Honey for Nutrition and Health: A Review

Article *in* Journal of the American College of Nutrition · January 2009

DOI: 10.1080/07315724.2008.10719745 · Source: PubMed

After: American Journal of the College of Nutrition, 2008, 27: 677-689

Honey for Nutrition and Health: a Review

Stefan Bogdanov, PhD, Tomislav Jurendic, Robert Sieber, PhD, Peter Gallmann, PhD[1]

Swiss Bee Research Centre, Agroscope Liebefeld-Posieux Research Station ALP, Berne, Switzerland

Key words: honey, nutrition, composition, glycemic index

Due to the variation of botanical origin honey differs in appearance, sensory perception and composition. The main nutritional and health relevant components are carbohydrates, mainly fructose and glucose but also about 25 different oligosaccharides. Although honey is a high carbohydrate food, its glycemic index varies within a wide range from 32 to 85, depending on the botanical source. It contains small amounts of proteins, enzymes, amino acids, minerals, trace elements, vitamins, aroma compounds and polyphenols. The review covers the composition, the nutritional contribution of its components, its physiological and nutritional effects. It shows that honey has a variety of positive nutritional and health effects, if consumed at higher doses of 50 to 80 g per intake.

---

[1] Adress reprint requests to: Peter Gallmann, PhD, Swiss Bee Research Centre, Agroscope Liebefeld-Posieux Research Station ALP, CH-3003 Bern, Switzerland

Abbreviations: CHO = carbohydrate, GI = glycemic index, GL = glycemic load, ORAC = oxygen radical absorbance capacity; PGE = prostaglandin E; PGF = prostaglandin F, RDI = recommended daily intake

Key teaching points:

- About 95% of the honey dry matter is composed of carbohydrates, mainly fructose and glucose. 5-10 % of the total carbohydrates are oligosaccharides, in total about 25 different di- and trisaccharides.
- The Glycemic Index of honey varies from 32 to 85, depending on the botanical source which is lower than sucrose (60 to 110). Fructose-rich honeys such as acacia honey have a low GI.
- Besides, honey contains small amounts of proteins, enzymes, amino acids, minerals, trace elements, vitamins, aroma compounds and polyphenols.
- Honey has been shown to possess antimicrobial, antiviral, antiparasitory, anti-inflammatory, antioxidant, antimutagenic and antitumor effects.
- Due to its high carbohydrate content and functional properties honey is an excellent source of energy for athletes.
- Most of the health promoting properties of honey are only achieved by application of rather high doses of honey such as 50 to 80 g per intake.

INTRODUCTION

As the only available natural sweetener honey was an important food for Homo sapiens from his very beginnings. Indeed, the relation between bees and man started as early as Stone Age [1]. In order to reach the sweet honey, man was ready to risk his life (Figure 1). The first written reference to honey, a Sumerian tablet writing, dating back to 2100-2000 BC, mentions honey's use as a drug and an ointment [2]. In most ancient cultures honey has been used for both nutritional and medical purposes [2-5]. According to the bible, King Solomon has said: “Eat honey my son, because it is good” (Old Testament, proverb 24:13). The belief that honey is a nutrient, a drug and an ointment has been carried into our days. For a long time in human history it was an important carbohydrate source and the only largely available sweetener until industrial sugar production began to replace it after 1800 [2]. In the long human tradition honey has been used not only as a nutrient but also as a medicine [3]. An alternative medicine branch, called apitherapy, has developed in recent years, offering treatments based on honey and the other bee products against many diseases. The knowledge on this subject is compiled in various books [e.g. 6,7] or on relevant web pages such as www.apitherapy.com, www.apitherapy.org. The major use of honey in healing today is its application in the treatment of wounds, burns and infections which is not a subject of this review since it is reviewed elsewhere [8].

At present the annual world honey production is about 1.2 million tons, which is less than 1% of the total sugar production. The consumption of honey differs strongly from country to country. The major honey exporting countries China and Argentina have small annual consumption rates of 0.1 to 0.2 kg per capita. Honey consumption is higher in developed countries, where the home production does not always cover the market demand. In the European Union, which is both a major honey importer and producer, the annual consumption per capita varies from medium (0.3-0.4 kg) in Italy, France, Great Britain, Denmark and Portugal to high (1-1.8 kg) in Germany, Austria, Switzerland, Portugal, Hungary and Greece, while in countries such as USA, Canada and Australia the average per capita consumption is 0.6 to 0.8 kg/year [see http://www.apiservices.com/].

Different surveys on nutritional and health aspects of honey have been compiled [8-13]. However, as they are not complete and comprehensive, we undertook the task to review all the available relevant sources on this topic.

COMPOSITION

Table 1 The overall composition of honey is shown in Table 1. The carbohydrates are the main constituents, comprising about 95% of the honey dry weight. Beyond carbohydrates, honey contains numerous compounds such as organic acids, proteins, amino acids, minerals, polyphenols, vitamins and aroma compounds. Summarising the data shown in Table 1 it can be concluded that the contribution of honey to the recommended daily intake is small. However, its importance with respect to nutrition lies in the manifold physiological effects [16]. It should be noted that the composition of honey depends greatly on the botanical origin [17], a fact that has been seldom considered in the nutritional and physiological studies.

Carbohydrates

The main sugars are the monosaccharides fructose and glucose. Additionally, about 25 different oligosacharides have been detected [18,19]. The principal oligosaccharides in blossom honey are the disaccharides sucrose, maltose, trehalose and turanose, as well as some nutritionally relevant ones such as panose, 1-kestose, 6-kestose and palatinose. Compared to blossom honey honeydew honey contains higher amounts of the oligosaccharides melezitose and raffinose. In the process of digestion after honey intake the principal carbohydrates fructose and

Table 2 glucose are quickly transported into the blood and can be utilized for energy requirements by the human body. A daily dose of 20 g honey will cover about 3% of the required daily energy (Table 2).

