REVIEW ARTICLE

Honey: Food or Medicine?

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ABSTRAK

Madu adalah bahan semulajadi yang dihasilkan oleh lebah madu, Apis mellifera, berpunca daripada madu yang diambil dari bunga yang berkembang atau cecair dari pokok dan tumbuhan yang dikenali sebagai madu nektar dan madu serangga masing-masing. Ia adalah larutan tepu gula, yang kaya dengan protein, mineral, vitamin, asid organik dan polifenol. Madu mempunyai pelbagai khasiat, sifat penyembuhan dan profilaktik disebabkan oleh komponen-komponen yang terkandung di dalamnya. Madu mempunyai beberapa khasiat kesihatan seperti penyembuhan luka, antimikrob, antioksidan dan potensi anti-radang. Ulasan ini adalah berkaitan komposisi nutrien, antioksidan dan kesan terapeutik madu dengan penekanan kepada madu di Malaysia.

Kata kunci: madu, produk semula jadi, khasiat kesihatan, antioksidan, anti-radang

ABSTRACT

Honey is a natural substance produced by honeybees, *Apis mellifera*, from the nectar of blossomed flowers or exudates of trees and plants producing nectar honeys or honeydews, respectively. It is a supersaturated solution of sugars, enriched with proteins, minerals, vitamins, organic acids and polyphenols. Honey possesses numerous nutritional, healing and prophylactic properties attributed by the rich components found in honey. Some of the health beneficial properties include wound healing, antimicrobial, antioxidant and anti-inflammatory potential. This review relates the nutritional composition, antioxidant and therapeutical effects of honey with emphasis on Malaysian honeys.

Keywords: honey, natural product, health beneficial properties, antioxidant, anti-inflammatory

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INTRODUCTION

Honey is a natural sweet substance produced by honey bees from the nectar of blossomed flowers which is called blossom (floral) or nectar honey and can either be unifloral (nectar from same flower) or mulifloral (nectar of various types of flowers). It can also be found from the secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants which is called honeydew (non floral) honey. The collected nectar and honeydew by the honey bees are transformed and combined with specific substances from the bees, and stored in the honey comb to ripen and mature (Codex Alimentarius Commission 2001).

Honey production and its use have a long and varied history. It has been traditionally used as food and medicine products since the earliest times by primeval humans as well as the Ancient people of Egypt, China, India, Greece and Rome. The first written reference about honey was on a clay tablet of the Sumerians in the Euphrates valley dating back to 2100-2000 BC, which mentioned the use of honey as a drug and an ointment (Crane 1975).

In the year 200 AD, it was mentioned in a written form in ancient Chinese Medicine Shennong, in which many prescriptions and medical indications contain honey (Bogdanov 2010a). Likewise, in ancient India, *Ayurvedic* medicine (a Hindu system of traditional medicine native to India and a form of alternative medicine) uses honey for many purposes.

According to the bible, King Solomon has said: "Eat honey my son, because it is good" (Old Testament, proverb 24:13). In Islam, there is an entire surah in the Al-Qur'an called Al-Nahl (the bee) that narrates the goodness of honey: "*And your Lord inspired to the bee, take for yourself among the mountains, houses, and among the trees and [in] that which they construct. Then eat from all the fruits and follow the ways of your Lord laid down [for you]. There emerges from their bellies a drink, varying in colors, in which there is healing for people. Indeed in that is sign for a people who give thought*" (Al-Qur'an, Al-Nahl 16:68-69) and also Allah says that "*In paradise will be rivers of pure honey*" (Al-Qur'an, Muhammad 47:15). Prophet Muhammad (peace be upon him) strongly recommended honey for the healing purposes and commented on its good values 1400 years ago (Sahih Bukhari).

In the past decade, the benefits of honey become more focused on its medicinal properties such as antibacterial, antioxidant, anti-inflammatory and anticancer properties (Al-Mamary et al. 2002; Ghashm et al. 2010; Mohd Nasir et al. 2010; Wen et al. 2012). An alternative medicine branch called "*Apitherapy*" has developed offering treatments based on honey and other bee products against many diseases (Bogdanov 2009a).

