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ASSESSING THE QUALITY OF HONEY IN THE TEMA METROPOLIS OF GHANA

BY

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(BSc. AGRICULTURE TECHNOLOGY)

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THIS THESIS IS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIRMENT FOR THE AWARD OF THE DEGREE OF

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NYANSAPƆ WƆSANE NO BADWENMA

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DECLARATION

I confirm that the intellectual content of this work submitted towards the MSc is the result of my own efforts and no other person and that, it contains no material previously been submitted in any form to the University or to any other body whether for the purpose of assessment, publication or for any other purpose, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this dissertation to Mrs Elizabeth A. Stilson, Maame Afua Ampomaa Stilson and Nana Nti Stilson

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ABSTRACT

Honey, a valuable commodity accepted and used worldwide, is vulnerable to adulteration. Currently, very little information on the quality of honey have been reported in the country. The study seeks to reveal the physicochemical properties, such as viscosity, moisture, fructose, glucose and sucrose contents of honey in the Tema metropolis of Ghana and compare them to the maximum and minimum limits set by Codex and EU standards. In all 20 samples were analysed for their viscosity, moisture, sum of fructose and glucose and sucrose contents using standard methods. From the study, the mean values of moisture content, sum of fructose and glucose content, sucrose content and viscosity were 17.28%, 67.44%, 6.39% and 6,575.89cP respectively. This reveals that the mean values for moisture content and sum of fructose and glucose content were within the acceptable limits of 20% maximum and 60% minimum respectively of Codex and EU standards. However, the mean value of sucrose content exceeded the maximum limit of 5% set by Codex and

EU standards. The study showed that the moisture content was inversely proportional to the viscosity of samples investigated.

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ABBREVIATIONS

CODEX	Codex Alimentarius Commission
EU	European Union
US FDA	United States Food and Drug Administration
C4	Monocotyledonous plants sugar
C3	Dicotyledonous plant sugar
DSC	Differential Scanning Calorimetry
NMR	Nuclear magnetic resonance
CS	Corn syrup
HFCS	High-fructose corn syrup
GS	Glucose syrup
IS	Inverted syrup
HFIS	High-fructose inulin syrup
SS	Sucrose syrup
HMF	Hydroxymethylfurfural
SCIRA	Stable Carbon Isotope Ratio Analysis NIR
Near-infrared	
HFLS	Human Fibroblast-Like Synoviocytes
US	Ultrasound
HHP	High hydrostatic pressure
GMO	Genetically Modified Organism
PCB	Polychlorinated biphenyl
AChE	Acetylcholinesterase
BDNF	Brain-derived neurotrophic factor

ACh	Acetylcholine
RVA	Rapid Visco Analyzer

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CHAPTER ONE

INTRODUCTION

1.1 Background

Even though the term "quality" is used commonly, its definition is not easy. Unnevehr and Jensen (1999) define quality as the blend of features that makes a product acceptable. Quality can also be looked at as the ability to produce a zero defect product on the first attempt (*i.e* zero error rate) (Parasuraman *et al*., 1985). In addition, quality is seen when a producer is able to meet the expectations of consumers. Zeithaml (1988) observed quality from the costumer's perpestive, which states that quality is perceived to be the overall excellence or superiority of the product. In the narrow sense, Singham *et al*. (2015) defined food quality as factors such as appearance, nutritional and taste as well as keeping quality impact on its degree of excellence. He explained further that food quality and food acceptability go together, and it is important to observe food quality both from a safety viewpoint and ensure public acceptability or likeness of a particular product. According to Sikora (2005) food quality is the entire traits and criteria which describes food in respects of its sensory value, nutritional value, convenience as well as safety for consumer's health. Food law regulates food safety to ensure that food which consumers purchase meet their safety requirements, hence making food safety a relevant aspect of food quality (hazardfree) (Sikora, 2005). It has been established that, the farmer goes through some unfavourable circumstances before the produce finally gets to the consumer. Among these are pests, microorganisms which infest the farmland, foreign matter which may be dangerous, poisonous substances or impurities which get into products from materials used in processing, microorganisms and dirt introduced into the product through unhygienic practices of the people who handle the produce, as well as loss of quality that results from short-comings in storage practices (George, 1998).

It is reported that there are two major attributes that contribute to quality, which are categorised into two. Thus, Physical attributes, such as sensory qualities eg. size, shape, color, viscosity, taste etc. and Hidden attributes, which is measured only by standard microbiological and chemical procedures (George, 1998). Some of these attributes can make food unsafe for human consumption whiles others are positive because of their nutritive content, which need to be preserved. Studies have revealed that quality can be grouped into four areas, which are distinguished between objective and subjective quality (Grunert *et al*., 1995). Objective quality comprises of productoriented quality, process-oriented quality and quality control, since they are able to be determined by measuring phases of the product and the production process. Subjective quality consists of useroriented quality, since only consumers are able to measure and may differ among consumers for the same product

1.2 Problem statement

It has been reported that people view quality in different ways; nutritive, appearance, tasteful and easy to process (Van de Vijver, 2007). Outside parameters, such as looks, firmness and shelf life are very important for acceptability, as well as inside parameters (analytical measurements and taste). According to Krell (1996), the quality of honey is an important aspect for both domestic and international markets, as it helps achieve competitive premium prices and promote human health. It is proven that honey is consumed worldwide by all manner of people (children, youth, aged, sick and healthy), and has widely been used to cure ailments such as cough, fever, infections, and inflammation, as well as its antioxidant, anti-immunomodulatory, and antibacterial and therapeutic effects (Khalil *et al*., 2010). There have been serious reports of poor quality honey on the market and their safety is also increasingly being questioned (Kugonza and Nabakabya, 2008).

It is reported that producers are likely to unhygienically handle the process of honey, intentionally adulterate and possibly contaminate the honey, making them unsafe and also of low quality. Honey adulteration has been reported to take different forms (Dinu, 2018), including the addition of sweeteners like cheap sugars and syrups after gathering of honey from hives (Burns *et al*., 2018; Yilmaz *et al*., 2014), overfeeding bees with saccharides or invert saccharide derivatives to increase honey production (Kolayli *et al*. 2012) and misrepresentation of the floral or geographical origin of the honey (Daniele *et al*. 2012). Others include mislabelling of honey (Moore *et al*. 2012; Fairchild *et al*. 2003) or dilution of high quality honey with low quality honey (Zhu *et al*., 2010; Guelpa *et al*., 2016). Many people take honey for medicinal purposes but children in particular are treated specially because of the belief enhancement of brain power (Bianchi, 1977; Ajibola *et al*., 2012). Honey quality consideration is an aspect disregarded by producers and processors especially in developing economies (Kugonza and Dorothy, 2008). A food is said to be wholesome when it conforms with appropriate nutritional and safety standards as well as specific quality attributes. Though there seem to be standards that define honey (Bogdanov and Martin. 2002; Codex Standard of Honey, 2001), regulation is poorly controlled thus, quality and safety is often left in the hands of producers and sellers. However, there are anthropogenic activities such as illegal mining, especially in areas where honey is produced. Honey production in such areas are mostly contaminated with heavy metals, and this leaves us a course to worry. The safety and quality control of honey products have become an international issue (Wang *et al.,* 2011) thus, it is important to strengthen the standards and regulation of the production and handling of honey in order to protect life.

1.3 Objective

To determine the quality (viscosity, moisture and sugars) of honey on the market.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Concept of quality

Quality can be seen as the blend of features that makes a product acceptable (Unnevehr and Jensen, 1999). Zeithaml, (1988) observed quality from the costumer's perspective, which states that quality is perceived to be the overall excellence or superiority of the product (Zeithaml, 1988). In the narrow sense, Singham *et al*. (2015) defined food quality as factors such as appearance, nutritional, and taste, as well as keeping quality, impact on its degree of excellence. Studies have revealed that quality can be distinguished into four types, namely product-oriented quality, processoriented quality, quality control and user-oriented quality, which is grouped under objective and subjective quality (Grunert *et al*., 1995). It has been shown that food quality can be measured in both subjective and objective manner (Dijksterhuis, 1997). Stone and Sidel (1993), explained that in subjective evaluation, consumers of a product react to stimuli through analytical or effective test by trained panels or consumers. On the other hand, objective evaluations are not based on human variations and are repeated, which involves all instrumental analysis to determine chemical composition, nutrient composition and bacterial composition through laboratory test to give accurate results if equipment is maintained properly, and measure a specific attribute of a food product rather than the total quality (Singham *et al*., 2015). According to George (1998), physical attributes and hidden attributes are the main attributes to quality, with physical attribute defined in terms of sensations, which include kinaesthetic factors like texture, viscosity, consistency, finger feel and mouth feel, flavor factors. Different from the physical attributes, hidden features (nutrient content of food) can only be measured by standard chemical or microbiological procedures because they are neither seen nor felt (George, 1998). Food law regulates food safety to ensure that food what consumers purchase meet their safety requirements, hence making food safety a relevant aspect of food quality (hazard-free) (Sikora, 2005).

2.1.1 Major quality attributes

It is reported that physical attributes and hidden attributes are the main attributes to quality, in the sense that the farmer is hit with adverse conditions, such as pests, micro-organisms which infest the farmland, foreign matter which may be dangerous, poisonous substances from production through to the time the produce finally gets to the consumer (George, 1998). The handlers of these products through unhygienic practices introduce these adverse conditions into the end product, from materials used in processing, leading to loss of quality. Physical attributes are occasionally referred to as sensory or quantitative qualities, since they are defined in terms of sensations, which include kinaesthetic factors like texture, viscosity, consistency, finger feel and mouth feel, flavor factors or sensations combining odour and taste and kinaesthetic factors like texture, viscosity, consistency, finger feel and mouth feel. Different from the physical attributes, hidden features (nutrient content of food) can only be measured by standard chemical or microbiological procedures because they are neither seen nor felt (George, 1998).

2.1.2 Types of quality

Studies have revealed that quality can be distinguished into four types, namely product-oriented quality, process-oriented quality, quality control and user-oriented quality, which is grouped under objective and subjective quality (Grunert *et al*., 1995). Product-oriented quality deals with all the physical aspects of a product that completely describes a specific food product. Starch content in cassava, muscle size and fat content of meat, amount of cell in milk are some examples of product quality. Process-oriented quality, as the name suggest deals with the way we produce a food product,

eg producing food product without growth inhibitors and pesticides, by organic production, and according regulations. This aspect provides information to the consumer on the way the food product was produced, and may not affect the physical features of the product. In the aspect of quality control, the product has to conform to a particular standard for it to be approved under a specific quality class, eg Codex standard for honey, the EUROP classification of meat etc. Quality control covers the conformity to specific standards for product and process-oriented quality. In that sense we can view product and process-oriented quality as types of quality that deal with the level of quality of a product or process, whiles quality control deals with the conformity to quality standards. However, user-oriented quality is viewed form the user standpoint, and it is subjective, since the end-user only has the ability to measure, and can differ from users for the same product. Product and process-oriented quality and quality control are seen as Objective quality, since they are able to be determined by measuring and documenting product and production process respectively. According to Steenkamp and van Trijp (1991), user-oriented quality impacts on all the three types of objective quality, making them interrelated. Moreover, it has been established that factors that are not features of the product itself (price, brand etc) has the ability to influence user-oriented quality (Brunsø *et al*., 2002).

2.1.3 Measurement of quality

It has been shown that food quality can be measured in both subjective and objective manner (Dijksterhuis, 1997). Stone and Sidel (1993), explained that in subjective evaluation, consumers of a product react to stimuli through analytical or effective test by trained panels or consumers. In other to judge a product, evaluators make observations and record during sensory test upon receipt of ballots, which is a sheet of paper containing information and instruction of food samples. This information helps food companies make more informed business decisions (Stone and Sidel, 1993). However, a multi-modality sensing to aid human panels in making good decision, due to innate weakness of panel teste, is been proposed by researchers, with the aim of partly emulating the human sensory systems, such as smell and taste in electronic system, combining them in a way to how they operate in human system (Robertsson *et al*., 2007; Linder and Poppl, 2003). This multi-modality sensor has been applied in military, medicine and agricultural sectors because of its acceptability worldwide (Laureati *et al*., 2010; 2010; Cosio *et al*., 2007) due to its superiority over single modality sensor (Zakaria *et al*., 2011). However, it is reported that human panels are still the best way to measure quality due to the subjectivity involved (Buettener and Beauchamp, 2010). On the other hand, objective evaluations are not based on human variations and are repeated, which involves all instrumental analysis to determine chemical composition, nutrient composition and bacterial composition through laboratory test to give accurate results if equipment is maintained properly, and measure a specific attribute of a food product rather than the total quality (Singham *et al*., 2015). It is reported that due to the limited laboratories at hand, such measurements are not able to meet the demand since traditional products are increasing (Buettener and Beauchamp, 2010; Zakaria *et al*., 2011).