Proteins, enzymes and amino acids

Honey contains roughly 0.5% proteins, mainly enzymes and free amino acids. The contribution of that fraction to human protein intake is marginal (Table 2).
The three main honey enzymes are diastase (amylase), decomposing starch or glycogen into smaller sugar units, invertase (sucrase, α-glucosidase), decomposing sucrose into fructose and glucose, as well as glucose oxidase, producing hydrogen peroxide and gluconic acid from glucose.

Vitamins, minerals and trace compounds

The amount of vitamins and minerals is small and the contribution of honey to the recommended daily intake (RDI) of the different trace substances is marginal (Table 2). It is known that different unifloral honeys contain varying amounts of minerals and trace elements [26]. From the nutritional point of view chromium, manganese and selenium are important, especially for 1 to 15 years old children. The elements sulphur, boron, cobalt, fluoride, iodide, molybdenum and silicon can be important in
Table 3 human nutrition too, although there are no RDI values proposed for these elements (Table 3).

Honey contains 0.3-25 mg/kg choline and 0.06 to 5 mg/kg acetylcholine [12]. Choline is essential for cardiovascular and brain function as well as for cellular membrane composition and repair, while acetylcholine acts as a neurotransmitter.

Aroma compounds, taste-building compounds and polyphenols

There is a wide variety of honeys with different tastes and colours, depending on their botanical origin [29]. The sugars are the main taste-building compounds. Generally, honey with a high fructose content (e.g. acacia) are sweeter compared to those with high glucose concentration (e.g. rape). The honey aroma depends also on the quantity and type of acids and amino acids present. In the past decades extensive research on aroma compounds has been carried out and more than 500 different volatile compounds were identified in different types of honey. Indeed, most aroma building compounds vary in the different types of honey depending on its botanical origin [30]. Honey flavour is an important quality for its application in food industry and also a selection criterion for the consumer's choice.

Polyphenols are another important group of compounds with respect to the appearance and the functional properties of honey. 56 to 500 mg/kg total polyphenols were found in different honey types [31,32]. Polyphenols in honey are mainly flavonoids (e.g. quercetin, luteolin, kaempferol, apigenin, chrysin, galangin), phenolic acids and phenolic acid derivatives [33]. These are compounds known to have antioxidant properties. The main polyphenols are the flavonoids, their content can vary between 60 and 460 µg/100 g of honey and was higher in samples produced during a dry season with high temperatures [34].

Contaminants and toxic compounds

The same as any other natural food, honey can be contaminated by the environment, e.g. by heavy metals, pesticides, antibiotics etc. [35]. Generally, the contamination levels found in Europe do not present a health hazard. The main problem in recent years was the contamination by antibiotics, used against the bee brood diseases, but at present this problem seems to be under control. In the European Union antibiotics are not allowed for that purpose, and thus honey containing antibiotics is also not permitted to be traded on the market.

A few plants used by bees are known to produce nectar containing toxic substances. Diterpenoids and pyrrazolidine alkaloids are two main toxin groups relevant in nectar. Some plants of the *Ericaceae* family belonging to the sub-family *Rhododendron*, e.g. *Rhododendron ponticum* contain toxic polyhydroxylated cyclic hydrocarbons or diterpenoids [36]. The substances of the other toxin group, the pyrrazolidine alkaloids, found in different honey types and the potential intoxication by these substances is reviewed [37]. Cases of honey poisoning have been reported rarely in the literature and have concerned individuals from the following regions: Caucasus, Turkey, New Zealand, Australia, Japan, Nepal, South Africa, and also some countries in North and South America. Observed symptoms of such honey poisoning are vomiting, headache, stomach ache, unconsciousness, delirium, nausea and sight weakness. In general the poisonous plants are known to the local beekeepers and honey, which can possibly contain poisonous substances, is not marketed. To minimise risks of honey born poisoning in countries where plants with poisonous nectar are growing tourists are advised to buy honey in shops and not on the road and from individual beekeepers.

Glycemic index and fructose

The impact of carbohydrates on human health is discussed controversially, especially the understanding of how the carbohydrates of a given food affect the blood glucose level. Today, the dietary significance of carbohydrates is often indicated in terms of the glycemic index (GI). Carbohydrates with a low GI induce a small increase of glucose in blood, while those with a high GI induce a high blood glucose level. The only comprehensive data on honey GI are the one presented in Table 4, based mainly on data of different Australian honeys [38,39]. There is a

Table 4

significant negative correlation between fructose content and GI, probably due to the different fructose/glucose ratios of the honey types tested. It is known that unifloral honeys have varying fructose content and fructose/glucose ratios [17]. Some honeys, e.g. acacia and yellow box, with relatively high concentration of fructose, have a lower GI than other honey types (Table 4). There was no significant correlation between GI and the other honey sugars. The GI values of 4 honeys found in one study varied between 69 and 74 [40], while in another one the value of a honey unidentified botanical origin was found to be 35 [41]. As the GI concept claims to predict the role of carbohydrates in the development of obesity [42], low GI honeys might be a valuable alternative to high GI sweeteners. In order to take into consideration the quantity of ingested food, a new term, the glycemic load, was introduced. It is calculated as follows: the GI value is multiplied by the carbohydrate content in a given portion and divided by 100. Values lower than 10 are considered low, between 10 and 20 are intermediate and above 20 belong to the category high. For an assumed honey portion of 25 g the glycemic load of most honey types is low and some types are in the intermediate range (Table 4).