In this review, we highlighted the components present in honey, its therapeutic properties beneficial to human health as well as its nutritional values based on scientific evidences.

MODE OF PROCESSING

Honey can be categorized regarding the mode of processing given below (Joshi 2008):

- Squeezed honey: a traditional method of honey extraction, which involves squeezing the honey combs.
- Drained honey: honey is obtained by draining decapped and broodless combs.
- Extracted honey: honey is obtained by centrifuging decapped honey combs which is mainly produced by beekeepers who manage bees in moveable comb hives.
- Pasteurized honey: honey that has been heated in a pasteurization process (71.7˚C or higher). Pasteurization reduces the moisture level, destroys yeast cells and liquefies any microcrystals in the honey. However, excessive heat exposure also results in product deterioration, as it increases the level of hydroxymethylfurfural (HMF) and reduces enzyme activity (e.g. diastase). The heat also affects appearance (darkens the natural honey color), taste and fragrance (Manley 1985).

CONSISTENCY AND APPEARANCE

Honey can be classified also according to its consistency and appearance (Joshi 2008):

- Liquid honey: the honey is thinner or thicker in consistency and also free of any visible crystals.
- Crystallized honey: honey is completely granular or solidified; it is also called "granulated honey".
- Partially crystallized honey: a mixture of liquid and crystallized honey.

COLOR OF HONEY

The color of honey can be categorized into seven categories with Pfund color scale of 0 to more than 114 mm, as shown in Table 1 (The National Honey Board 2010). The color of honey partly reflects the content of pigments with antioxidant properties such as carotenoids and flavonoids (Khalil et al. 2011). In addition, the color intensity of honey may be considered as a good indication of its antioxidant capacity (Pilijac-Zegarac et al. 2009).

COMPOSITION OF HONEY

Honey is a supersaturated solution of sugars, mainly composed of fructose and glucose, containing also other important compounds such as minerals, proteins, enzymes, free amino acids, vitamins and many phenolic compounds (Alvarez-Suarez et al. 2010) as well as some organic acids and volatile substances (Perez et al. 2002; Mato et al. 2003). The composition of honey is summarised in Table 2 (The National Honey Board 2010). The composition of honey is rather variable and primarily depends on the botanical origin and the floral source (Persano-Oddo & Piro 2004). However, certain external factors also play a role such as seasonal, environmental, processing, handling, storage, and climatic conditions (Lachman et al. 2010).

CARBOHYDRATES

Honey is mainly made up of carbohydrates (82.3%) which is a highly complex mixture of sugars. The major sugars in honey are monosaccharides

Table 1: The color classification in honey.

Color	Pfund scale (mm)	Optical Density
Water White	< 8	0.0945
Extra White	09 - 17	0.189
White	18 - 34	0.378
Extra Light Amber	35 - 50	0.595
Light Amber	51 - 85	1.389
Amber	86 - 114	3.008
Dark Amber	> 114	-----

Source: The National Honey Board (2007)

Table 2: The composition commonly found in honey.

Composition	Range
Fructose/Glucose ratio	0.76 - 1.86
Fructose %	30.91 - 44.26
Glucose %	22.89 - 40.75
Mineral %	0.020 - 1.028
Moisture %	13.4 - 22.9
Reducing sugar %	61.39 - 83.72
Sucrose %	0.25 - 7.57
pH	3.42 - 6.10
Total acidity meq/kg	8.68 - 59.49
Protein mg/100g	57.7 - 567

Source: The National Honey Board (2010)

consisting of fructose (38%) and glucose (31%) (Lawal et al. 2009; Alvarez-Suarez et al. 2010) which are responsible for most of the physical and nutritional charactristics of honey (Sato & Miyata 2000). Some of the disaccharides have also been identified in honey such as sucrose, which is composed of fructose and glucose linked together, maltose, kojibiose, turanose, isomaltose, and maltulose, which comprise less than 8% of the composition of honey. Honey also contains trisaccharides such as melezitose and raffinose (Cotte et al. 2004; The National Honey Board 2010).