2.2.1 Honey and nature of honey bees

According to Kędzierska-Matysek *et al.* (2016), honey is naturally produced by honey bees from the nectar of blossoms parts of plants which is very sweet and viscus. Honey is prepared when honeybees forage over a wide area (more than 7 km^2) to collect nectar, water, and pollen as they visit flower to flower rich in pollen and nectar (Jia *et al*., 2008). It is reported that fructose and glucose are the main constituents of honey (65%), with water (18%), as well as protein (0.3%), minerals (0.7%), vitamins and antioxidants in minute levels (Khalil *et el.,* 2001). Honey composition is dependent on the type of flower the bees utilised. Studies have shown that honey has been used as food and medicine since time immemorial, and is the most ancient sweetener ever known (Crane, 1975), with a lot of nutrients (White and Doner, 1980) as well as immense health benefits (Ajibola, 2007). Research has shown that out of about 20,000 species of bees that dwells on earth, only 6 to 11 species produce honey (Ball, 2007). According to Frisch (1967), honeybees travel a long distance in search for flowers rich in pollen and nectar to visit to make honey. Those that are fruitful decides to employ more forager to the same patch, by way of "dance communication", a dance language used to communicate a resourced flower location among honey bees. Donaldson-Matasci and Dornhaus (2014) indicated that dance communication (waggle dance) helps honeybee's colonies to gather more nectar, in areas where there are high quality sources, by directing more forager to the same location. It has been revealed that European bees gather a lot of nectar load to manufacture more honey than Africanized bees, in situations of good nectar availability (Rinderer *et al*., 1985). It has been established that several responsibilities are performed by bees in different way in the hive from 2 to 3 weeks of adulthood, involving nursing (brood care), to foraging for nectar and pollen outside the hive for their remaining lifes (Winston, 1987). The need of the colony dictates the transition period from nursing bee to foraging bee, and can be delayed or hastened due to its variability (Whitfield *et al*., 2003). Oster and Wilson (1978), reported that there are differences in the speed of performance by both nursing and foraging bees, with some working tougher than others. A recent study conducted by Gould (1986), submits that honey bees have a broader knowledge of spatial organisation of landmark in their environment than many previous workers had suggested. Bees can traverse over longer distances between their hive and foraging area (Wehner and Srinivasan, 1981) and it had been supposed that in doing so they become acquainted only with the pattern they saw while traversing a small number of specific routes. Research has shown that swarm intelligence is a technique device by cooperate behaviour of social insects to solve problem, such as mounting defences against pathogens, building nests from antimicrobial materials (Christe *et al*., 2003), nurturing offspring in sterile nurseries (Burgett, 1997), and social fever in reaction to a disease (Starks *et al*., 2000), and removal of infected larvae from healthy brood (Spivak and Reuter, 2001) eg. bees swarming around their hive (Bonabeau *et al*., 1999).

2.2.2 Honey quality

Studies have shown that honey quality covers a wide range of specifications, which includes organoleptic properties (color, aroma, taste and texture), chemical composition (water, sugars, protein, minerals, enzymes and vitamins content, free acidity, water insoluble solids, diastase activity, electrical conductivity and hydroxymethylfurfural), level of contaminants (pesticides and antibiotic residues, heavy metals and additives), microbiological characteristics, analytical method through to labelling (Bogdanov *et el*., 1999; Khalil *et al*., 2012). International standards, such as Codex Alimentarius Commission (CODEX), European Commission (EU) and US Food and Drug Administration (FDA) define honey quality (Codex Standard for Honey, 2001; EU Council, 2002; Bogdanov *et el*., 1999). According to Codex standards for honey (2001), compositional criteria are set out for honey comprise of maximum limits of moisture (20%), sucrose (5%), water insoluble solids (0.1%) and minimum limits of sum of fructose and glucose (60%). Both standards of EU Council and Codex Alimentarius commission were revised recently, taking into account analytical methods used, following the advice of International Honey Commission (Bogdanov *et el*., 1999). Both standards are similar even though Codex standards are more detailed, containing references to quality factors such as heavy metals, pesticides and adulteration. It is reported that honey exist in two types, thus blossom and nectar honey and honeydew honey, with the later consisting of mainly excretions of plant sucking insects (Hemiptera) or secretions of living parts of plants.

2.2.3 Factors affecting honey quality

2.2.3.1 Fraud

Codex Alimentarius standard (Codex Standard for honey, 2001) and the EU Honey Directive (Council Directive, 2001) define the composition and quality standards of honey, which state that honey should be free from any added ingredients; no removal of specific constituent; no intolerable matter, flavour, aroma or taint absorbed from foreign matter during processing and storage; and not processed in other to change or impair its vital composition or quality. Food fraud is seen by researchers in different ways. Spink and Moyer (2011) sees it as deliberately tempering, adding, substituting or misrepresenting food, food ingredient or misleading statement about a product for financial gain. It has been established that food fraud is said to happen if food or food ingredients is modified or adulterated with the intension of gaining profit (Johnson, 2014; Sobrino-Gregorio *et al*., 2017). Honey adulteration has been reported to take different forms (Dinu, 2018), including the addition of sweeteners like cheap sugars and syrups after gathering of honey from hives (Burns *et al*., 2018; Yilmaz *et al*., 2014), overfeeding bees with saccharides or invert saccharide derivatives to increase honey production (Kolayli *et al*., 2012), misrepresentation of the floral or geographical origin of the honey (Daniele *et al*., 2012), mislabelling of honey (Moore *et al*., 2012; Fairchild *et al*., 2003) or dilution of high quality honey with low quality honey (Zhu *et al*., 2010; Guelpa *et al*., 2016). Bogdanov and Martin (2002) also revealed heat treatment, inappropriate storage conditions, filtering and addition of colorants as means of adulteration, including harvesting prior to maturity, and the abuse of veterinary drugs (Bogdanov *et al*., 2004; Guler *et al*., 2007). Studies has shown that 35 honey samples were adulterated with monocotyledonous plants (C4) sugar or dicotyledonous (C3) sugar by impairing protein extraction (Dong *et al*., 2017). It is believed that honey is the most susceptible to food fraud because it is perceived to be of high quality with medicinal properties and the fact that its production is unable to meet the growing market demands (Food Fraud Database, 2016). Studies have viewed honey adulteration in different standpoints. The first is Public health, which includes the presence of unrestricted ingredients that impacts seriously on health when the adulterant is poisonous or toxic, or allergic (Everstine *et al*., 2013). The second aspect is Legal issues, as requirements by regulatory bodies, such as Codex and EU have prohibited the addition of any substance to honey. Finally, Economic issues come into play as markets are destabilized by unfair competition relating to industry, distributors and the livelihood of beekeepers (Longobardi *et al*., 2015). It is evident that adulteration does not only rob consumers of their monies but also weaken confidence in a product (Chen *et al*., 2014; RuizMatute *et al*., 2007), impacting adversely on public health (Popp *et el*., 2018), as well as promoting unfair competition (Longobardi *et al*., 2015).

In view of all these problems associated with adulteration, it is therefore prudent to have scientific ways to verify the authenticity of honey. Lately, there have been several studies that have revealed scientific ways of certifying the authenticity of honey (Danezis *et al*., 2016). In the study of Shafiee *et al*. (2016), hyper-spectral imaging was used to authenticate honey samples. Other methods like high performance liquid chromatography (Wang *et al*., 2015), stable carbon isotopic ratio mass spectrometry (Çinar *et al*., 2014; Simsek *et al*., 2012), reflectance-Fourier transform infrared spectroscopy and NMR spectroscopy (Rios-Corripio *et al*., 2012; De Oliveira *et al*., 2014) and Differential Scanning Calorimetry (DSC) (Dahimi *et al*., 2014; Tomaszewska-Gras, 2016) have all been employed.

2.2.3.2 Processing

It has been reported that during honey processing, there are possible sources of contamination and adulteration, which ought to be considered (Bett, 2017). It requires time and patience to achieve positive results as honey is food and must be handled in a hygienic manner (Honey Care Africa, 2010). Adulteration of honey such as the addition of sugars and syrups, thermal heating, addition of water or using equipment which are not thoroughly dry, mislabelling and other contaminants must be guarded against as they can potentially alter the final quality (Krell *et al*., 1988). According to Wilczyńska *et al*. (2017), honey samples were adulterated with spices like cinnamon significantly altered the taste and smell, which is against Codex and EU regulations, even though some consumers desired them. The study further revealed that samples adulterated with spices exhibited the capability to hinder growth of bacteria, but refused the increase of antimicrobial activities. In the following subheadings, adulteration such as addition of sugars and syrups, thermal processing, storage, water content and environmental contaminants would be explained in detailed.

2.2.3.2.1 Addition of sugars and syrups

It has been proven that sugars are the main components of honey (67.3%), mainly comprised of fructose and glucose with little sucrose (Khalil *et al*., 2012). People adulterate honey by adding sugars in various ratios after production to make the product very sweet, or overfeeding bees with sugar or syrup during the period of nectar collection to maximise yield. Cheap sugars and syrups like corn syrup (CS) and high-fructose corn syrup (HFCS), glucose syrup (GS), sucrose syrup, inverted syrup (IS), or high-fructose inulin syrup (HFIS), produced from sugar cane or sugar beet are mainly used (Anklam 1998; Guler *et al*., 2007; Tosun, 2013). According to Ajlouni and Sujirapinyokul (2010), honey adulterated with sugar exhibited changes in chemical or biochemical parameters such us enzymatic activity, electrical conductivity, and contents of specific compounds

(HMF, glucose, fructose, sucrose, maltose, isomaltose, proline, ash), when matched with a control (from authentic source). Moreover, in the study of Guler *et al*. (2007), with the aim of differentiating pure blossom honey from adulterated ones by excessive feeding of bees with sucrose syrup (SS) established that it was impossible to use sugar content (sucrose syrup) to discriminate adulterated honeys because of the conversion of more than 95% of sucrose syrup fed to bees to fructose and glucose. Several researchers have adopted various techniques to discover adulterated honeys with different levels of sugars and syrups. For instance, Guler *et al*. (2014) used SCIRA to identify adulterated honeys produce by bees fed with levels of commercial industrial sugar (C3 and C4 plants) syrups. Moreover, near-infrared (NIR) spectroscopy in combination with chemometric technique has been used to identify honey adulterated with beet syrup, adulteration with glucose and fructose mixtures (Zhu *et al*., 2010) and adulterated honey with HFLS (Chen *et al*., 2011).

2.2.3.2.2 Heating

It is a known fact that processing honey requires heating to reduce viscosity, dissolves crystals to promote liquid honey, which is desired by consumers, reducing moisture content to required state (20% max.), to promote shelf life (Abu-Jdayil *et al*., 2002), and preventing microbial contamination (Kabbani *et al*., 2011). However, it has been established that during thermal treatment of honey, reactions such as browning and changes in color, texture, off-flavours and appearance occur which are very harmful, and at the end implicate its quality. Contaminants such as 5-hydroxymethyl-2-furfural (HMF) is a potential human carcinogen and it is produced through heat processing (Escriche *et al*., 2008; Kowalski, 2013). Moreover, Bucekova *et al*. (2017) concluded in their work that Microwave thermal processing of honey totally eradicated antimicrobial activity while conventional thermal treatment at 45 and 55°C had no impact on antimicrobial activity of honey samples. Not only does thermal processing of honey eliminated antimicrobial activity and releasing harmful contaminant like HMF, it also causes loss of volatile compounds (Bogdanov and Martin, 2002) and decline enzymatic activities, such as invertase, glucose oxidase, catalase, peroxidase etc. which originate from honey bees and/or nectar (AlvarezSuarez *et al*., 2010; Weston, 2000). However, Samborska *et al*. (2017) indicated that thermal treatment is not the only cause for enzymatic activity reduction. Meanwhile Codex standards forbids processing of honey in a manner that alters its essential composition or ruins its quality. In order to preserve, and not to deteriorate the quality of honey during processing, several novel techniques have been employed. Among these are ultrasound (US) and high hydrostatic pressure (HHP), which are appropriate options to thermal treatment, proficient in decreasing viscosity, liquefying honey, and reducing the negative impact of thermal treatment, such as minimising the formation of HMF and preserving nutritional attributes of honey (Kabbani *et al*., 2011; LeyvaDaniel *et al*., 2017). It has been proven that antioxidants properties of honey has been improved and also inhibited microbial load and preserving its general quality parameters, with HHP treatment at 600 MPa for 2 minutes (Leyva-Daniel *et al*., 2017).