The GI concept was developed to provide a numeric classification of carbohydrate foods, assuming that such data are useful in situations where the glucose tolerance is impaired. Therefore, food with a low GI should provide benefits with respect to diabetes and to the reduction of coronary heart disease [43]. The consumption of honey types with a low GI, e.g. acacia honey might have beneficial physiological effects and could be used by diabetes patients. An intake of 50 g honey of unspecified type by healthy people and diabetes patients led to smaller increases of blood insulin and glucose than the consumption of the same amounts of glucose or of a sugar mixture resembling to honey [44,45]. It was shown that consumption of honey has a favourable effect on diabetes patients, causing a significant decrease of plasma glucose [46-48]. Honey was well tolerated by patients with diabetes of unspecified type [49] and by diabetes type-2 patients [50-52]. According to recent studies, long term consumption of food with a high GI is a significant risk factor for type-2 diabetes patients [53]. However, the GI concept for the general population is still an object of discussions [54].

Fructose is the main sugar in most honey types (Table 1). A surplus consumption of fructose in today's American diet, mainly in the form of high-fructose corn syrup, is suspected to be one of the main causes for overweight problems [55]. By reviewing clinical studies these authors found that fructose ingestion causes a rise of de-novo lipogenesis, which has an unfavourable effect on energy regulation and on body weight. In rat feeding experiments the hypertriglyceridemic effect observed after intake of fructose does not take place after feeding of honey [56]. Compared to rats fed with fructose, honey-fed rats had higher plasma α-tocopherol levels, higher α-tocopherol/triacylglycerol ratios, lower plasma NO_x concentrations and a lower susceptibility of the heart to lipid peroxidation. These data suggest a potential nutritional benefit of substituting fructose by honey in the ingested diets.

Ingestion of both honey (2 g/kg body weight) and fructose prevented the ethanol-induced transformation of erythrocytes in mice. In humans faster recovery from ethanol intoxication after honey administration has been reported while a higher ethanol elimination rate has also been confirmed [58,59].

DIFFERENT PHYSIOLOGICAL EFFECTS

Antimicrobial, antiviral and antiparasitic activity

Honey inhibits the growth of micro-organisms and fungi. The antibacterial effect of honey, mostly against gram-positive bacteria, is well documented [60-63]. Both bacteriostatic and bactericidal effects have been reported for many strains, many of them pathogenic (Table 5). Further, it was reported that honey has also been shown to inhibit *Rubella* virus in vitro [64], three species of the *Leishmania* parasite [65] and *Echinococcus* [66].

Table 5

The antimicrobial effect of honey is due to different substances and depends on the botanical origin of honey [60-63]. The low water activity of honey inhibits bacterial growth. Honey glucose oxidase produces the antibacterial agent hydrogen peroxide [67], but the peroxide production capacity depends also on honey catalase activity [68]. There are also other non-peroxide antibacterial substances with different chemical origin, e.g. aromatic acids [69], unknown compounds with different chemical properties [63] and phenolics and flavonoids [70,71]. The low honey pH can also be responsible for the antibacterial activity [72].

Contrary to the non-peroxide activity, the peroxide one can be destroyed by heat, light and storage [63] (Table 6). These different factors had a bigger effect on the antibacterial activity of blossom honey than on honeydew honey. Thus, for optimum antibacterial activity, honey should be stored in a cool, dark place and be consumed when fresh.

Table 6

Antioxidant effects

The term “oxidative stress” describes the lack of equilibrium between the production of free radicals and the antioxidant protective activity in a given organism. Protection against oxidation is thought to prevent some chronic diseases [73]. The oxidative modification of the lipoproteins is considered to be an important factor for the pathogenesis of arteriosclerosis [74]. Honey has been found to contain significant antioxidant activity including glucose oxidase, catalase, ascorbic acid, flavonoids, phenolic acids, carotenoid derivatives, organic acids, Maillard reaction products, amino acids and proteins [31,75-84]. The antioxidative activity of honey polyphenols can be measured in vitro by comparing the oxygen radical absorbance capacity (ORAC) with the total phenolics concentration (Table 7). There is a significant
Table 7 correlation between the antioxidant activity, the phenolic content of honey and the inhibition of the in vitro lipoprotein oxidation of human serum [85]. Furthermore, in a lipid peroxidation model system buckwheat honey showed a similar antioxidant activity as 1 mM α-tocopherol [83]. The influence of honey ingestion on the antioxidative capacity of plasma was tested in two studies [86,87]. In the first one, the trial persons were given maize syrup or buckwheat honeys with a different antioxidant capacity in a dose of 1.5 g/kg body weight. In comparison to the sugar control, honey caused an increase of both the antioxidant and the reducing serum capacity. In the second study humans received a diet supplemented with a daily honey serving of 1.2 g/kg body weight. Honey increased the body antioxidant agents: blood vitamin C concentration by 47%, β-carotene by 3%, uric acid by 12%, and glutathione reductase by 7% [87]. It should be borne in mind that the antioxidant activity depends on the botanical origin of honey and varies to a great extent in honeys from different botanical sources [31,77,78,88-90].

The impact of heat and storage time on the antioxidant capacity of clover and buckwheat honey was analysed recently [91]. While processing of clover honey did not significantly influence its antioxidant capacity, storage during 6 months reduced it by about 30%. After a given storage period the antioxidant capacity of processed and raw honeys was similar. In another study both antioxidant activity and brown pigment formation increased upon heat treatment and storage [92].

