.4	0.4–0.7
pH	3.5–4.5	4.5–6.5

This study focused on the nectar honey whereby three types of Malaysia's honey are selected based on the most popular and highly demanded. These honey types were also used in the local community for the treatment of various diseases, as it contains a large amount of antioxidants, vitamins and essential ingredients such as minerals.

2.2.1 Tualang Honey

Tualang honey is a Malaysian multifloral jungle honey. The honey is produced by the rock bee (Apis dorsata), which builds hives on branches of tall Tualang trees located mainly in the north-western region of Peninsular Malaysia (Ahmed & Othman, 2013). In general, Tualang honey has been used in the local community for the treatment of various diseases, as it contains a large amount of antioxidant. The internal composition of the different types of honey vary with different floral sources as well as climatic and environmental conditions (Aljadi & Kamaruddin, 2004; Gheldof, Wang, & Engeseth, 2002; Küçük et al., 2007). Studies on the antioxidant activity of different types of honey from different countries and different botanical origins have been carried out (Al-Mamary, Al-Meeri, & Al-Habori, 2002; Aljadi & Kamaruddin, 2004; Beretta, Granata, Ferrero, Orioli, & Facino, 2005; Estevinho, Pereira, Moreira, Dias, & Pereira, 2008; Socha, Juszczak, Pietrzyk, & Fortuna, 2009). However, the antioxidant properties of the local Tualang honey have not been well documented in terms of botanical origins.

2.2.2 Acacia Honey

Acacia honey is quite a unique honey in Malaysia produced by Apis mellifera bees. It is one of the brightest honey type. When it is in a liquid form, acacia honey is almost transparent but once it crystallizes, it becomes white or very pale yellow in