2.2.3.2.3 Addition of water

Aside factors such as storage, climatic conditions and season of production, influencing the moisture contents of honey, others such as intentional addition of water and using equipment which are not thoroughly dry also increase the moisture content, which affect physical properties of honey, such as viscosity and crystallization, and as a result its quality (Gallina *et al*., 2010). However regulatory bodies, such as Codex and EU require maximum moisture content of 20%, excluding heather honey, which is 23% maximum (Directive 2001/110/EC; Codex Standard for

Honey, 2001), because any excess water can cause fermentation and spoilage (Bogdanov and Martin, 2002).

2.2.3.3 Storage

Research has proven that some physical and chemical modifications could arise due to reactions which occur during storage, leading to honey adulteration, regardless of proper processing and packaging (Da Silva *et al*., 2016). It is reported that changes in color (darkening) of honey is dependent on its initial color (Milium, 1948; Soares *et al*., 2017). For instance, Gonzales *et al*. (1999) revealed that the functions which initiates darkening of honey increased when stored for a long time, after browning occurred initially. Moreover, Wang *et al*. (2004) concluded that honey stored for 6 months decreased it antioxidant properties. On the other hand, Gheldof *et al*. (2002) found no changes in the antioxidant properties of honey stored for periods of more than 2 years, using the same method or approach, resulting in contradictory outcomes.

2.2.3.4 Environmental contaminants

Studies have revealed that honey is not only contaminated by beekeeping practices, but also the environmental surroundings of hives (Bogdanov and Gallmann, 2008). Environmental contaminants include pesticides (fungicides, insecticides, bactericides, and herbicides), pathogenic bacteria, heavy metals (lead, mercury, cadmium etc.) and GMO. Oliver (2012) reported that insecticides, herbicides, and fungicides which are applied to crops for treatments, finally reach the honey bee through nectar, pollen, and air, water or soil, through foraging activates, consequently contaminating the honey. Similarly, polychlorinated biphenyl (PCB's), from coolants, lubricants, and motor oil find it way in honey products, as well as organic contaminants, because they are present in the environment (Carrié *et al*., 2012; Bett, 2017). Moreover, it is reported that honey bees pick up pollen and nectar from diverse plants over a long distance without distinguishing between a conventional and GM plants, risking unintended contamination of honeys with GM pollen, provided these plants are within the vicinity of foraging bees (Bogdanov and Martin, 2002; Soares *et al*., 2017). It has been established that pesticides contamination can occur either out-hive or in-hive, with the later arising from the application of chemicals, such as coumaphos and acaricides used in controlling *Varroa destructor* mites, build up in comb wax, extending honey bee exposure (Martel *et al*., 2007; Moritz *et al*., 2010). The study of Colwell *et al*. (2017) revealed that pollen collected by honey bees were contaminated with lethal levels of residues. Similarly, a study conducted in France revealed neonicotinoid imidacloprid together with 1 to 5 different residues in 49.4% samples (Chauzat *et al*., 2006; Porrini *et al*., 2016).

2.2.4 Sugar content of honey

It has been reported that other minor sugars including sucrose, maltose, trehalose, erlose, raffinose, turanose, melezitose, isomaltose (Kristina *et al*., 2013; Anklam, 1998; Ouchemoukh *et al*., 2010) are present in honey, with monosaccharide, such as fructose and glucose being the main constituents, making sugars (saccharides) the main components of honey (Zielińska *et al*., 2014). According to Ouchemoukh *et al*. (2010) the amount and type of sugar is influenced by the regional climatic condition and the nectar type. It has been revealed that sucrose is the main sugar in several nectars whereas fructose, glucose and sucrose can be present in equal amounts in some nectars.

For instance, sucrose is largely present in the families of Lamiacea (mints) and Ranunculacea (buttercups and clematis) whiles nectars from the families of Brassicaceae (mustard and cabbage) and Asteraceae (asters, daisies, and sunflowers) have different quantities of fructose and glucose with minimal sucrose contents (Baker and Baker, 1983). The classification of unifloral honey is somehow dependant on the variations in the amount of the two monosaccharides (fructose and glucose), with comparatively low analytical value for the determination of botanical origin using minor sugars (Anklam, 1998). In the study of Adriana *et al*. (2012), it was shown that the ratio of fructose and glucose affects the disposition of crystallization, as it is impeded by fructose and promoted by glucose.

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2.2.5 Viscosity of honey

Studies have proven that the most relevant physical traits that could impact on texture, sensory rating, and other quality factors, such as shelf stability during storage, is rheological property (Dak *et al*., 2007), and it is a relevant honey quality attribute (Dobre *et al*., 2012). Knowing the rheological properties of honey is very key from storage and handling perspective, as it has been acknowledged as an analytical tool to offer basic understanding on the structural composition of food and relevant in heat transfer of fluids (Assil *et al*., 1991). In the study of White (1978), he revealed that factors such as temperature, composition and amount and size of crystals as well as water content influence the viscosity of honey. Different types of honeys have variations in moisture content, with some as low as 13% and high as 29% (Junzheng *et al*., 1998; White, 1978). It has been established that the more the water content in honey the lower its viscosity, as AlMahasneh *et al*. (2013), concluded that the rise in viscosity in analysed honey samples were as a result of increased water content owing to fact that intermolecular friction reduced due to the plasticizing effect of water. However, the influence of temperature in the prediction of viscosity is also very important (Ramzi *et al*., 2015), lauding to the fact that temperature increase lowered viscosity due to decreased hydrodynamic forces and molecular friction linked to temperature rise (Davis 1995; Kędzierska-Matysek *et al*., 2016). According to Kabbani *et al*. (2011), ultrasound treatment decreased viscosity of honey as it accelerated its liquefaction particularly at temperatures below 50 °C. Studies have shown that honey exhibits Newtonian behavior, where shear stress is proportional to shear rate (Yilmaz *et al*., 2014; Witczak *et al*., 2011), whiles non-Newtonian behavior of honey was attributed to the presence of crystallized sugars and polysaccharides dextran (Karasu *et al*., 2014). However, other fluids exhibited a change in viscosity with time at a constant shear rate and were classified as thixotropic, where the viscosity decreases with time, and rheopectic, where the viscosity increases with time (Witczak *et al*., 2011).

2.2.6 Moisture content of honey

It is reported that moisture content is very critical to the quality of honey, in the sense that it can speed up crystallization in certain types of honey, as well as increasing its water activity to the extent of initiating the growth of certain yeasts and moulds (Yanniotis *et al*., 2006). Moisture contents of honey may vary due to processing procedures, storage conditions, handling by beekeepers at harvesting period and environmental conditions such as climate, the water content of nectar and floral origin (Bogdanov *et al*., 2004; Gomes *et al*., 2010;). In the study of Attard and Mizzi (2013), it was indicated that when honey is exposed to humid air during harvesting for longer periods, or high levels of immature unsealed cells are present in honey, moisture contents appreciate. Other causes like moisture levels of original plant, maturity level of honey in the hive, and harvest season also influence the moisture content of honey (Finola *et al.,* 2007). Research have proven that viscosity is significantly influenced by moisture content (Lazaridou *et al*., 2004), and can cause fermentation, flavour loss, spoilage, leading to quality loss if it is not managed well (Terrab *et al*., 2003). Moisture content plays a very key role in accessing honey maturity and shelf life, making it a very important element (Singh and Bath, 1997). According to Codex standard for honey (2001), moisture content of honey should not exceed 20%, except for Heather honey *(Calluna)* which has maximum of 23%. Studies have revealed that several honey samples have recorded high moisture content above Codex standard thus, 25.84 to 36.04% for *M. capixaba* honey (Lage *et al*., 2012), 26.80% to 32.00% for *M. asilvai* honey (Souza *et al*., 2004), 23.14% to 32.50% for *M. mandacaia* honey (Alves *et al*., 2005), 24.8% to 30.6% for the Amazon *M. compressipes manaoense* and *M. seminigra merribae* honey (Almeida-Muradian *et al*., 2007) and 24% for Yateí (*Tetragonisca angustula*) honey (Pucciarelli *et al*., 2014). Other samples recorded acceptable levels of 15.9% to 17.2% (Pavelková *et al*., 2013), 17.19% to 19.19% (Islam *et al*., 2012), 13.8% to 16.6% (Fahim *et al*., 2014) and 15% to 17% (Kristina *et al*., 2013) moisture content.

2.2.7 Benefits of honey

Most studies have proven that constituents of honey, such as water, sugars (fructose, glucose, sucrose etc), vitamins (riboflavin, niacin, ascorbic acid and pantothenic acid), mineral (copper, iron, calcium, zinc, potassium etc) as well as antioxidants are of high nutritional and health value (Ajibola *et al*., 2007; White and Doner, 1980). It has been established that these essential nutrients in honey are in small quantities, and in order to get the complement of its nourishment, metabolic activities, growth and health importance, it is advised to take it in large quantities of about 70 to 95 g per day (Yaghoobi *et al*., 2008; Al-Waili and Boni, 2003). In the study of Al-Himyari (2009), he concluded that honey and its properties serve as defensive therapies for both dementia and cognitive decline. Studies have proven honey to provide defensive effects against oxidative wounds of the kidney, liver, and rat myocardium because of its antioxidant abilities (Khalil *et al*., 2012). The consumption of honey and other foods rich in antioxidant is able to guard against pathological modifications and thus avert pathogenesis and other chronic diseases (Al-Waili and Boni, 2003; Schramm *et al*., 2003). According to Othman *et al*. (2015), Tualang honey reduces *acetylcholinesterase* (AChE) in the brain homogenates and brain oxidative stress, increases brainderived neurotrophic factor (BDNF) and *acetylcholine* (ACh) concentrations as well as improving the morphology of memory-related brain regions and the memory of Postmenopausal women after injected with 20 g of Tualang honey supplement and Femoston conti 1/5. Additionally, the calcium component in honey is absorbed readily and strengthens the growth of the bone mass, which helps minimise the risk of osteoporosis (causative agent of fracture) in older persons if consumed (Ariefdjohan *et al*., 2008). The sugar components of honey are very sweet and provides more energy making it the preferred choice than artificial sweeteners (Bogdanov *et al*., 2008). Moreover, it has revealed that natural honey can be used as cheap substitute for commercial sporting activities enhancers, such as glucose taken before, during and after physical exercise to improve performance and accelerate muscles rejuvenation (Kreider *et al*., 2002). It is reported that honey is comparatively tolerated than sterile water by infants because of its palatability, and it reduced their crying phases (Ramenghi *et al*., 2001). One will mean well to children to substitute the feeding of other sugary substances they are inclined to consume with honey, as it reduces anxiety, boosts their performance in later life, most importantly improves memory and growth (Chepulis *et al*., 2009), improved skin color, less susceptible to diseases, no digestion problem, steady weight gain (Bianchi, 1977), prevent harmful and genotoxic effects of mycotoxins, and improve the gut microflora (El-Arab *et al*., 2006). Studies have indicated that consumers are becoming aware of the food they eat in recent times in that functional foods are attracting larger markets because of their health promoting benefits due to functional constituents inherent in these products (Saarela *et al*., 2000). Researchers have tested the hydrogen peroxide and non-peroxide in honey for its antimicrobial properties (Al-Mamarya *et al*., 2002), with some attributing the antimicrobial properties of honey to hydrogen peroxide (Dustmann, 1979; Morse, 1986), whereas others believe that the nonperoxide activity more important to that effect (Radwan *et al*., 1984).

The medicinal importance of honey cannot be overlooked, since it has widely been used as a cure for ailments such as fever, cough, infections and inflammation, and has been reported to have antiimmunomodulatory, and antibacterial effects (Khalil *et al*., 2010; Hussain *et al*., 2015). A study conducted by Tahir *et al*. (2015), concluded that, combining ginger and Gelam honey may be an effective chemopreventive and therapeutic approach for inducing the death of colon cancer cells. According to Yusof *et al*. (2007), radiation sterilized Gelam honey considerably stimulated the degree of burn wound healing, whether applied topically or administered systemically (Suguna *et al*., 1992). Furthermore, honey has been reported to treat burns, by aiding the spontaneous healing of wounds with less scarring (Subrahmanyam, 1991). Additionally, it is proven that honey is able to manage type II diabetes due to the resistance in reduction of insulin content of patients (Katsilambros *et al*., 1988). The medicinal effect of honey has compelled its usage in most food formulas as is perceived to be therapeutic (Kujawska *et al*., 2012). It has been established that medicinal honey can decrease catheter infections and skin colonization when positioned at the insertion site of catheter (Timsit, 2013). According to Maksoud and Rahman (2006), the best way to control asthma with honey is by inhalation rather than oral injected because it enables the deposit of enough honey in the airways to treat the illness (Maksoud and Rahman, 2006). It was revealed in the study of Kamaruzaman *et al*. (2014), that asthma in rabbits was managed using aerosolised honey, in that it reduced the quantity of airway inflammatory cells present in bronchoalveolar lavage fluid and inhibited the goblet cell hyperplasia, and concluded that it could be a promising treatment in humans.