Antimutagenic and antitumor activity

Mutagenic substances act directly or indirectly by promoting mutations of the genetic structure. During the roasting and frying of food heterocyclic amines are formed, e.g. Trp-p-1 (3-Amino-1,4-dimethyl-5H-pyridol [4,3-b] indole). The antimutagenic activity of honeys from seven different floral sources (acacia, buckwheat, fireweed, soybean, tupelo and Christmas berry) against Trp-p-1 was tested by the Ames assay and compared to a sugar analogue as well as to individually tested simple sugars [93]. All honeys exhibited a significant inhibition of Trp-p-1 mutagenicity. Glucose and fructose were found to have a similar antimutagenic activity as honey. Nigerose, another sugar, present in honey [18,19] has an immunoprotective activity [94]. The anti-metastatic effect of honey and its possible mode of anti-tumor action was studied by the application of honey in spontaneous mammary carcinoma in methylcholanthrene-induced fibrosarcoma of CBA mice and in anaplastic colon adenocarcinoma of Y59 rats [95]. A statistically significant anti-metastatic effect was achieved by oral application of honey. These findings indicate that honey activates the immune system and honey ingestion may be advantageous with respect to cancer and metastasis prevention. In addition, it is postulated that honey given orally before tumour cell inoculation may have a decreased effect on tumour spreading. In another study of the same group the effect of honey on tumour growth, metastasising activity and induction of apoptosis and necrosis in murine tumour models (mammary and colon carcinoma) was investigated [96]. A pronounced antimetastatic effect was observed when honey was applied before tumour-cell inoculation (per oral 2 g kg^{-1} for mice or 1 g kg^{-1} for rats, once a day for 10 consecutive days).

In another study the anti-tumour effect of honey against bladder cancer was examined in vitro and in vivo in mice [97]. According to these results honey is an effective agent for inhibiting the growth of different bladder cancer cell lines (T24, RT4, 253J and MBT-2) in vitro. It is also effective when administered intralesionally or orally in the MBT-2 bladder cancer implantation mice models.

Anti-inflammatory effects

Anti-inflammatory effects of honey in humans were studied by Al Waili and Boni [98] after ingestion of 70 g honey. The mean plasma concentration of thromboxane B(2) was reduced by 7%, 34%, and 35%, that of PGE(2) by 14%, 10%, and 19% at 1, 2, and 3 hours, respectively, after honey ingestion. The level of PGF(2α) was decreased by 31% at 2 hours and by 14% at 3 hours after honey ingestion. At day 15, plasma concentrations of thromboxane B(2), PGE(2) and PGF(2α) decreased by 48%, 63% and 50%, respectively. The ingestion of honey decreased inflammation in an experimental model of inflammatory bowel disease in rats [99]. Honey administration is as effective as prednisolone treatment in an inflammatory model of colitis. The postulated mechanism of action is by preventing the formation of free radicals released from the inflamed tissues. The reduction of inflammation could be due to the antibacterial effect of honey or to a direct antiinflammatory effect. The latter hypothesis was supported in animal studies, where antiinflammatory effects of honey were observed in wounds with no bacterial infection [100].

Various physiological effects

The effect of honey on the antibody production against thymus-dependent antigen in sheep red blood cells and thymus-independent antigen (*Escherichia coli*) in mice was studied [101]. Oral honey intake stimulates antibody production during primary and secondary immune responses against thymus-dependent and thymus-independent antigens.

In animal experiments honey showed an immunosuppressive activity [102]. This might explain why it has been hypothesised, that ingestion of honey can relieve pollen hypersensitivity.

In a study humans received a diet supplemented with a daily honey consumption of 1.2 g/kg body weight [87]. The effects observed in blood serum were an increase of monocytes (50 %), iron (20%), copper (33%), a slight increase of lymphocyte and eosinophil percentages, zinc, magnesium, hemoglobin and packed cell volume and a reduction of: ferritin (11%), immunoglobulin E (34%), aspartate transaminase (22%), alanine transaminase (18%), lactic acid dehydrogenase (41%), creatine kinase (33%) and fasting sugar (5%).

NUTRITION AND HEALTH EFFECTS

Oral health

There is much debate whether honey is harmful to teeth. Some reports show a cariogenic effect of honey [103-106] or a much less cariogenic effect than sucrose

[107]. Due to its antibacterial activity honey ingestion inhibits the growth of bacteria, causing caries [108,109] and might induce a carioprotective effect [110,111]. It was shown that Manuka honey, a very potent antimicrobial honey, has a positive effect against dental plaque development and gingivitis [112] and can be used instead of refined sugar in the manufacture of candy [109].

According to electron microscope studies the ingestion of honey causes no erosion of tooth enamel as observed after drinking fruit juice [113]. Ten minutes after consumption of fruit juice tooth erosion was observed, while 30 minutes after honey ingestion the erosion was only very weak. This effect can be explained only partially by the calcium, phosphorous and fluoride levels of honey and other colloidal honey components might also play a role.

Summarising the different findings, it can be concluded that honey is probably not as cariogenic as other sugars and in some cases it can be carioprotective. But to be on the safe side, it is advised to clean the teeth after consumption of honey.

Gastroenterology

According to the Muslim holy book "The Holy Hadith", dating back to the 8th century AD prophet Mohamed recommended honey against diarrhoea [114]. Also, the Roman physician Celsus (ca. 25 AD) used honey as a cure for diarrhoea [115]. The application of honey for prevention and treatments of gastro-intestinal disorders such as peptic ulcers, gastritis, gastroenteritis has been reported in various books and publications from Eastern Europe [6,7,116-120] and from Arab countries [121].