MOISTURE

The moisture in honey or water content is the most important component and related to honey quality especially concerning the risk of spoilage due to fermentation and granulation or crystallization during storage (Finola et al. 2007). In general, moisture content in ripe honey is less than 20% while under very humid or tropical conditions the moisture can be more than 20% (Bogdanov 2010b) but only honeys with less than 18% moisture content can be stored with little or no risk of fermentation.

PROTEINS, ENZYMES AND AMINO ACIDS

Honey naturally contains small amount of enzymes that are introduced into honey by the bees during various phases of the honey manufacturing process. The three main honey enzymes are amylase, which decomposes starch or glycogen into smaller sugar units dextrin and maltose, invertase which converts sucrose to fructose and glucose, and glucose oxidase which produces hydrogen peroxide and gluconic acid from glucose in the presence of water (Bansal et al. 2005; Bogdanov et al. 2008). Other enzymes present in lesser amounts are catalase and acid phosphatase (Weston 2000; The National Honey Board 2010).

The amino acids identified in honey from different botanical and geographical origin are: glutamic acid, aspartic acid, glutamine, histidine, glycine, threonine, β-alanine, arginine, α-alanine, γ-aminobutyric acid, proline, tyrosine, valine, methionine, cysteine, isoleucine, leucine, tryptophan, phenylalanine, ornithine and lysine (Iglesias et al. 2004; Perez et al. 2007).

VITAMINS AND MINERALS

Honey contains varying amounts of vitamins, minerals and trace elements. The vitamins content in honey is low. However, vitamins such as phyllochinone (K), thiamin (B1), riboflavin (B2), niacin (B5) and pyridoxine (B6) as well as vitamins A, E and C have been reported to be present in honey (Al-Waili 2003; Bogdanov et al. 2008). The minerals content of honey depends mainly on the botanical and geographical origin of honey (Bogdanov et al. 2007). Light color blossom honeys have a lower mineral content than dark color honeys (Bogdanov 2009b). The minerals commonly found in honey are potassium, aluminium, cadmium, barium, nickel, chromium, cobalt, antimony, calcium, iron, zinc, mangnesium, copper, sodium, manganese and selenium (Stocker et al. 2005; Bogdanov 2009b).

VOLATILE SUBSTANCES

The main volatile compounds in honey have their origins in different chemical families such as alcohols, ketones, aldehydes, acids, esters and terpenes and are present in honey at very low concentrations. The volatile substances mainly derived from the nectar sources give distinctive flavours and aroma to honey (Zhou et al. 2002; Cuevas-Glory et al. 2007).

POLYPHENOLIC COMPOUNDS

Polyphenolics are important group of organic compounds responsible for the appearance of honey and its antioxidant capacity (Tomas-Barberan et al. 2001). The polyphenols present in honeys are flavonoids such as hesperetin, kaempferol, quercetin and chrysin, and phenolic acids such as *p*-coumaric, abscisic, ellagic, gallic and ferulic acids (Yaoa et al. 2005; Kenjeric et al. 2007). Our laboratory found the following polyphenols to be prominent in Malaysian Gelam honey as evaluated by HPLC method: caffeic acid, chlorogenic acid, p-coumaric,

quercetin and hesperitin (Hussein et al. 2011).

HYDROXYMETHYLFURFURAL (HMF)

Hydroxymethylfurfural (HMF) or 5-hydroxymethyl-2-furaldehyde, is a heterocyclic aldehyde (Figure 1) (Bogdanov 2009b) which forms as a result of hexoses degradation in an acidic environment (Semkiw et al. 2010). The presence of simple sugars such as glucose and fructose with many acids in honey is a favorable condition for the production of this substance (Khalil et al. 2010).

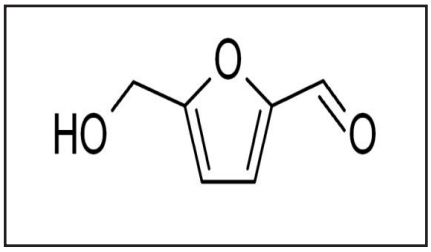

Figure 1: Chemical structure of Hydroxymethylfurfural (HMF).