2.3 Conclusion

The quality of honey is a key factor for both local and international markets (Krell, 1996). It will help attain competitive premium prices and ensure human health. But honey adulteration has been reported to have taken different forms (Dinu, 2018), including the addition of sweeteners like cheap sugars and syrups after gathering of honey from hives (Daniele *et al*. 2012; Yilmaz *et al*., 2014), overfeeding bees with saccharides or invert saccharide derivatives to increase honey production (Kolayli *et al*., 2012) and misrepresentation of the floral or geographical origin of the honey (Daniele *et al*., 2012). Others include mislabelling of honey (Moore *et al*., 2012; Fairchild *et al*., 2003) or dilution of high quality honey with low quality honey (Zhu *et al*., 2010; Guelpa *et al*., 2016). Honey quality consideration is an aspect disregarded by producers and processors especially in developing economies (Kugonza and Dorothy, 2008) even though people take honey for medicinal and other purposes, children in particular are treated specially because of the belief enhancement of brain power (Bianchi, 1977; Ajibola *et al*., 2012). Though there seem to be standards that define honey (Bogdanov and Martin, 2002; CODEX Standard of Honey 2001), regulation is poorly controlled thus, quality and safety is often left in the hands of producers and sellers. However, there are anthropogenic activities such as illegal mining, especially in areas where honey is also produced. Honey production in such areas are mostly contaminated with heavy metals, and this leaves us a course to worry. The safety and quality control of honey products have become an international issue (Wang *et al*., 2011) thus, it is important to strengthen the standards and regulation of the production and handling of honey in order to protect life.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

The reagent and solutions used were; neutral lead acetate, potassium oxalate, methylene, iodine, sodium carbonate, sodium bicarbonate solution, H_2SO_4, sodium thiosulphate, analar grade sucrose, distilled water. The instruments used were; Perten Rapid Visco Analyzer (RVA 4500, Australia) and Reichert refractometer (AR200, USA)

3.1.1 Source of honey

All honey samples were obtained in the Tema metropolis. Honey samples were picked from super markets, hawkers as well as the market places.

3.2 Methods

3.2.1 Sampling

Honey samples were randomly picked from market places, drug stores, normal provision shops as well as super markets. In all 20 honey samples were identified. 19 samples were from within the

Tema metropolis whiles the control was from a farm in Asankrangwa in the Wassa Amanfi West District of the Western region of Ghana

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3.2.2 Determination of sugars

3.2.2.1 Determination of factor (for invert sugar) of Fehling solution

A sample of 4.75 g of analar grade sucrose was accurately weighed and transferred to 500 mL volume flask with 50 mL distilled water to make up to volume, which was transferred to a burette having an offset tip. Similar procedure above was used to perform the titration of Fehling solution: Equation 1

Fehling Factor (for invert sugar) = $\frac{Titre\ x\ Weight\ of\ sucrose\ in\ gm}{500}$ - (1) (JCAM, 2001)

3.2.2.2 Determination of reducing sugars

A sample of 25 g was accurately weighed and transferred into 250 mL volumetric flask and then added 10 mL of neutral lead acetate solution and diluted to volume with water and filter. An aliquot of 25 mL of the clarified filtrate was added to 500 mL volumetric flask containing 100 mL water. Potassium oxalate was added in small quantities until there is no further precipitation to make up to volume. Solution was mixed well and filtered through Whatmann No.1 filter paper and transferred to a 50 mL burette.

Preliminary Titration: a solution of 5 mL each of Fehling A and B was pipetted into 250 mL conical flask. About 10 mL water and a few boiling chips or glass beads were added and mixed. Solution was dispensed. The flask was heated to boiling. 3 drops of methylene blue indicator were added. The dropwise addition of solution was continued until the blue colour disappeared to a brick-red end point. (The concentration of the sample solution should be such that the titre value is between 15 and 50 mL). Note down the titre.

Final Titration: a solution of 5 mL each of Fehling A and B was Pipetted. Sample solution was added to about 2 mL less than titre value of the preliminary titration. The flask was heated to boiling within 3 minutes to complete the titration. The titration was duplicated and average taken. The reducing sugars % was calculated as in Equation 2.

Reducing sugars (% as invert sugar) $= \frac{Dilution\ x\ factor\ of\ Fehling\ (in\ gm) x\ 100}{weight\ of\ sample\ x\ titre}$. - (2) (JCAM, 2001)

3.2.2.3 Determination of fructose and glucose

A sample 2 g was weighed to 250 mL volumetric flask to make up to volume. The solution was well mixed and an aliquot of 25 mL was transferred to a 250 mL of iodine flask. A solution of 50 mL of 0.1N Iodine was pipetted and added 50 mL of 0.2 sodium carbonate and 50 mL of sodium bicarbonate solution. The solution was allowed to stand in dark for 2 hours. The solution was acidified with 12 mL of 25% H_2SO_4 and titrated with standard sodium thiosulphate using starch as indicator. Blank was carried out simultaneously. The titre value of blank was subtracted from the titre value of sample. Calculation was done as in Equation 3

Glucose % = $\frac{Normality\ of\ thiosulphate\ x\ dilution\ x\ (B-S) x\ 0.009005\ x\ 100}{0.1N\ x\ weight\ of\ sample}$ - (3) (JCAM, 2001)

Fructose % = Reducing sugars % - glucose % - (4) (AOAC, 2000)

3.2.2.4 Determination of sucrose

Sucrose was determined using Equation 5

Sucrose% = (Total reducing sugars / invert sugar % - reducing sugar %) x 0.95. – (5) (JCAM, 2001)

3.3 Determination of moisture content

Refractive index of the honey samples was found using refractometer by putting two drops of sample into the sample compartment, and moisture content determined by Wedmore (1955) equation.

Moisture (%) = $[-0.2681-\log(RI-1)]/0.002243$ - (4) (Giulio and Lorenzo, 2008)

Where RI= refractive index

3.4 Determination of viscosity

The viscosities of honey samples were determined with Rapid Visco Analyzer (RVA 4500, Australia) at a constant time, temperature and speed of 10 min, 30°C and 50 rpm respectively. Samples were put in a canister and inserted into the sample compartment of the machine. The canister was pressed down by the overhead lever to display the result on a screen.

3.5 Data analysis

Data was analysed using Palisade@RISK 7.5 software, and results presented in tables. In the analysis, the data were fit to distribution and ranked by Akaike Information Criterion (AIC) to determine the statistical distributions (Traing, Uniform, Kumaraswamy and Expon) and central tendencies matrix (max., min., mean and std. dev.) values for moisture, sugars and viscosity of samples. Excel was used to determine the correlation between viscosity and moisture content.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Trends of mean values of quality parameters in honey samples

In this study (Table 4.1) the mean values of moisture content (17.28%) and reducing sugar content (sum of fructose and glucose) (67.44%) were within the Codex (Codex Alimentarius, 2001) and EU (Bogdanov and Martin, 2002; Council Directive 2001/110/EC) limits. However, the sucrose content of 6.39% was above the Codex and EU limits of not more than 5%. On the other hand, the moisture content of 17.28% was higher than the control (authentic source) value of 16.49 whiles the reducing sugar content of 67.44% was lower than the control value of 74.01%, even though the mean values fall within the international standards. The mean value of the sucrose content of 6.39% was in the same range as the control value of 6.71%, even though both are above the Codex and EU limits of 5% minimum.

Table 4.1 Levels of moisture content, sugars and viscosity of honey compared to control and international standards

Quality Parameters	Mean values	Control values (authentic source)	International standards	
			Codex	EU
Moisture content (%)	17.28	16.49	20 max.	20 max.
Reducing sugar (fructose + glucose) %	67.44	74.01	60 min.	60 min.

Sucrose (%)	6.39	6.71	5 max.	5 max.
Viscosity (cP)	6,575.89	6124	-	-

SOURCE: (Codex standards for honey, 2001; Bogdanov and Martin, 2002; Council Directive 2001/110/EC)

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4.2 Moisture content

The moisture content values ranged from 14.99% to 20.36%, with the mean value of 17.28% (Table 4.2), which was below the Codex (Codex standard for honey, 2001) and EU (Council Directive 2001/110/EC) maximum limits (Table 4.1). According to Yanniotis *et al*. (2006), Islam *et al*. (2012) and Pavelková *et al*. (2013), moisture contents of honey samples studied ranged from 15% to 17.1%, 17.19% to 19.19% and 15.9% to 17.2% respectively, which confirmed the results and were within Codex maximum limits of 20%. Moreover, mean values of moisture content of honey samples in the studies of Fahim *et al*. (2014), Aazza *et al*. (2013), and Alves *et al*. (2013) were in the limit of acceptable international standards of honey moisture content (≤ 20 %). However, two samples recorded moisture content of 20.36% and 20.32% which were slightly above Codex maximum limit of 20%. Similar findings revealed levels ranging from 14.3% and 20.2% (Chakir *et al*., 2016) and 18.19% to 20.27% (Ulloa *et al*., 2015) which indicated that some samples in their studies recorded levels slightly above Codex limit but considered by European Community regulations of 21% (The Council of the European Union, 2002). The variation in moisture content is due to the differences in environmental conditions such as climate, floral origin of honey samples, the water content of nectars, processing techniques and storage conditions (Bogdanov *et al*., 2004). Moisture content is very significant element in assessing the extent of honey maturity and shelf life (Singh and Bath, 1997). Generally, high levels of water causes honey fermentation, loss of flavour and loss of its quality (Terrab *et al*., 2003). It also indicates extraction of honey under high humidity or premature extraction conditions (Feás *et al*., 2010).

Table 4.2 Statistical presentation of honey results

Quality Parameters	Statistical Distributions	Central Tendencies Matrix			
		Min.	Max.	Mean	Std Dev.
Moisture content (%)	Kumaraswamy (0.11515,0.23807,14.9913,20.3594)	14.99	20.36	17.28	1.50
Reducing sugar (fructose + glucose) %	Triang (27.762, 82.093, 82.093)	33.24	82.09	67.44	14.89
Fructose (%)	Triang (22.181, 77.109, 77.109)	27.19	77.11	62.67	14.92
Glucose (%)	Unifrom (3.1645, 6.2645)	3.32	6.11	4.74	0.95
Sucrose (%)	Uniform (2.6395, 9.8511)	3.00	9.49	6.39	1.95
Viscosity (cP)	Expon (5266.9)	1,309.00	17,239.00	6,575.67	4,664.66

4.3 Sugar contents

4.3.1 Reducing sugar (Sum of Fructose and Glucose)

Form the study, the reducing sugar content ranged from 33.24% to 82.09% (Table 4.2), with the mean value of 67.44%, which is above the codex and EU minimum limits of 60% (Table 4.1). Several studies by different researchers revealed the same trend thus, 73.64% (Ulloa *et al*., 2015), 64.72% (Khalil *et al*., 2012), and 72.96% (Jalili, 2016). Reducing sugars, which consist of mainly glucose and fructose, are the major constituents of honey (Aazza *et al*., 2013; Doner, 1977), with fructose being the most represented (Ouchemoukh *et al*., 2010; Pérez-Arquillué *et al*., 1995). According to the results obtained, 6 samples recorded levels of 33.24%, 57.84%, 46.99%, 58.19%, 54.72% and 38.65% below the minimum limits of 60% by codex and EU standards. Studies by others showed similar trend, thus one out of three honey samples recorded 57.748% (Fahim *et al*., 2014), five out of seven samples recorded 49.0%, 58.1%, 43.3%, 57.0% and 47.8% (Saxena *et al*., 2010).

4.3.2 Sucrose content

From the study (Table 4.2) the sucrose content ranged from 3.00% to 9.49%, with the mean value of 6.39%, which is above the maximum limits of 5% set by Codex and EU standards (Table 4.1). According to Adjlane *et al*. (2014), samples recorded a mean of 7.15% sucrose content of Algerian honey, which confirmed results obtained. The high sucrose content observed in most of the sample could be attributed to overfeeding of honeybees with sucrose syrup, adulteration, or prematurely harvest of honey before sucrose conversion into glucose and fructose is completed (Saxena *et al*., 2010; Anklam, 1998; Guler *et al*., 2007). Additionally, it is reported that high sucrose concentration of honey may be due to the addition of commercial sugar to honey (Gebremariam and Brhane, 2014). However, five samples revealed levels of 4.69%, 3.00%, 4.47%, 4.97%, and 3.31%, which were within acceptable limits by Codex and EU specifications. Other studies by El Sohaimy *et al*. (2015), Jalili (2016) and Venir *et al*. (2010) indicated mean values of 2.92%, 3.85% and 1.50% respectively, confirmed this results. Anklam (1998) reported that sucrose content can decrease during storage of honey due to the presence of invertase. According to Da Costa Leite *et al*. (2000), the reason for the variable levels of sucrose could be that a transglucosylation reaction is initiated by transference of the a-D-glucopyranosyl unit from sucrose to an acceptor molecule.