Honey is a potent inhibitor of the causing agent of peptic ulcers and gastritis, *Helicobacter pylori* [122-124]. In rats honey acted against gastric ulcers experimentally induced by indomethacin and alcohol [125-128]. Honey is not involved in prostaglandin production, but it has a stimulatory effect on the sensory nerves in the stomach that respond to capsaicin [125,129]. A second mechanism of action has been proposed, postulating that this effect is due to the antioxidant properties of honey. Honey intake in rats prevented indomethacin-induced gastric lesions in rats by reducing the ulcer index, microvascular permeability, and myeloperoxidase activity of the stomach [130]. In addition, honey was found to maintain the level of non-protein sulfhydryl compounds (e.g. glutathione) in gastric tissue subjected to factors inducing ulceration [125,129,131,132]. Ingestion of dandelion honey reduced gastric juice acidity by 56% [133]. The gastric emptying of saccharides after ingestion of honey was slower than that after ingestion of a mixture of glucose and fructose [134].

Other important effects of honey on human digestion have been linked to oligosaccharides. These honey constituents have prebiotic effects, similar to that of fructo-oligosaccharides [135,136]. The oligosaccharide panose was the most active oligosaccharide. The oligosaccharides cause an increase of bifidobacteria and lactobacilli and exert the prebiotic effect in a synergistic mode of action [137].

According to an invitro study on five bifidobacteria strains honey has a growth promoting effect similar to that of fructose and glucose oligosaccharides [138].

Unifloral honeys of sour-wood, alfalfa and sage origin stimulated the growth of five human intestinal bifidobacteria [139]. In another study honey increased both in vivo (small and large intestines of rats) and in vitro the building of *Lactobacillus acidophilus* and *Lactobacillus plantarum*, while sucrose had no effect [140].

In clinical studies with infants and children honey shortens the duration of bacterial diarrhoea and did not prolong the duration of non-bacterial diarrhoea [141].

In certain cases, consumption of relatively large amounts of honey (50 to 100 g) can lead to a mild laxative effect in individuals with insufficient absorption of honey fructose [142,143]. Fructose alone is less readily absorbed in the intestinal tract than fructose together with glucose [144]. The mild laxative properties of honey are used for the treatment of constipation in Eastern Europe [6].

Supplementation of honey in concentrations of 2, 4, 6 and 8 g/100 g protein fed to rats, improved protein and lipid digestibility [145].

Cardiovascular health

The effects of ingestion of 75 g of natural honey compared to the same amount of artificial honey (fructose plus glucose) or glucose on plasma glucose, plasma insulin, cholesterol, triglycerides (TG), blood lipids, C-reactive proteins and homocysteine, most of them being risk factors for cardiovascular diseases, were studied in humans [47]. Elevation of insulin and C-reactive protein was significantly higher after glucose intake than after honey consumption. Glucose reduced cholesterol and low-density lipoprotein-cholesterol (LDL-C). Artificial honey slightly decreased cholesterol and LDL-C and elevated TG. Honey reduced cholesterol, LDL-C, and TG and slightly elevated high-density lipoprotein-cholesterol (HDL-C). In patients with hypertriglyceridemia, artificial honey increased TG, while honey decreased TG. In patients with hyperlipidemia, artificial honey increased LDL-C, while honey decreased LDL-C. In diabetic patients, honey compared with dextrose caused a significantly lower rise of plasma glucose [47].

Honey can contain nitric oxide (NO) metabolites which are known indicators for cardiovascular disease risk. Increased levels of nitric oxides in honey might have a protecting function in cardiovascular diseases. Total nitrite concentration in different biological fluids from humans, including saliva, plasma, and urine was measured after ingestion of 80 g of honey [146,147]. Salivary, plasma and urinary NO metabolite concentrations showed a tendency to increase. Different honey types contained various concentrations of NO metabolites, darker or fresh honeys containing more NO metabolites than light or stored honey. After heating, NO metabolites decreased in all honey types.

Compared to fructose-fed rats, honey-fed rats had a higher plasma α-tocopherol level, and a higher α-tocopherol/triacylglycerol ratio, as well as lower plasma nitrate levels and lower susceptibility of the heart to lipid peroxidation [56].

Infants

The application of honey in infant nutrition used to be a common recommendation during the last centuries and there are some interesting observations. Infants on a diet with honey had better blood formation and a higher weight gain than when a diet without honey was applied [148]. Honey was better tolerated by babies than sucrose [149] and compared to a water based placebo significantly reduced the crying phases of infants [150]. Infants had a higher weight increase when fed by honey than by sucrose, and showed less throw up than the sucrose controls [151]. When infants were fed on honey rather than on sucrose an increase of haemoglobin content, a better skin colour and no digestion problems were encountered [152,153]. Infants on honey diet had a better weight increase and were less susceptible to diseases than infants fed normally or when given blood building agents [148].

The positive effects of honey in infant diet are attributed to effects on the digestion process. One possible cause is the well established effect of oligosaccharides on *B. bifidus* [154], see also section Gastroenterology. When fed on a mixture of honey and milk infants showed a regularly steady weight gain and had an acidophilic micro-organism flora rich in *B. bifidus* [155]. Another experiment with honey and milk showed that infants were suffering less frequently from diarrhoea, and their blood contained more haemoglobin compared to those on a diet based on sucrose sweetened milk [152]. Honey fed infants had an improved calcium uptake, and lighter and thinner faeces [156].

However, there is a health concern for infants regarding the presence of *Clostridium* (*Cl.*) *botulinum* in honey. Since the presence of this bacterium in natural foods is ubiquitous and honey is a non sterilized packaged food from natural origin the risk of a low contamination level cannot be excluded. Spores of this bacterium can survive in honey, but they cannot build toxin. Thus, in the stomach of infants younger than one year the bacteria spores from honey can survive and theoretically build the toxin, while children older than 12 months can ingest honey without any risk. In some cases, infant botulism has been attributed to ingestion of honey [157-160]. In Germany one case of infant botulism per year is reported [160]. As a result of the reported infant botulism cases some honey packers (e.g. the British Honey Importers and Packers Association) place a warning on the honey label that “honey should not be given to infants under 12 months of age”. Recently, a scientific committee of the EU examined the hazard of *Cl. botulinum* in honey [161]. It has concluded that microbiological examinations of honey are necessary for controlling the spore concentration in honey, as the incidence of *Cl. botulinum* is relatively low and sporadic and as such tests will not prevent infant botulism. In the EU countries the health authorities have not issued a regulation for placing a warning label on honey jars.