HMF is almost absent or very low in fresh honey and its concentration increases as a result of heating processes, long-term storage or stored in non-adequate conditions, use of metallic containers and adulterated with invert syrup. HMF measurement is used to evaluate the freshness and quality of honey (Zappala et al. 2005; Ajlouni & Sujirapinyokul 2010). The Codex Alimentarius (2001) and International Honey Commission (2002) set the maximum concentration of HMF to 40 mg/kg for honey from non-tropical region and 80 mg/kg for honey from tropical regions. Honey is thus best consumed within six months of purchase to reduce the production of HMF.

NUTRITIONAL BENEFITS OF HONEY

Honey is one of the oldest and best-loved sweetening agents for foods from olden days until now (Al-Qassemi & Robinson 2003). It is an important source of carbohydrates and the only widely available sweetener which provides strength and energy to our body (Benefits of Honey 2012). The carbohydrates in honey are easily digested and quickly transported into the blood to be utilized for energy requirements by the human body. The glucose in honey is absorbed by the body quickly and gives an immediate energy boost, while the fructose is absorbed more slowly providing sustained energy. It is known that honey has also been found to keep levels of blood sugar fairly constant compared to other types of sugar. Thus, honey is particularly recommended for children and sportsmen because it can help to improve on the efficiency of the energy system of the elderly and invalids (Alvarez-Saurez et al. 2010; Benefits of Honey 2012).

THERAPEUTIC PROPERTIES OF HONEY

Apitherapy (the medical use of honey bee products) has recently become the focus of attention as a form of preventive medicine for treating certian conditions and diseases, as well as promoting

Table 3: Summary of the properties of several types of honey: *in vivo* and *in vitro* studies.

Properties of Honey	References
Antioxidant effect:	
Tualang Honey (TH) reduces MDA, SOD and GPx in pancreas tissues of STZ-induced diabetic rats	Erujewa et al. (2010)
Reduces MDA, TAS and CAT in serum of hypertensive rats	Erujewa et al. (2012)
Anti microbial and gastrointestinal protective effect:	
Inhibits growth of E.coli; Salmonella and Shigella species	Adebolu (2005), Molan (2001a)
Inhibits growth of *H. pylori* in chronic ulcer and gastritis patients	Manyi-Loh et al. (2010), Ndip et al. (2007)
Enhances anti S.aureus effect when combined with antibiotic	Al Jabri et al.(2005)
Cardioprotective effect:	
Reduces total cholesterol, TG and LDL in overweight individuals	Yaghoobi et al. (2008)
Polyphenols in honey prevent heart disease	Khalil & Sulaiman (2010)
Wound healing effect:	
Enhances healing in burns, diabetic foot ulcers, chronic wounds:	Visavadia et al. (2008), Simon et al. (2009)
Tualang honey (TH) enhances wound healing effect by inhibiting growth of *Pseudomonas aeruginosa*	Khoo et al. (2010)
Anti-tumour property:	
Gelam honey induces apoptosis of colon cancer cells; HT29 and HT116	Jaganathan & Mandal (2009a), Wen et al. (2012)
TH induces apoptosis in oral squamous cell carcinomas (OSCC) and human osteosarcoma (HOS) by reducing mitochondrial membrane potential and activating caspases 7/9	Fauzi et al. (2011)
TH induces apoptotic activity and reduces tumour size in DMBA induced mammary cancer in rats	Abdul Kadir et al. (2013)
Anti-inflammatory property:	
Gelam honey reduces the production of pro-inflammatory NO, PGE2, TNF- and IL-6 in plasma of carrageenan-induced paw oedema inflammation	Hussein et al. (2012), Owayele et al. (2011), Kassim et al. (2010b)
Honey decreases inflammation in an experimental model of inflammatory bowel disease in rats	Prakash et al. (2008)
Reproductive Health:	
Egyptian honey and royal jelly had an enhancing effect on sperm motility; particularly in subnormal samples	Abdelhafiz & Muhamad (2008)
Daily treatment of 5% Palestinian honey for 20 days increased spermatogenesis in adult rats	Abdul-Ghani et al. (2008)
Tualang honey prevents uterine atrophy, increases bone density and suppresses body weight increase in menopausal rats	Zaid et al. (2010)

overall health and well being. Table 3 summarizes data collected from animal and human studies on the health beneficial effect of honey. It has been reported to be effective as an antioxidant, in gastrointestinal disorders, in the healing of wounds and burns, and as an antimicrobial and anti-tumour agents. However, because some of these diseases are a consequence of oxidative damage, it seems that part of the therapeutic properties of honey is due to its antioxidant capacity (Jaganathan & Mandal 2009; Ferreira et al. 2009)