Table 4.3 Correlation between moisture content and viscosity

Quality Parameter	Moisture Content	Viscosity
Moisture content	1	-
Viscosity	-0.83865068	1

4.4 Viscosity

From the study (Table 4.3) moisture content has a strong correlation on viscosity of honey (c = 0.84). This indicates that moisture content is inversely proportional to viscosity, thus as moisture content increases as viscosity decreases and vice versa. For instance, the two honey sample with the lowest moisture contents of 14.50% and 15.19% recorded the highest viscosity of 17239 cP and 15480 cP respectively. Likewise, the two samples with the highest moisture of 20.36% and 20.32% showed the lowest viscosity of 1460 cP and 1309 cP respectively. The study of Saxena *et al*. (2010) revealed the same trend as honey sample with the lowest moisture content of 17.2% recorded the highest viscosity of 8500 cP compared with sample with the highest moisture content of 21.6% with the lowest viscosity of 1140 cP. According to Ramzi *et al*. (2015) moisture content decreased with increased viscosity as honey with lowest moisture of 15.25% showed viscosity of 270.5 Pa s whiles the sample with the highest moisture of 19.92% recorded a low viscosity of 22.1 Pa s. In the study of Abu-Jdayil *et al*. (2002), 6 honey samples analysed at a temperature of 25 °C revealed that samples with the lowest moisture contents (15.78% and 15.92%) recorded the highest viscosities (30.0 Pa s ≈ 30000 cP and 24.4 Pa s ≈ 24400 cP respectively) whereas those with the highest moisture content (17.37% and 17.90%) recorded the lowest viscosities (24.4 Pa s ≈ 24400 cP and 11.6 Pa s ≈ 11600 cP) respectively. Likewise, 4 honey samples analysed at temperature of 30 °C showed the same trend, as sample with the lowest moisture content of 15.3% noted the highest viscosity (11.1 Pa s ≈ 11100 cP) whereas the one with the maximum moisture content (19.9%) recorded the minimum viscosity (1.7 Pa s ≈ 1700 cP). Moreover, Junzheng and Changying (1998) established that 10 honey samples from different sources analysed confirmed the impact of moisture content on viscosity, in that sample with the least moisture content (19.8%) recorded the most viscosity (2.9 Pa s ≈ 2900 cP) whiles the sample with the most moisture content (29.0%) recorded the least viscosity (0.2 Pa s ≈ 200 cP). The trends indicate that generally, honey with lowest moisture contents tend to be more viscos and vice versa (Saxena *et al*., 2010; Rairmez, 2000). Other factors influencing viscosity of honey are composition of individual sugars (Chirife and Buera, 1997), the amount and type of colloids present in the honey (Juszczak and Fortuna, 2006), temperature (Bhandari *et al*., 1999; Fauzi *et al*., 2014), amount and size of crystals and floral source (Rairmez, 2000).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the study it is concluded that, not all the honey sold in the markets of the Tema metropolis of Ghana meet the international standards, especially the sugar levels and will not be accepted in the international markets if not checked and corrected.

5.2 Recommendations

Based on the findings from this study, the following recommendations are made:

1. Further studies should be done on the other compositional and quality properties, such as ash, HMF, water insoluble solids contents, color, free acidity, diastase activity, electrical conductivity etc. to ascertain their compliance.
2. The FDA of Ghana should intensify its regulatory duties in the country to ensure compliance.

REFERANCES

Aazza, S., Lyoussi, B., Antunes, D. and Miguel, M.G. (2013). Physicochemical characterization and antioxidant activity of commercial portuguese honeys. *Journal of Food Science*, 78, C1159–C1165.

Abu-Jdayil, B., Ghzawi, A.A., Al-Malah, K.I.M. and Zaitoun, S. (2002). Heat effect on rheology of light- and dark-coloured honey. *Journal of Food Engineering*, 51(1), 33-38.

Adjlane, N., Haddad, N., Ameur, K.L., Kesraou, S. and Moussaou, D. (2014). Physicochemical and Microbiological Characteristics of some Samples of Honey Produced by Beekeepers in Algeria. *Acta Technologica Agriculturae*, 1, 1-5

Adriana, C., Szabo, E., Borbely, M., Czipa, N. and Purcarea, C. (2012). Comparative study of acacia and rape honey. *Analele Universitatii din Oradea. Fascicula: Ecotoxicologie, Zootechnie si Technologii de Industrie Alimentara*, XI/B (11), 325-332.

Ajibola, A., Chamunorwa, J.P. and Erlwanger, K.H. (2012). Nutraceutical values of natural honey and its contribution to human health and wealth. *Nutrition and Metabolism*, 9, 61-73

Ajibola, A., Idowu, G.O., Amballi, A.A., Oyefuga, O.H. and Iquot, I.S. (2007). Improvement of some haematological parameters in albino rats with pure natural honey. *Journal of Biological and Scientific Research*, 2, 67–69.

Ajlouni, S. and Sujirapinyokul, P. (2010). Hydroxymethylfurfuraldehyde and amylase contents in Australian honey. *Journal of Food Chemistry*, 119 (3), 1000-1005.

Al-Himyari, F. (2009). The use of honey as natural preventive therapy of cognitive decline and dementia in the Middle East, 5, 1-10

Al-Mahasneh, M.A., Rababah, T.M. and Ma'abreh, A.S. (2013). Evaluating the combined effect of temperature, shear rate and water content on wild-flower honey viscosity using adaptive neural fuzzy inference system and artificial neural networks. *Journal of Food Process Engineering*, 1–11.

Al-Mamary, M., Al-Meeri, A. and Al-Habori, M. (2002). Antioxidant activities and total phenolics of different types of honey. *Nutrition Research*, 22(9), 1041–1047.

Almeida-Muradian, L.B, Matsuda, A.H. and Bastos, D.H.M. (2007). Physicochemical parameters of amazon *Melipona* honey. *Quimica Nova,* 30, 707-708.

Alvarez-Suarez, J.M., Tulipani, S., Romandini, S., Bertoli, E. and Battino, M. (2010). Contribution of honey in nutrition and human health: a review. *Mediterranean Journal of Nutrition and Metabolism*, 3, 15–23.

Alves, A., Ramos, A., Gonçalves, M.M., Bernardo, M. and Mendes, B. (2013). Antioxidant activity, quality parameters and mineral content of portuguese monofloral honeys. *Journal of Food Composition and Analysis,* 30(2), 130–138.

Alves, R.M.O., Carvalho, C.A.L., Souza, B.A., Sodré, G.S. and Marchini, L.C. (2005). Características físico-químicas de amostras de mel de *Melipona mandacaia* Smith (Hymenoptera: Apidae). *Ciência e Tecnologia de Alimentos*, 25, 644-650.

Al-Waili, N.S. and Boni, N.S. (2003). Natural honey lowers plasma prostaglandin concentrations in normal individuals. *Journal Medicinal Food*, 6, 129–133.

Anklam, E. (1998). A review of the analytical methods to determine the geographical and botanical origin of honey. *Food Chemistry*, 63, 549–562.

Ariefdjohan, M.W., Martin, B.R., Lachcik, .P.J. and Weaver, C.M. (2008). Acute and chronic Effects of honey and its carbohydrate constituents on calcium. *Journal of Agricultural and Food Chemistry*, 56(8), 2649-2654

Assil, H. I., Sterling, R. and Sporns, P. (1991). Crystal control in processed liquid honey. *Journal of Food Science*, 56, 1034-1041.

Association of Official Analytical Chemists International. (2000). Sugars and sugar products. In: Official Methods of Analysis, 2(44), 16th Edition, DC 22-33

Attard, E. and Mizzi, J. (2013). Physicochemical characterization of Gozitan Honey. *International Journal of Food Studies*, 2, 180-187

Baker, H. G. and Baker, I. (1983). Chemistry of Floral Nectar. *The Biology of Nectaries;* Bently, B. Columbia University Press: New York,

Ball, D.W. (2007). The Chemical Composition of Honey. *Journal of Chemical Education*. 84(10), 1643-1646

Bett, C.K. (*2017*). Factors Influencing Quality Honey Production. *International Journal of Academic Research in Business and Social Sciences,* 7(11), 1-12

Bhandari, B., D'Arcy, D. and Chow, S. (1999). Rheology of selected Australian honeys. *Journal of Food Engineering*, 41, 61-68

Bianchi, E.M. (1977). Honey: Its importance in children's nutrition. *American Bee Journal*, 117733.

Bogdanov, S. (1999). International Honey Commission, Honey quality and international regulatory standards: review by the International Honey commission. *Bee-World*, 80 (2), 6169

Bogdanov, S. and Gallmann, P. (2008). Authenticity of honey and other bee products: State of the art. ALP science No 520, Agroscope Liebefeld-Posieux. *Swiss Federal Research Station for Animal Productionand Dairy Products (ALP), Bern*.

Bogdanov, S. and Martin, P. (2002). Honey authenticity: a review. *Mitteilungen aus dem Gebiete der Lebensmittel-untersuchung un Hygiene*, 93, 232–254

Bogdanov, S., Ruoff, K. and Oddo, L.P. (2004). Physico-chemical methods for the characterisation of unifloral honeys: a review. *Journal of Apidologie,* 35(1), 4–17.

Bonabeau, E., Dorigo, M. and Theraulaz, G. (1999). Swarm Intelligence: From Natural to Artificial Systems, New York, NY: *Oxford University Press*.

Brunsø, K., Fjord, T.A. and Grunert, K.G. (2002). Consumers' food choice and quality perception. *Working paper*, 77, 1-60

Bucekova, M., Juricova, V., Monton, E., Martinotti, S., Ranzato, E. and Majtan, J. (2017). Microwave processing of honey negatively affects honey antibacterial activity by inactivation of bee-derived glucose oxidase and defensin-1. *Journal of Food Chemistry,* 124

Buettener, A. and Beauchamp, J. (2010). Chemical input—Sensory output: Diverse modes of physiology–flavour interaction. *Food Quality and Preference*, 21, 915-924.

Burgett, D.M. (1997). Antibiotic systems in honey, nectar, and pollen. In: *Honey Bee Pest, Predators, and Diseases,* 455–468.

Burns, D.T., Dillon, A., Warren, J. and Walker, M.J. (2018). A Critical Review of the Factors Available for the Identification and Determination of Mānuka Honey. *Food Analytical Methods*, 1-7

Carrié, R.J.G, George, D.R. and Wäckers F.L. (2012). Selection of floral resources to optimize conservation of agriculturally-functional insect groups. *Journal of Insect Conservation,* 16, 635-640.

Chakir, C., Romane, A., Marcazzan, G.L. and Ferrazzi, P. (2016). Physicochemical properties of some honeys produced from different plants in Morocco. *Arabian Journal of Chemistry* 9, S946–S954

Chauzat, M.P., Faucon, J.-P., Martel, A.-C., LaChaize, J., Cougoule, N. and Aubert, M. (2006). A survey of pesticide residues in pollen loads collected by honey bees in France. *Apiculture and Social Insects*, *99*(2), 253–262.

Chen, L., Xue, X., Ye, Z., Zhou, J., Chen, F. and Zhao, J. (2011). Determination of Chinese honey adulterated with high-fructose corn syrup by near-infrared spectroscopy. *Journal of Food Chemistry,* 128(4), 1110–1114.

Chen, Q., Qi, S., Li, H., Han, X., Ouyang, Q. and Zhao, J. (2014). Determination of rice syrup adulterant concentration in honey using threedimensional fluorescence spectra and multivariate calibrations. *Spectrochim Acta A Molecular Biomolecular Spectroscopy,* 131:177–182.

Chepulis, L.M., Starkey, N.J., Waas, J.R. and Molan, P.C. (2009). The effects of long-term honey, sucrose or sugar-free diets on memory and anxiety in rats. *Physiology and Behavior*, 97, 359–368.

Chirife, J. and Buera, M.P. (1997). A simple model for predicting the viscosity of sugar and oligosaccharide solutions. *Journal of Food Engineering*, 33 121-126

Christe, P., Oppliger, A., Bancalà, F., Castella, G. and Chapuisat, M. (2003). Evidence for collective medication in ants. *Ecology Letters,* 6, 19–22.