Athletic performance

The physiological action of gel and powdered forms of honey as a carbohydrate source for athlete performance was studied recently under controlled conditions by Kreider and coworkers [162-165]. Honey increased significantly the heart frequency and the blood glucose level during the performance [162]. It did not promote physical or psychological signs of hypoglycaemia in fasted athletes [163], or during resistance training [164]. In another trial the effect of low and high GI carbohydrate gels and honey were tested on a 64 km cycling performance [162,165]. Both high (glucose) and low GI (honey) gels increased cycling performance and the effect of honey was slightly better than the one of glucose. According to the above studies honey is well tolerated and can be an effective carbohydrate source for athletic performance.

Different health enhancing effects

A positive effect of honey on hepatitis A patients was found after ingestion of clover and rape honey, causing a decrease of the alanine aminotranferase activity (by 9 to 13 times) and a decrease of bilirubin production by 2.1 to 2.6 times [133].
Honey has a supportive effect on patients who have undergone a cancer radiation therapy by reducing the incidence of radiation mucositis. Patients with head and neck cancer treated with radiation therapy were given honey. There was a significant reduction in the symptomatic grade 3/4 mucositis among honey-treated patients compared to the controls; i.e. 20% versus 75%. The compliance of the honey-treated group of patients was better than the controls. 55% of the patients treated with honey showed no change or a positive gain in body weight compared to the controls, the majority of which lost weight [166]. Honey was administered to chemotherapy patients with neutropenia and was found to reduce the need for colony-stimulating factors [167]. Febrile neutropenia is a serious side effect of chemotherapy.

Allergy

Honey allergy seems relatively uncommon; allergies reported can involve reactions varying from cough to anaphylaxis [145]. In this study it was reported that patients allergic to pollen are rarely allergic to honey, although there is one reported case of combined honey pollen allergy [168]. The incidence of honey allergy, reported in a group of 173 food allergy patients was 2.3% [cited in 169]. In this study the honey allergy is explained by the presence of components of bee origin.

CONCLUSION

Due to variation of botanical origin honey differs in appearance, sensory perception and composition. It contains mainly carbohydrates. The glycemic index of honey varies from 32 to 87, depending on botanical origin and on fructose content. The main nutrition- and health relevant components are the carbohydrates, which make it an excellent energy source especially for children and sportsmen. Besides its main components, the carbohydrates fructose and glucose, honey contains also a great number of other constituents in small and trace amounts, producing numerous nutritional and biological effects: antimicrobial, antioxidant, antiviral, antiparasitic, antiinflammatory, antimutagenic, anticancer and immunosuppressive activities. Different nutritional studies have confirmed various effects after honey ingestion, e.g.

enhanced gastroenterological and cardiovascular health. Besides, honey showed physiological effects on blood health indicators as well as effects on hepatitis A and radiation mucositis patients. However, it should be pointed out that most of these studies were based on relatively high honey intakes of 50 to 80 g. Honey compositions, and also its different biological effects, depend to a great extent on the botanical origin of honey. This fact was often not considered in the reviewed studies.

Figure 1: Prehistoric man gathering honey
A rock painting, made around 6000 BC. La Arana shekter, Bicorp, Eastern Spain.

Table 1: Honey composition (data in g/100 g) [14,15]

	Blossom honey		Honeydew honey	
	average	min. - max.	average	min. - max.
Water	17.2	15-20	16.3	15-20
Monosaccharides				
fructose	38.2	30-45	31.8	28-40
glucose	31.3	24-40	26.1	19-32
Disaccharides				
sucrose	0.7	0.1-4.8	0.5	0.1-4.7
others	5.0	2-8	4.0	1-6
Trisaccharides				
melezitose	<0.1		4.0	0.3-22.0
erlose	0.8	0.5-6	1.0	0.1-6
others	0.5	0.5-1	3.0	0.1-6
Undetermined oligosaccharides	3.1		10.1	
Total sugars	**79.7**		**80.5**	
Minerals	0.2	0.1-0.5	0.9	0.6-2.0
Amino acids, proteins	0.3	0.2-0.4	0.6	0.4-0.7
Acids	0.5	0.2-0.8	1.1	0.8-1.5
pH-value	3.9	3.5-4.5	5.2	4.5-6.5

Table 2: Honey nutrients (values compiled after different authors [14,20-27] and recommended daily intake [28])