ANTIOXIDANT ACTIVITY

Gelam honey has antioxidative and radical scavenging activities, which are mainly attributed to its phenolic contents (Hussein et al. 2011; Khalil et al. 2012). Erujewa et al. showed that Tualang honey supplementation reduces considerably elevated systolic blood pressure via amelioration of oxidative stress in the kidney of spontaneously hypertensive rats, SHR (Erujewa et al. 2012). The gene expression of Nrf2, a potential renoprotective transcription factor, which was markedly reduced or impaired in the kidney of SHR was upregulated by honey supplementation (Erujewa et al. 2012).

PROTECTIVE EFFECT IN GASTROINTESTINE

Infections of the intestinal tract are common throughout the world and affect people of all ages. The use of honey for prevention and treatments of gastrointestinal disorders such as peptic ulcers, gastritis and gastroenteritis has been reported in various publications around the world (Bogdanov et al. 2008). Honey has antimicrobial activity against bacteria that can cause diarrhea especially the ones that are caused by *E. coli* (Adebolu 2005) and against many enteropathogenic organisms including those of the *Salmonella* and *Shigella* species (Molan 2001a).

Helicobacter pylori (H. pylori) infection is probably one of the most common bacterial infections worldwide and complications resulting from this infection caused gastritis, gastric and duodenal ulcers (Sherif et al. 2004; Tiwari et al. 2005). Honey derived remedies comprise a potential source of new compounds that may be useful in the management of *H. pylori* infections (Manyi-Loh et al. 2010). A study carried out by Ndip et al. (2007) on four selected honeys (Mountain, Manuka, Capillano and Eco) was found to exhibit antibacterial activity against *H. pylori* associated gastrointestinal disease.

Honey was also shown to have a dose-dependent effect protecting the stomach from ulceration caused by indomethacin (an aspirin-type anti-inflammatory drug) and alcohol in rats experimentally induced with peptic ulcer (Ali & Al-Swayeh 1997; Gharzouli et al. 2002).

CARDIOVASCULAR HEALTH

Yaghoobi et al. (2008) studied the effect of honey in normal and overweight persons with higher risk for cardiovascular disease. The normal persons received 70 g of

sucrose while cardiovascular disease patients received 70 g of honey, for 30 days. The effect of natural honey was investigated on total cholesterol, LDL-C, HDL-C, triacylglyceride, fasting blood glucose (FBG) and body weight in overweight individuals. The results showed that consumption of natural honey reduces cardiovascular risk factors, by modulating the plasma levels of total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triacylglyceride and homocysteine. It is highly likely that the antioxidant polyphenols in honey such as quercetin, acacetin, caffeic acid, phenethyl ester, kaempferol and galangin are the components with promising pharmaceutical action in the treatment of cardiovascular diseases (Khalil & Sulaiman 2010).

WOUNDS AND BURNS HEALING

The healing properties of honey have been known since time immemorial and have recently gained recognition from the scientific community (Molan 2000). Honey has been used for the treatment of chronic wounds, burns, diabetic foot ulcers and many other ailments (Visavadia et al. 2008; Simon et al. 2009). Honey accelerates wound healing whether applied topically or administered systemically. An infected wound will not heal unless bacteria are eliminated because bacteria stimulate the inflammatory response which can prevent or slow the process of wound healing. Molan (2002) reported that honey has an inhibitory effect on approximately 60 species of bacteria such as *aerobes* and *anaerobes* as well as *gram-positive* and *gram-negative* bacteria. Honey creates a moist environment without the risk of bacterial growth and with no adverse effects to slow the healing process. Honey has high viscosity which provides a protective barrier thus preventing cross-infection (Molan 2006; Khoo et al. 2010).