Çinar, S. B., Ekşi, A. and Coşkun, I. (2014). Carbon Isotope Ratio (13C/12C) of Pine Honey and Detection of HFCS Adulteration. *Food Chemistry,* 157: 10–13.

Codex Alimentarius Commission. Revise codex standard for honey, Codex Standards 12-1981, Adopted in 1981, Revision 1 (1987), Revision 2 (2001), pp.1-8.

Cosio, M.S., Ballabio, D., Benedetti, S. and Gigliotti, C. (2007). Evaluation of different storage conditions of extra virgin olive oils with an innovative recognition tool built by means of electronic nose and electronic tongue. *Food Chemistry*, 101, 485-491.

Council Directive (2001). 110/EC relating to honey. Official Journal of the European Communities, L10, 47–52.

Crane, E. (1975). In Honey. A Comprehensive Survey. Edited by Crane E. London: William Heinemann, 439–488.

Da Costa Leite, J.M., Trugo, L.C., Costa, L.S.M., Quinteiro, L.M.C., Barth, O.M., Dutra, V.M.L. and Maria, C.A.B. (2000). Determination of oligosaccharides in Brazilian honeys of different botanical origin. *Food Chem*estry, 70, 93–98.

Da Silva, P.M., Gauche, C., Gonzaga, L.V., Costa, A.C.O. and Fett, R. (2016). Honey: Chemical composition, stability and authenticity. *Food Chemistry*, 196, 309–323

Dahimi, O., Abdul Rahim, A., Mohammed, A., Sukri Hassan, M., Zam Hashari, S., Siti Mashitoh, A. and Saadi, S. (2014). Multivariate statistical analysis treatment of DSC thermal properties for animal fat adulteration. *Food Chemistry,* 158, 132-138.

Dak, M., Verma, R. C. and Jaaffrey, S. N. A. (2007). Effect of temperature and concentration on Rheological properties of "Kesar" mango juice. *Journal of Food Engineering*, 80(4), 1011–1015

Danezis, G.P., Tsagkaris, A.S., Brusic,V. and Georgiou, C.A. (2016). Food authentication: State of the Art and Prospects. *Trends in Analytical Chemistry,* 85, 123-132, 2016. 36.

Daniele, G., Maitre, D. and Casabianca, H. (2012). Identification, quantification and carbon stable isotopes determinations of organic acids in monofloral honeys. A powerful tool for botanical and authenticity control. *Journal of Rapid Communications Mass Spectrometry* 26(17):1993–1998

Davis, E.A. (1995). Functionality of sugars: Physiochemical interactions in foods. *American Journal of Clinical Nutrition, 62*, 170–177.

De Oliveira, R., Teixeira, E., Da Silva, C., Guerra, M. L., Conte, C. and Oliveira de Jesus, E. F. (2014). Detection of honey adulteration of high fructose corn syrup by low field Nuclear Magnetic Resonance. *Journal of Food Engineering,* 43, 321-135, 322-339.

Dijksterhuis, G. B. (1997). Multivariate data analysis in sensory and consumer science: An overview of developments. *Trends in Food Science and Technology*, 6, 206-211.

Dinu, V. (2018). Food Safety in the Context of the European Union. *Amfiteatru Economic,* 20(47), pp. 5-7.

Dobre, I., Georgescu, L. A., Alexe, P., Escuredo, O. and Seijo, M. C. (2012). Rheological behavior of different honey types from Romania. *Food Research International*, 49(1), 126–132,

Donaldson-Matasci, M. and Dornhaus, A. (2014). Dance Communication Affects Consistency, but Not Breadth, of Resource Use in Pollen-Foraging Honey Bees. *PLoS ONE,* 9(10), 1-9

Doner, L. W. (1977). The sugars of honey – A review. *Journal of the Science of Food and Agriculture*, 28, 443–456.

Dong, H., Xiao, K., Xian, Y. and Wu, Y. (2017). Authenticity determination of honeys with nonextractable proteins by means of elemental analyzer (EA) and liquid chromatography (LC) coupled to isotope ratio mass spectroscopy (IRMS). *Food Chemistry,* 1-36

Dustmann, J. H. (1979). Antibacterial effect of honey. *Apiacta*, 14, 7–11

El-Arab, A.M.E., Girgis, S.M., Hegazy, E.M. and El-Khalek, A.B.A. (2006). Effect of dietary honey on intestinal microflora and toxicity of mycotoxins in mice. *BMC Complementary and Alternative Medicine*, 1-12

Escriche, I., Visquert, M., Carot, J. M., Domenech, E. and Fito, P. (2008). Effect of honey thermal conditions on hydroxymethylfurfural content prior to pasteurization. *Journal of Food Science and Technology,* 14 (5), 29-35.

Everstine, K., Spink, J. and Keennedy, S. (2013). Economically motivated adulteration (EMA) of food: common characteristics of EMA incidents. *Journal Food Protection,* 76, 723-735.

Fahim, H., Dasti, J.I., Ali, I., Ahmed, S. and Nadeem, M. (2014). Physico-chemical analysis and antimicrobial potential of Apis dorsata, Apis mellifera and Ziziphus jujube honey samples from Pakistan. *Asian Pacific Journal of Tropical Biomedicine*, 4(8), 633-641

Fairchild, G. F., Nichols, J. P. and Capps, O. Jr. (2003). Observations on economic adulteration of high-value food products: the honey case. *Journal of Food Distribution* Res 34:38–45

Fauzi, N.A., Farid, M.M. and Silva, F.V.M. (2014). High-pressure processing of Manuka honey improvement of antioxidant activity, preservation of colour and flow behaviour. *Food Bioprocess Technology*, 7, 2299–2307.

Feás, X., Pires, J., Estevinho, M.L., Iglesias, A. and de Araujo, J.P.P. (2010). Palynological and physicochemical data characterisation of honeys produced in the Entre-Douro e Minho region of Portugal. *International Journal of Food Science and Technology*, 45, 1255-1262.

Finola, M. S., Lasagno, M. C. and Marioli, J. M. (2007). Microbiological and chemical characterisation of honeys from central Argentina. *Food Chemistry*, 100(4), 1649-1653.

Food Fraud Database (2016). https://www.foodfraud.org/ Accessed: 05/09/17.

Frangaki, D. (1988). Metabolic effects of honey (alone or combined with other foods) in type II diabetics. *Acta Diabetologica Latina*, 25(3), 197–203.

Frisch, K.V. (1967). The dance language and orientation of bees. Oxford University Press, Oxford

Gallina, A., Stocco, N. and Mutinelli, F. (2010). Karl Fischer titration to determine moisture in honey: a new simplified approach. *Journal of Food Control,* 21(6), 942–4.

Gebremariam, T. and Brhane, G. (2014). Determination of Quality and adulteration effects of honey from Adigrat and its surrounding areas. *International Journal of Emerging Technologies in Engineering* Research, 2(10), 71-76.

George, C. K. (1998): Spices- Taste of success, The Hindu Survey of Indian Industry, 385-38

Gheldof, N., Wang, X.H. and Engeseth, N.J. (2002). Identification and quantification of antioxidant components of honeys from various floral sources. *Journal of Agricultural and Food Chemistry,* 50(21), 5870–5877.

Giulio, S. and Lorenzo, L. (2008). Refractometric determination of water content in royal jelly. *Apidologie*, Springer Verlag, 39 (2), 225-232.

Gomes, S., Dias, L.G., Moreira, L.L., Rodrigues, P. and Estevinho, L. (2010). Physicochemical, microbiological and antimicrobial properties of commercial honeys from Portugal. *Food Chemical Toxicology*, 48(2), 544–548.

Gonzales, A.P., Burin, L. and Buera, M.A.D.P. (1999). Color changes during storage of honeys in relation to their composition and initial color. *Journal of Food Research International*, 32, 185–191.

Gould, J.L. (1986). The local map of honey bees: do insects have cognitive maps. *Science*, 232, 861-863

Grunert, K. G. and Grunert, S. C. (1995). Measuring subjective meaning structures by the laddering method: Theoretical considerations and methodological problems. *International Journal of Research in Marketing*, 12*,* 209-225.

Guelpa, A., Marini, F., du Plessis, A., Slabbert, R. and Manley, M. (2016). Verification of Authenticity of South African Honey and Fraud Detection using NIR Spectroscopy. *Food Control,* 73, 1388–1396.

Guler, A., Bakan, A., Nisbet, C. and Yavuz, O. (2007). Determination of important biochemical properties of honey to discriminate pure and adulterated honey with sucrose (Saccharum officinarum L.) syrup. *Food Chemistry*, 105(111), 1109–1125.

Guler, A., Kocaokutgen, H., Garipoglu, A. V., Onder, H., Ekinci, D. and Biyik, S. (2014). Detection of adulterated honey produced by honeybee (Apis mellifera L.) Colonies fed with different levels of commercial industrial sugar (C3 and C4 plants) syrups by the carbon isotope ratio analysis. *Food Chemistry, 155*, 155-160.

Honey Care Africa. (2010). Beekeeping in Africa Honey Care Agricultural Services Bulletin 68/6. Nairobi.

Hussain1, M.B., Hannan, A., Akhtar, N., Fayyaz, G.O., Imran, M., Saleem, S. and Qureshi, I.A. (2015). Evaluation of the antibacterial activity of selected Pakistani honeys against multidrug resistant Salmonella typhi. *BMC Complementary and Alternative Medicine*, 1-9

Islam, A., Khalil, I., Islam, N., Moniruzzaman, M., Mottalib, A., Sulaiman, S.A. and Gan, S.H. (2012). Physicochemical and antioxidant properties of Bangladeshi honeys stored for more than one year. *BMC Complementary and Alternative Medicine,* 1-10

Jalili, M. (2016). Evaluating the Quality and Physicochemical Properties of Honey Commercialized in Iran. *Journal of Chemical Health Risks,* 6(3), 175-184

Japan Customs Analysis Methods. (2001). Quantitative Analysis of Reducing Sugars in Sugar Preparations consisting of Sugar and Dextrin, No. 114-R1

Jia, S., Liu, Z., Zhang, S., Liu, P., Zhang, L., Lee, S.H., Zhang, J., Signoretti, S., Loda, M. and Roberts, T.M., (2008). Essential roles of PI(3)K-p110β in cell growth, metabolism and tumorigenesis. *Nature,* 454, 776–779.

Johnson, R. (2014). Food Fraud and ''Economically Motivated Adulteration'' of Food and Food Ingredients. *Congressional Research Service Report,* R43358

Junzheng, P. and Changying, J. (1998). General rheological models for natural honeys in China. *Journal of Food Engineering*, 36, 165-168

Juszczak, L. and Fortuna, T. (2006). Rheology of selected Polish honeys. *Journal of Food Engineering,* 75(1), 4349.

Kabbani, D., Sepulcre, F. and Wedekind, J. (2011). Ultrasound-assisted liquefaction of rosemary honey: influence on rheology and crystal content. *Journal of Food Engineering*. 107 (2), 173-178.

Kamaruzaman, N.A., Sulaiman, S.A., Kaur, G. and Yahaya, B. (2014). Inhalation of honey reduces airway inflammation and histopathological changes in a rabbit model of ovalbumin-induced chronic asthma. *BMC Complementary and Alternative Medicine*, 14, 176-187

Karasu, S., Toker, O.S., Yilmaz, M.T., Karaman, S. and Dertli, E. (2014a).Thermal loop test to determine structural changes and thermal stability of creamed honey: Rheological characterization. *Journal of Food Engineering*, 150, 90–98.

Katsilambros, N., Philippides, P., Touliatou, A., Georgakopoulos, K., Kofotzouli, L. and Kędzierska-Matysek, M. and Florek, M., Wolanciuk, A., Skałecki, P. and Litwińczuk, A. (2016). Characterisation of viscosity, colour, 5 hydroxymethylfurfural content and diastase activity in raw rape honey (Brassica napus) at different temperatures. *Journal of Food Science and Technology,* 53(4), 2092–2098

Khalil, M. I., Moniruzzaman, M., Boukraâ, L., Benhanifia, M., Islam, M.A., Islam, M.N., Sulaiman, S.A. and Gan, S.H. (2012). Physicochemical and antioxidant properties of Algerian honey. *Molecules,* 17(9), 11199–11215.

Khalil, M. I., Motallib, M. A., Anisuzzaman, A. S. M., Sathi, Z. S., Hye, M. A. and Shahjahan, M. (2001). Biochemical analysis of different brands of unifloral honey available at the northern region of Bangladesh. *The Sciences*, 1(6), 385–388.