Ingredient		Amount in 100 g	Recommended Daily Intake[1]		
			1-4 years old	4-15 years old	After 15 years old
Energy	kcal				
Carbohydrates	kcal	300	1000-1100	1400-2700	2400-3100
Proteins	g	0.5	13-14	17-46	44-59
Fats	g	0	-	-	-
Minerals	mg				
Sodium (Na)		1.6-17	300	410-550	550
Calcium (Ca)		3-31	600	700-1200	1000-1200
Potassium (K)		40-3500	1000	1400-1900	2000
Magnesium (Mg)		0.7-13	80	120-310	300-400
Phosphorus (P)		2-15	500	600-1250	700-1250
Zinc (Zn)		0.05-2	3	5-9.5	7-10
Copper (Cu)		0.02-0.6	0.5-1	0.5-1	0.5-1
Iron (Fe)		0.03-4	8	8-15	10-15
Manganese (Mn)		0.02-2	1-1.5	1.5-5	2-5
Chromium (Cr)		0.01-0.3	0.02-0.06	0.02-0.1	0.03-1.5
Selenium (Se)		0.002-0.01	0.001-0.004	0.001-0.006	0.003-0.007
Vitamins	mg				
Phyllochinon (K)		ca. 0.025	15	20-50	60-70
Thiamin (B_1)		0.00-0.01	0.6	0.8-1.4	1-1.3
Riboflavin (B_2)		0.01-0.02	0.7	0.9-1.6	1.2-1.5
Pyridoxin (B_6)		0.01-0.32	0.4	0.5-1.4	1.2-1.6
Niacin[2]		0.10-0.20	7	10-18	13-17
Panthothenic acid		0.02-0.11	4	4-6	6
Ascorbic acid (C)		2.2-2.5	60	70-100	100

*-only major components considered
1 after the German Nutrition Society [28]
[2] Niacin equivalents: 1 mg nicotinamide = 1 mg niacin = 60 mg tryptophan (= niacin-precursor)

Table 3: Other trace elements in honey [14,20-27]

Element	mg/100 g	Element	mg/100 g
Aluminium (Al)	0.01-2.4	Lead (Pb)*	0.001-0.03
Arsenic (As)	0.014-0.026	Lithium (Li)	0.225-1.56
Barium (Ba)	0.01-0.08	Molybdenum (Mo)	0-0.004
Boron (B)	0.05-0.3	Nickel (Ni)	0-0.051
Bromine (Br)	0.4-1.3	Rubidium (Rb)	0.040-3.5
Cadmium (Cd)*	0-0.001	Silicon (Si)	0.05-24
Chlorine (Cl)	0.4-56	Strontium (Sr)	0.04-0.35
Cobalt (Co)	0.1-0.35	Sulfur (S)	0.7-26
Floride (F)	0.4-1.34	Vanadium (V)	0-0.013
Iodide (I)	10-100	Zirconium	0.05-0.08

*- elements regarded as toxic, can be partially of man-made origin

Table 4: Glycemic index (GI) and glycemic load (GL) for a serving (25 g) of honey [38,39]

	honey origin	Fructose g/100 g	GI	AC g/serving	GL (per serving)
Acacia (black locust)*	Romania	43	32	21	7
Yellow box	Australia	46	35±4	18	6
Stringy bark	Australia	52	44±4	21	9
Red gum	Australia	35	46±3	18	8
Iron bark	Australia	34	48±3	15	7
Yapunya	Australia	42	52±5	17	9
Pure Australia	Australia		58±6	21	12
Commercial blend	Australia	38	62±3	18	11
Salvation June	Australia	32	64±5	15	10
Commercial blend	Australia	28	72±6	13	9
Honey of unspecified origin	Canada		87±8	21	18
average		55	55±5	18	10
Sucrose (mean of 10 studies)			68±5		
Glucose			100		

AC = available carbohydrate

Table 5: List of bacteria that were found to be sensitive to honey [60,61]

Pathogen	Infection caused
Bacillus anthracis	anthrax
Corynebacterium diphtheriae	diphtheria
Escherichia coli	diarrhoea, septicaemia, urinary infections, wound infections
Haemophilus influenzae	ear infections, meningitus, respiratory infections, sinusitis
Klebsiella pneumoniae	pneumonia
Mycobacterium tuberculosis	tuberculosis
Proteus sp.	septicaemia, urinary infections
Pseudomonas aeruginosa	urinary infections, wound infections
Salmonella sp.	diarrhoea
Salmonella cholerae-suis	septicaemia
Salmonella typhi	typhoid
Salmonella typhimurium	wound infections
Serrata marcescens	septicaemia, wound infections
Shigella sp.	dysentery
Staphylococcus aureus	abscesses., boils, carbuncles, impetigo, wound infections
Streptococcus faecalis	urinary infections
Streptococcus mutans	dental carries
Streptococcus pneumoniae	ear infections, meningitis, pneumonia, sinusitis
Streptococcus pyogenes	ear infections, impetigo, puerperal fever, rheumatic fever, scarlet fever, sore throat, wound infections
Vibrio choleriae	cholera
Actinomyces pyogenes, Klebsiella pneumoniae, Nocardia asteroids, Staphylococcus aureus, Streptococcus agal., dysgal., uber	mastitis
Epidermophyton floccosum, Microsporum canis, M.. gypseum, Trichophyton rubrum, T. tonsurans, T. mentagrophytes var. **?**	tinea
diff. *Escherichia coli, Salmonella, Shigella, Vibrio, Helicobacter pylori*	peptic ulcer

Table 6: Effect of heat, light and storage time on the antibacterial activity of honey. The antibacterial activity is expressed in % of the untreated controls [63]

	Non-peroxide activity		Peroxide activity	
Storage: 15 months rt	light	dark	light	dark
Blossom honey	76	86	19	48
Honeydew honey	78	80	63	70
Heat: 15 min 70^{o}C				
Blossom honey	86		8	
Honeydew honey	94		78	

rt = room temperature 15-20^{o}C

Table 7. Antioxidative activity (ORAC) and total phenol content of different unifloral honeys [32]