Therapeutic effects of honey in burn treatment have been reported to cause rapid healing of wounds with less scarring (Yusof et al. 2007). Molan (2001a) found that the application of New Zealand Manuka honey accelerated healing in acute wounds, chronic ulcers, burns and infected wounds. Zohdi et al. (2004) reported that topical application of Malaysian Gelam honey in the form of hydro gel dressings was effective in accelerating wound healing due to burn in rats (Zohdi et al. 2012). In another study, Aljadi et al. (2000) found that combined Gelam honey treatment (topical and oral) offers a distinct advantage to wound healing and may be a useful adjuvant in wound management. Malaysian Tualang honey was able to control the infection from *Pseudomonas aeruginosa* and accelerates contraction of wound due to burn (Khoo et al. 2010). Zaharil et al. (2011) found that Tualang honey impregnated dressings were as effective as silver impregnated hydrofibre dressings in terms of dressing properties, promotion of wound healing and inflammatory reaction for full thickness wounds in rats.

ANTIMICROBIAL AND ANTIVIRAL ACTIVITIES

The major contributor to the antimicrobial activity of honey is hydrogen peroxide (Temaru et al. 2007) which is formed from the oxidation of glucose by glucose oxidase to gluconic acid and hydrogen peroxide when honey is diluted (Bang et al. 2003; Iurlina & Fritz 2005). The varying antimicrobial activity in different types of honey is because of the different concentrations of hydrogen peroxide (Molan 1999). The antimicrobial activity of honey is also attributed by some physical factors such as acidity (low pH) and osmolarity (Hamouda & Abouwarda 2011). The high osmolarity of honey is due to the high content of sugar (over 85% of honey) and these sugars have high affinity for water molecules leaving little or no water to support the growth of different microorganisms such as bacteria and yeast. Consequently, the microorganisms become dehydrated and eventually die (Hamouda & Abouwarda 2011). Honey is acidic with a pH range of 3.2 to 4.5 which is low enough to inhibit the presence and growth of many pathogens (Allen et al. 1991).

Honey has a broad-spectrum antimicrobial activity on *gram-negative* and *gram-positive* bacteria (Agbaje et al. 2006). Several studies have revealed that honey is effective against Methicillin resistant *Staphylococcus aureus* (MRSA), β-*hemolytic Streptococci* and *Vancomycin-resistant Enterococci* (VRE) (Allen et al. 2000; Kingsley 2001). Due to its antibacterial activity, honey has carioprotective effect by inhibiting the growth of bacteria causing caries (Steinberg et al. 1996; Sela et al. 1998; Molan 2001b). It was reported that Manuka honey has a positive effect against dental plaque development and gingivitis (English et al. 2004) making it a useful substitute of refined sugar in the manufacture of candy (Molan 2001b).

Honey can also inhibit the growth of a wide range of fungi, protozoa and viruses (Blair & Carter 2005). It was shown to have inhibitory effect on the *Rubella* virus (Zeina et al. 1996) and *Leishmania* parasite (Zeina et al. 1997) as well as fungi such as *Candida spp.* and *Trichosporon spp.* (Koc et al. 2009).

ANTI-TUMOR ACTIVITY

Many studies have shown that high polyphenols in honey has been attributed for its anti-tumor property (Russo et al. 2004; Jaganathan & Mandal 2009a). Jaganathan & Mandal (2009b) illustrated the ability of the honey to induce apoptosis in human colorectal cancer cells attributed by the high phenolics and tryptophan contents. Additionally, Malaysian Tualang honey was found to have significant anticancer activity against human breast cancer (MCF-7) and cervical cancer (HeLa) cell lines (Fauzi et al. 2011) by reducing mitochondrial membrane potential and activating caspase-3/7 and -9, leading to apoptosis. Ghashm et al. (2010) showed that Tualang honey induces apoptosis in oral squamous cell carcinomas (OSCC) and human osteosarcoma (HOS). Wen et al. (2012) reported that Malaysian Gelam and Nenas honeys were capable of suppressing the growth of HT 29 colon cancer cells by inducing apoptosis and

suppressing inflammation. Swellam et al. (2003) showed that honey inhibited the growth of bladder cancer cell lines *in vitro* as well as *in vivo* when administered intralesionally or orally in the bladder cancer implantation models.