Khalil, M.I., Sulaiman, S.A. and Boukraa, L. (2010). Antioxidant properties of honey and its role in preventing health disorder. *Open Neutraceuticals Journal*, 3, 6–16.

Khalil, M.I., Sulaiman, S.A. and Gan, S.H. (2010). High 5-hydroxymethylfurfural concentrations are found in Malaysian honey samples stored for more than one year. *Journal of Food Chemistry and Toxicology*, 48, 2388-2392.

Kolayli, S., Boukraâ, L., Şahin, H. and Abdellah, F. (2012). Sugars in honey. In: Preedy VR (ed) Dietary sugars: chemistry, analysis, function and effects. Royal Society of Chemistry, Cambridge, pp 3–15.

Kowalski, S. (2013). Changes of antioxidant activity and formation of 5- hydroxymethylfurfural in honey during thermal and microwave processing. *Food Chemistry*, 141 (2), 1378-1382.

Kreider, R.B., Rasmussen, C.J., Lancaster, S.L., Kerksick, C. and Greenwood, M. (2002). Honey: An alternative sports gel. *Strength and Conditioning Journal*, 24, 50–51.

Krell, R. (1996). Value –Added products from bee keeping. *Food and Agriculture Organization of the United Nations*, bulletin No.124.

Krell, R., Ricciardelli, D. G. and Oddo, P. (1988). The influence of harvesting and processing methods on honey quality in Zambia and Malawi. *Proceedings of the 4th International Conference on Apiculture in tropical Climates*, 268-273. Cairo.

Kristina, B., Lazarević, Jelena, Đ., Trifković, Andrić, F.L., Tešić, Ž.L., Anđelković, I.B., Radović, D.I., Nedić, N.M. and Milojković-Opsenica, D.M. (2013). Quality parameters and pattern recognition methods as a tool in tracing the regional origin of multifloral honey. *Journal of Serbian Chemical Society, 78* (12) 1875–1892

Kugonza, D.R. and Nabakabya, D. (2008). Honey Quality as Affected by Handling, Processing and Marketing Channels in Uganda. *Tropicultura*, 26(2), 113-118

Kugonza, D.R. and Nabakabya, D. (2008). Honey Quality as Affected by Handling, Processing and Marketing Channels in Uganda. *Tropicultura*, 26, 2, 113-118

Kujawska, M., Zamudio, F. and Hilgert, N.I. (2012). Honey-Based Mixtures Used in Home Medicine by Nonindigenous Population of Misiones, Argentina. *Evidence-Based Complementary and Alternative Medicine*, 1-15

Lage, L.G.A., Coelho, L.L., Resende, H.C., Tavares, M.G., Campos, L.A.O. and FernandesSalomão, T.M. (2012). Honey physicochemical properties of three species of the Brazilian *Melipona. Annals of the Brazilian Academy of Sciences*, 84(3), 605-608

Laureati, M., Buratti, Bassoli, A., Borgonovo, G. and Pagliarini, E. (2010). Discrimination and characterization of three cultivars of Perilla frutescens by means of sensory descriptors and electronic nose and tongue analysis. *Food Research International.* 43, 959-964.

Lazaridou, A., Biliaderis, C., Bacandritsos, N. and Sabatini, A. G. (2004). Composition, thermal and rheological behaviour of selected Greek honeys. *Journal of Food Engineering*, 64, 9–21.

Leyva-Daniel, D.E., Escobedo-Avellaneda, Z., Villalobos-Castillejos, F., Alamilla-Beltrán, L. and Welti-Chanes, J. (2017). Effect of high hydrostatic pressure applied to a Mexican honey to increase its microbiological and functional quality. *Journal of Food Bioproducts Processing*, 102, 299-306.

Linder, R. and Poppl, S.J. (2003). A new neural network approach classifies olfactory signals with high accuracy. *Food Quality and Preference, 14*, 435-440.

Longobardi, F., Casiello, G., Ventrella, A., Mazzilli, V., Nardelli, A., Sacco, D., Catucci, L. and Agostiano, A. (2015). Electronic nose and isotope ratio mass spectrometry in combination with chemometrics for the characterization of the geographical origin of Italian sweet cherries. *Food Chemistry,* 170:90–96

Maksoud, A.M. and Rahman, A.M. (2006). Bee honey nebulisation as a non-traditional treatment of acute bronchial asthma in infants and children. First North–south Conference and Workshop on Pharmacogenetics (Beating the Gene: From the Bench to the Bedside), 115.

Martel, A.-C., Zeggane, S., Aurières, C., Drajnudel, P., Faucon, J.P. and Aubert, M. (2007). Acaricide residues in honey and wax after treatment of honey bees colonies with Apivar or Asuntol. *Apidologie*, *38*, 534–544.

Milium, V. G. (1948). Some factors affecting the color of honey. *Journal of Economic Entomology*, 41, 495-505.

Moore, J.C, Spink, J. and Lipp, M. (2012). Development and application of a database for food ingredient fraud and economically motivated adulteration from 1980-2010. *Journal of Food Science,* 77:R119–R126

Moritz, R. F. A., de Miranda, J., Fries, I., Le Conte, Y., Neumann, P. and Paxton, R. J. (2010). Research strategies to improve honeybee health in Europe. *Apidologie*, *41*, 227–242.

Morse, R. A. (1986). The antibiotic properties of honey. *Pan-Pacific Entomologist*, 62, 370–371

Oliver, R. (2012). Neonicotinoids: Trying To Make Sense of the Science.

Oster, G. and Wilson, E. O. (1978). Castes and Ecology in the Social Insects, Princeton, NJ: *Princeton University Press*,

Othman, Z., Zakaria, R., Hussain, N.H.N., Hassan, A., Shafin, N., Al-Rahbi, B. and Ahmad, H.A. (2015). Potential Role of Honey in Learning and Memory. *Medical Sciences*, *3*, 3-15

Ouchemoukh, S., Schweitzer, P., Bey, M.B., Djoudad-Kadji, H. and Louaileche, H. (2010). HPLC sugar profiles of Algerian honeys. *Food Chemistry*, 121, 561–568.

Parasuraman, A., Zeithaml, V. A. and Berry, L. L. (1985). A Conceptual Model of Service Quality and its Implications for Future Research. *The Journal of Marketing*, 49(4), 41–50.

Pavelková, A., Kačániová, M., Čuboň, J., Švecová, Z., Kňazovická, V. and Felsöciová, S. (2013). Physicochemical and Microbiological Quality of honey from Liptov Region. *Journal of Microbiology, Biotechnology and Food Sciences,* 2 (1) 1185-1193

Pérez-Arquillué, C., Conchello, P., Ariño, A., Juan, T. and Herrera, A. (1994). Quality evaluation of Spanish rosemary (*Rosmarinus offcinalis*) honey. *Food Chemistry*, 51, 207-210.

Porrini, C., Mutinelli, F., Bortolotti, L., Granato, A., Laurenson, L., Roberts, K. and Lodesani, M. (2016). The status of honey bee health in Italy: Results from the nationwide bee monitoring network. *PLoS One*, *11*(5)

Pucciarelli, A.B., Schapovaloff, M.E., Kummritz, S., Señuk, I.A., Brumovsky, L.A. and Dallagnol, A.M. (2014). Microbiological and physicochemical analysis of yateí (*Tetragonisca angustula*) honey for assessing quality standards and commercialization. *Revista Argentina de Microbiología*, 46(4), 325-332

Radwan, S. S., El-Essawy, A. A. and Sarhan, M. M. (1984). Experimental evidence for the occurrence in honey ofspecific substances active against micro-organisms. *Zentralblatt für Mikrobiologie*, 139, 249–255

Ramenghi, L.A., Amerio, G. and Sabatino, G. (2001). Honey, a palatable substance for infants: from De Rerum Natura to evidence-based medicine. *European Journal of Pediatrics,* 160, 677–678.

Ramirez, C.M.A., Gonzales, N.SA and Sauri, D. E (2000). Effect of the temporary thermic treatment of honey on variation of the quality of the same during storage. *Apiacta*, 35: 162 – 170

Ramirez, M.A., Cervantes, S.A., Novelo, G. and Duch, E.S. (2000). Effect of the temporary thermic treatment of honey on variation of the quality of the same during storage. *Apiacta,* 35(4), 162 – 170.

Ramzi, M., Kashaninejad, M., Salehi, F., Mahoonak, A.R.S. and Razavi, S.M.A. (2015). Modeling of rheological behaviour of honey using genetic algorithm–artificial neural network and adaptive neuro-fuzzy inference system. *Food Bioscience*, 9(2), 60-67

Rinderer, T.E., Collins, A.M. and Tucker, K.W. (1985). Honey production and underlying nectar harvesting activities of Africanised and European honeybees. *Journal of apicultural Research*, 24(3), 161-167.

Rios-Corripio, M. A., Rojas-López, M. and Delgado-Macuil, R. (2012). Analysis of adulteration in honey with standard sugar solutions and syrups using attenuated total reflectance-Fourier transform infrared spectroscopy and multivariate. *Journal of Food*, 10, 119-122.

Robertsson, L., Iliev, B., Palm, R. and Wide, P. (2007). Perception modeling for human-like artificial sensor systems. *International Journal of Human-Computer Studies, 65*, 446-459.

Ruiz-Matute, A. I., Soria, A. C., Martínez-Castro, I. and Sanz, M. L. (2007). A New Methodology Based on GC−MS to Detect Honey Adulteration with Commercial Syrups. *Journal of Agricultural and Food Chemistry, 55*(18), 7264-7269.

Saarela, M., Lahteenmaki, L., Crittenden, R., Salminen, S. and Mattila-Sandholm, T. (2000). Gut bacteria and health foods – the European perspective. *International Journal of Food Microbiology*, 278, 99-117.

Samborska, K., Wasilewska, A., Gondek, E., Jakubczyk, E. and Kamińska-Dwórznicka, A. (2017). Diastase Activity Retention and Physical Properties of Honey/Arabic Gum Mixtures after Spray Drying and Storage. *International Journal of Food Engineering*, 1-11

Saxena, S., Gautam, S. and Sharma, A. (2010). Physical, biochemical and antioxidant properties of some Indian honeys. *Food Chemistry*, 118, 391-397

Schramm, D.D., Karim, M., Schrader, H.R., Holt, R.R., Cardetti, M. and Keen, C.L. (2003). Honey with high levels of antioxidants can provide protection to healthy human subjects. *Journal of Agricultural and Food Chemistry*, 51, 1732–1735.

Shafiee, S., Polde,r, G., Minaei, S., Moghadam-Charkari, N., Van Ruth, S. and Kuś, P.M. (2016). Detection of Honey Adulteration using Hyperspectral Imaging. *IFAC-PapersOnLine,* 49(16), 311-314.

Sikora, T. (2005). Methods and Systems of Food Quality and Safety Assurance. *Polish Journal of Food and Nutrition Sciences*. 14/55, 41-48

Simsek, A., Bilsel, M. and Goren, A. C. (2012). 13C/12C Pattern of Honey from Turkey and Determination of Adulteration in Commercially Available Honey Samples using EA-IRMS. *Food Chemistry,* 130(4):1115–1121.

Singh, N. and Bath, P.K. (1997). Quality evaluation of different types of Indian honey, *Food Chemistry*, 58, 129–133

Singham, P., Birwal, P. and Yadav, B.K. (2015). Importance of Objective and Subjective Measurement of Food Quality and their Inter-relationship. *Journal of Food Processing and Technolog,y* 6, 488.

Soares, S., Pinto, D., Rodrigues, F., Alves, R.C. and Oliveira, M.B.P. P. (2017). Portuguese Honeys from Different Geographical and Botanical Origins: A 4-Year Stability Study Regarding Quality Parameters and Antioxidant Activity. *Journal Molecules*, 22, 1338, 1-15

Sobrino-Gregorio, L., Vargas, M., Chiralt, A. and Escriche, I. (2017). Thermal properties of honey as affected by the addition of sugar syrup. *Journal of Food Engineering*, 1-25

Souza, B.A., Carvalho, C.A.L., Sodré, G.S. and Marchini, L.C. (2004). Características físicoquímicas de amostras de mel de *Melipona asilvai* (Hymenoptera: Apidae. *Ciência Rural*, 34, 1623-1624.

Spink, J. and Moyer, D. C. (2011). Defining the Public Health Threat of Food Fraud. *Journal of Food Science,* **7**6 R157-R163

Spivak, M. and Reuter, G.S. (2001). Resistance to American foulbrood disease by honey bee colonies Apis mellifera bred for hygienic behavior. *Apidologie,* 32, 555–565.