ANTI-INFLAMMATORY ACTIVITY

Inflammation is the response of vascularized living tissue to local injury and plays an important role in various diseases such as rheumatoid arthritis, atherosclerosis and asthma, which all show a high prevalence globally (Tran et al. 2009; Mueller et al. 2010). During an inflammatory response, several pro-inflammatory mediators are released including interleukins (IL-1, IL-6, IL-2 and IL-8), tumor necrosis factor (TNF) and interferon (IFN-γ) as well as cyclooxygenase-2 (COX-2) and inducible nitric oxide synthase (iNOS) which are suppressed by anti-inflammatory cytokines such as IL-4, IL-10, IL-13, IFN- and transforming growth factor (TGF-β), which therefore help to balance the inflammatory response (Hanada & Yoshimura 2002; Goldstein et al. 2006; Mueller et al. 2010). Thus, inhibition of the overproduction of inflammatory mediators, especially pro-inflammatory cytokines (IL-1β, IL-6 and TNF-α), may prevent or suppress a variety of inflammatory diseases (Kim et al. 2003).

Honey has been reported to have anti-inflammatory effect in *in vitro* and *in vivo* studies. Kassim et al. (2010a) found that Gelam honey extract inhibited the level of nitric oxide (NO) in LPS-stimulated macrophage RAW264.7 cells. Honey and its extracts have anti-inflammatory effects by reducing the inflammatory mediators NO and PGE_2 in rat paw tissues (Kassim et al 2010b). It was also shown to decrease inflammation in an experimental model of inflammatory bowel disease in rats (Prakash et al. 2008). Owayele et al. (2011) reported that honey can inhibit the NO release in carrageenan-induced inflammation in rats.

Our research group has demonstrated that Malaysian Gelam honey has a potent *in vivo* anti-inflammatory effect by inhibiting the production of pro-inflammatory mediators NO, PGE_2, TNF-α and IL-6 in plasma of carrageenan-induced paw oedema inflammation.

REPRODUCTIVE HEALTH

There is a traditional belief that honey may enhance fertility and vitality as well as improve male reproductive health. It had been reported that daily treatment of 5% Palestinian honey for 20 days increased spermatogenesis in adult rats (Abdul-Ghani et al. 2008). Abdelhafiz & Muhamad (2008) observed that diluted Egyptian honey and royal jelly had an enhancing effect on sperm motility, particularly in subnormal samples (*in vitro* study).

Mahaneem et al. (2007, 2011) reported that Tualang honey (1.2 g/kg of body weight) significantly increased the percentages of rats achieving intromission and ejaculation as well as increased mating and fertility indexes of male rats exposed to Cigarette Smoke (CS) (Mohamed et al. 2012).

Their result suggests that honey has a protective effect against CS-induced impaired sexual behavior and fertility in male rats. Likewise, Asiyah et al. (2011) reported that Malaysian Gelam honey (1.0 ml/100g of body weight) was potentially useful in increasing the fertility of juvenile male rats by increasing sperm motility and number of morphologically normal sperm compared with male rats injected with nicotine.

A study by Zaid et al. (2010) on the effects of Tualang honey on female reproductive organs (uterus and vagina) and tibia bone in menopause rats (ovariectomised) showed that Tualang honey has a beneficial effect on menopausal rats by preventing uterine atrophy, increased bone density and suppression of body weight increase. Thus, these findings may suggest honey could be an alternative to hormone replacement therapy (HRT).

CONCLUSION

Honey is one of the oldest and best sweetening agents for foods over the centuries. It is made up of a vast amount of different compounds that can be of nutritional and health benefits. The main nutrition and health-relevant components are the carbohydrates, especially fructose and glucose, which make it an excellent energy source for human. Honey also contains a great number of other constituents in small and trace amounts including proteins, enzymes, vitamins, minerals and phenolics compounds, producing numerous nutritional and biological effects such as: wound healing, antimicrobial, antiviral, antioxidant, anti-inflammatory and antitumor activities. Thus, the use of honey either as a food or an alternative medicine in the treatment of different disorders is safe, beneficial and free from side effects.

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