Starks, P.T., Blackie, C.A., Thomas, D. and Seeley, P.T. (2000). Fever in honeybee colonies. *Naturwissenschaften,* 87, 229–231.

Steenkamp, J. B. E. M. and van Trijp, H. C. M. (1991). The use of LISREL in validating marketing constructs. *International Journal of Research in Marketing*, 8*,* 283-299.

Stone, H. and Sidel, J.L. (1993). Sensory Evaluation Practices. *Food Science and Technology*, Academic Press, Incoperation

Subrahmanyam, M. (1991). Topical application of honey treatment of burns. *British Journal of Surgery*, 78 (4), 497–498.

Suguna, L., Chandrakasan, G., Thomas, J.K. (1992). Influence of honey on collagen metabolism during wound healing in rats. *Journal of Clinical Biochemistry and Nutrition*, 13, 7–12.

Tahir, A.A., Sani, N.F.A., Murad, N.A., Makpol, S., Ngah, W.Z.W. and Yusof, Y.A.M. (2015). Combined ginger extract and Gelam honey modulate Ras/ERK and PI3K/AKT pathway genes in colon cancer HT29 cells. *Nutrition Journal*, 14, 31-42

Terrab, A., Dıez, M.J. and Heredia, F.J. (2003). Palynological, physico-chemical and color characterization of Moroccan honeys. II. Orange (Citrus sp.) honey. *International Journal of Food Science and Technology*, 38, 379-386

Timsit, J.F. (2013). Topical honey: for bears, not for ICU catheters? *Critical Care*, 17, 103.

Tomaszewska-Gras, J. (2016). Rapid quantitative determination of butter adulteration with palm oil using the DSC technique. *Food Control,* 60, 629-635.

Tosun, M. (2013). Detection of adulteration in honey samples added various sugar syrups with 13C/12C isotope ratio analysis method. *Food Chemistry*, 138(2–3), 1629–1632.

Ulloa, P.A., Maia, M. and Brigas, A.F. (2015). Physicochemical Parameters and Bioactive Compounds of Strawberry Tree (*Arbutus unedo* L.) Honey**.** *Journal of Chemistry*, 1-10

Unnevehr, L. J. and Jensen, H.H., (1999). The Economic Implications of Using HACCP as a Food Safety Regulatory Standard. *Food Policy*, 24, 625-635

Van de Vijver, L. P.L. (2007). Measuring food quality: concepts, methods and challenges Seminar

Venir, E., Spaziani, M. and Maltini, E. (2010). Crystallization in "Tarassaco" Italian honey studied by DSC. *Food Chemistry*, 122, 410–415.

Wang, J. and Li, Q.X. (2011). Chemical composition, characterization, and differentiation of honey botanical and geographical origins. *Advances in Food and Nutrition Research*, 62, 89–137.

Wang, S., Guo, Q.,Wang, L., Lin, L., Shi, H., Cao, H. and Cao, B. (2015). Detection of Honey Adulteration with Starch Syrup by High performance Liquid Chromatography. *Food Chemistry*, 172:669–674.

Wang, X.H., Gheldof, N., Engeseth, N.J. (2004). Effect of processing and storage on antioxidant capacity of honey. *Journal of Food Science*, 69.

Wedmore, E.B. (1955). The accurate determination of the water content of honey. Part I. Introduction and results. *Bee World*, 36, 197-206

Wehner, R. and Srinivasan M.V. (1981). Dearching behaviour of dessert ants, genus *Cataglyphis* (*Formicidae, Hynenoptera*). *Journal of Comparative Physiology*, 142, 315-338

Weston, R.J. (2000). The contribution of catalase and other natural products to the antibacterial activity of honey: a review. *Food Chemistry*, 71, 235–239.

White, J. W. (1978). Honey. *Advances in Food Research*, 24, 287–374

White, J.W. and Doner, L.W., (1980). Honey Composition and Properties: Beekeeping in the United States. *Agriculture Handbook*, 335, 82–91.

Whitfield, C.W. and Anne-Marie, C. (2003). Gene E. Robinson Gene Expression Profiles in the Brain Predict Behavior in Individual Honey Bees. *Science* 302, 296, 1-5

Wilczyńska, A., Newerli-Guz, J. and Szweda, P. (2017). Influence of the Addition of Selected Spices on Sensory Quality and Biological Activity of Honey. *Journal of Food Quality*, 1-8

Winston, M.L. (1987). The Biology of the Honey Bee. Cambridge: Harvard University Press

Witczak, M., Juszczak, L. and Gałkowsk, D. (2011). Non-Newtonian behaviour of heather honey. *Journal of Food Engineering*, 104(4), 532–537.

Yaghoobi, N., Al-Waili, N., Ghayour-Mobarhan, M., Parizadeh, S.M., Abasalti, Z., Yaghoobi, Z., Yaghoobi, F., Esmaeili, H., Kazemi-Bajestani, S.M., Aghasizadeh, R., Saloom, K.Y. and Ferns, G.A. (2008). Natural honey and cardiovascular risk factors; effects on blood glucose, cholesterol, triacylglycerol, CRP, and body weight compared with sucrose. *Science World Journal*, 8:463 469.

Yanniotis, S., Skaltsi, S. and Karaburnioti, S. (2006). Effect of moisture content on the viscosity of honey at different temperatures. *Journal of Food Engineering*, 72, 372–377

Yilmaz, M. T., Tatlisu, N. B., Toker, O. S., Karaman, S., Dertli, E., Sagdic, O. and Arici, M. (2014). Steady, dynamic and creep rheological analysis as a novel approach to detect honey adulteration by fructose and saccharose syrups: Correlations with HPLC-RID results. *Food Research International, 64*, 634-646.

Yusof, N., Hafizaa, A.H.A., Zohdia, R.M. and Bakarb, M.Z.A. (2007). Development of honey hydrogel dressing for enhanced wound healing. *Radiation Physics and Chemistry*, 76, 1767–1770

Zakaria, A., Md Shakaff, A. Y., Masnan, M.J., Ahmad, M. N., Adom, A. H., Jaafar, M. N., Ghani, S. A., Abdullah, A. H., Abdul Aziz, A. H., Kamarudin, L. M., Subari, N. and Fikri, N. A. (2011). A Biomimetic Sensor for the Classification of Honeys of Different Floral Origin and the Detection of Adulteration. *Sensors* 11, 7799-7822.

Zeithaml, V. A. (1988). Consumer Perceptions of Price, Quality, and Value: A Means-End Model and Synthesis of Evidence. *Journal of Marketing*, 52(3), 2–22.

Zhu, X., Li, S., Shan, Y., Zhang, Z., Li, G., Su, D. and Liu, F. (2010). Detection of adulterants such as sweeteners materials in honey using nearinfrared spectroscopy and chemometrics. *Journal of Food Engineering,* 101(1), 92– 97.

Zielińska, S., Wesołowska, M., Bilek, M., Kaniuczak, J.and Dżugan M. (2014). The Saccharide Profile of Polish Honeys Depending on their Botanical Origin. *Journal of Microbiology, Biotechnology and Food Sciences, 3 (5) 387-390*

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APPENDIX

Appendix 1. Moisture content results of samples

Honey sample codes	Refractive Index (RI)	Moisture content (%)	Average (%)
control	1.4955	16.43	16.49
	1.4952	16.55	
H1	1.4940	17.02	17.16
	1.4933	17.29	
H2	1.4953	16.51	16.51
	1.4953	16.51	
H3	1.4920	17.80	17.84
	1.4918	17.88	
H4	1.4935	17.21	17.27
	1.4932	17.33	
H5	1.4993	15.03	14.99
	1.4991	14.95	

H6	1.4910	18.20	18.20
	1.4910	18.20	
H7	1.4924	17.65	17.69
	1.4922	17.73	
H8	1.4946	16.78	16.78
	1.4946	16.78	
H9	1.4925	17.61	17.73
	1.4919	17.84	
H10	1.4950	16.63	16.67
	1.4948	16.71	
H11	1.4894	18.83	18.85
	1.4893	18.87	
H12	1.4851	20.54	20.36
	1.4860	20.18	
H13	1.4988 1.4986	15.15 15.22	15.19
H14	1.4917 1.4914	17.92 18.04	17.98
H15	1.4958	16.31	16.43
	1.4952	16.55	
H16	1.4857	20.30	20.32
	1.4856	20.34	
H17	1.497	15.85 15.89	15.87
	1.4969		
H18	1.4982	15.38	15.36
	1.4983	15.34	
H19	1.4940	17.02	17.16
	1.4933	17.29	

Appendix 2. Sugar contents of samples

Sample codes	Reducing sugar		Average	Sucrose		Average	Glucose		Average	Fructose		Average
Control	74.01	74.01	74.01	6.58	6.85	6.71	3.57	3.11	3.34	70.44	70.90	70.67
H1	75.98	76.66	76.32	4.63	4.76	4.69	4.26	3.85	4.06	72.40	72.12	72.26
H2	33.31	33.18	33.24	7.60	7.92	7.76	5.88	6.22	6.05	27.30	27.09	27.19
H3	57.70	57.99	57.84	7.00	7.31	7.16	3.09	4.06	3.57	54.62	53.93	54.27
H4	81.24	80.56	80.90	2.99	3.01	3.00	4.26	3.77	4.02	76.98	76.79	76.89
H5	74.28	74.28	74.28	7.58	7.91	7.74	4.77	4.93	4.85	69.51	69.35	69.43
H6	72.79	72.79	72.79	4.41	4.53	4.47	4.57	3.38	3.98	68.21	68.53	68.37
H7	69.56	69.56	69.56	8.00	8.34	8.17	4.14	3.75	3.94	65.42	65.82	65.62
H8	80.31	79.73	80.02	4.90	5.05	4.97	6.43	5.33	5.88	73.89	74.40	74.14

H9	81.31	82.88	82.09	5.04	5.20	5.12	4.70	5.27	4.98	76.61	77.61	77.11
H10	78.66	78.66	78.66	5.25	5.41	5.33	4.30	4.62	4.46	74.36	74.04	74.20
H11	77.51	76.47	76.99	3.28	3.33	3.31	5.86	6.03	5.94	70.61	71.48	71.05
H12	75.95	75.45	75.70	7.99	8.34	8.16	5.16	6.19	5.68	70.29	69.76	70.02
H13	47.18	46.80	46.99	8.48	8.86	8.67	5.26	5.26	5.26	41.54	42.02	41.78
H14	77.33	77.85	77.59	5.57	5.78	5.68	4.07	4.85	4.46	73.26	73.00	73.13
H15	58.34	58.05	58.19	5.47	5.69	5.58	5.72	6.50	6.11	52.33	51.84	52.09
H16	78.48	79.66	79.07	8.59	8.97	8.78	3.06	4.70	3.88	75.42	74.96	75.19
H17	54.73	54.73	54.73	7.87	8.23	8.05	3.62	3.95	3.78	51.11	50.78	50.94
H18	38.73	38.58	38.65	9.28	9.70	9.49	3.32	3.32	3.32	35.26	35.41	35.33
H19	67.49	67.88	67.68	5.12	5.29	5.21	6.64	5.14	5.89	61.24	62.34	61.79

Appendix 3. Summary results of honey

HONEY SAMPLES	MOISTURE CONTENT (%)	REDUCING SUGAR (fructose + glucose) mg/100g	FRUCTOSE (mg/100g)	GLUCOSE (mg/100g)	SUCROSE (mg/100g)	VISCOSITY (cP)
H1	17.16	76.32	72.26	4.057	4.69	3699
H2	16.51	33.24	27.19	6.05	7.76	12644
H3	17.84	57.84	54.27	3.57	7.16	4555
H4	17.27	80.90	76.89	4.02	3.00	4788
H5	14.99	74.28	69.43	4.85	7.74	17239

H6	18.20	72.79	68.37	3.98	4.47	3999
H7	17.69	69.56	65.62	3.94	8.17	4459
H8	16.78	80.02	74.14	5.88	4.97	6553
H9	17.73	82.09	77.11	4.98	5.12	3575
H10	16.67	78.66	74.20	4.46	5.33	6366
H11	18.85	76.99	71.05	5.94	3.31	2397
H12	20.36	75.70	70.02	5.68	8.16	1460
H13	15.19	46.99	41.78	5.26	8.67	15480
H14	17.98	77.59	73.13	4.46	5.68	3432
H15	16.43	58.19	52.09	6.11	5.58	7126
H16	20.32	79.07	75.19	3.88	8.78	1309
H17	15.87	54.73	50.94	3.78	8.05	12831
H18	15.36	38.65	35.33	3.32	9.49	8163
H19	17.16	67.68	61.79	5.89	5.21	4867
CONTROL	16.49	74.01	70.67	3.34	6.71	6124

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