Honey type	ORAC µmol TE/g	total phenolics GAE mg/kg
Buckwheat Illinois	16.95 ± 0.76	796 ±3 2
Buckwheat	9.81 ± 0.34	nd
Buckwheat New York	9.75 ± 0.48	456 ± 55
Buckwheat	9.34 ± 0.57	nd
Buckwheat	9.17 ± 0.63	nd
Buckwheat	7.47 ± 0.27	nd
Soy (2000)	9.49 ± 0.29	nd
Soy (1996)	8.34 ± 0.51	269 ± 22
Hawaiian Christmas berry	8.87 ± 0.33	250 ± 56
Clover (January 2000)	6.53 ± 0.70	nd
Clover (July 2000)	6.05 ± 1.00	128 ± 11
Tupelo	6.48 ± 0.37	183 ± 9
Fireweed	3.09 ± 0.27	62 ± 6
Acacia	3.00 ± 0.16	46 ± 2

ORAC = Oxygen radical absorbance capacity,
TE = Trolox equivalent, GAE = gallic acid equivalent, nd = not determined

REFERENCES

1. Crane E: “The archaeology of beekeeping.” London: Gerald Duckworth & Co., 1983.

2. Crane E: History of honey. In Crane E (ed): “Honey, a comprehensive survey.” London: William Heinemann, pp. 439-488, 1975.

3. Jones R: Honey and healing through the ages. In Munn P, Jones R (ed): “Honey and healing.” Cardiff: International Bee Research Association IBRA, pp. 1-4, 2001.

4. Crane E: “The world history of beekeeping and honey hunting.” London: Gerald Duckworth & Co, 1999.

5. Allsop KA, Miller JB: Honey revisited: A reappraisal of honey in pre-industrial diets. Br J Nutr 75:513-520, 1996.

6. Potschinkova P: „Bienenprodukte in der Medizin. Apitherapie.“ München: Ehrenwirth Verlag, 1992.

7. Cherbuliez T, Domerego R: „L'Apitherapie.“ Bruxelles: Amyris SPRL, 2003.

8. Molan P: Why honey is effective as a medicine. 1. Its use in modern medicine. Bee World 80:79-92, 1999.

9. American Honey Board: Honey-Nutrition and Health. National Honey Board 1-27, 2005, www.honeystix.com/HoneyStix/compendium.pdf, assessed 13 June 2007.

10. Groeneveld M: Honig als Lebens- und Arzneimittel ? Dt Z Sportmed 56:364, 2005.

11. Al-Quassemi R, Robinson RK: Some special nutritional propeties of honey - a brief review. Nutr Food Sci 33:254-260, 2003.

12. Heitkamp K: Pro und kontra Honig - Sind Aussagen zur Wirkung des Honigs "wissenschaftlich hinreichend gesichert"? Schriften zur Oecotrophologie 1-60, 1984.

13. Molan P: Why honey is effective as a medicine. 2. The scientific explanation of its effects. Bee World 82:22-40, 2001.

14. White JW: Composition of honey. In Crane E (ed): “Honey. A comprehensive survey.” London: Heinemann Edition, pp. 157-206, 1975.

15. Bogdanov S, Bieri K, Gremaud G, Iff D, Känzig A, Seiler K, Stöckli H, Zürcher K: Bienenprodukte; 23 A Honig. Swiss Food Manual 1-35, 2003.

16. Heitkamp K, Busch-Stockfisch M: Pro und Kontra Honig - Sind Aussagen zur Wirkung des Honigs "wissenschaftlich hinreichend gesichert"? Z Lebensm Unters Forsch 182:279-286, 1986.

17. Persano Oddo L, Piro R: Main European unifloral honeys: descriptive sheets. Apidologie 35:S38-S81, 2004.

18. Doner LW: The sugars of honey - a review. J Sci Food Agric 28:443-456, 1977.

19. Siddiqui IR: The sugars of honey. Adv Carbohyd Chem 25:285-309, 1970.

20. Conti ME: Lazio region (Central Italy) honeys: a survey of mineral content and typical quality parameters. Food Control 11:459-463, 2000.

21. Terrab A, Hernanz D, Heredia FJ: Inductively coupled plasma optical emission spectrometric determination of minerals in thyme honeys and their contribution to geographical discrimination. J Agric Food Chem 52:3441-3445, 2004.

22. Iskander FY: Trace and minor elements in four commercial honey brands. J. Radioanalyt. Nuclear Chem 201:401-408, 1995.

23. Rodriguez-Otero JL, Paseiro P, Simal J, Cepeda A: Mineral content of the honeys produced in Galicia (North-west Spain). Food Chem 49:169-171, 1994.

24. Golob T, Dobersek U, Kump P, Necemer M: Determination of trace and minor elements in Slovenian honey by total reflection X-ray fluorescence spectroscopy. Food Chem 91:593-600, 2005.

25. Yilmaz H, Yavuz O: Content of some trace metals in honey from south-eastern Anatolia. Food Chem 65:475-476, 1999.

26. Bengsch E: Connaissance du miel. Des oligo-éléments pour la santé. Rev franç apicult 569:383-386, 1992.

27. Bogdanov S, Matzke A: Honig - eine natürliche Süsse. In Matzke A, Bogdanov S (ed): “Der Schweizerische Bienenvater, Bienenprodukte und Apitherapie.“ Winikon: Fachschriftenverlag VDRB, pp 7-40, 2003.

28. Deutsche Gesellschaft für Ernährung: „Referenzwerte für die Nährstoffzufuhr,“ 1st ed. Frankfurt am Main: Umschau/Braus, 2000.

29. Crane E, Walker P, Day R: “Directory of important world honey sources.” London: International Bee Research Association, 1984.

30. Bogdanov S, Ruoff K, Persano Oddo L: Physico-chemical methods for the characterisation of unifloral honeys: a review. Apidologie 35:S4-S17, 2007.

31. Al-Mamary M, Al-Meeri A, Al-Habori M: Antioxidant activities and total phenolics of different types of honey. Nutr Res 22:1041-1047, 2002.

32. Gheldof N, Engeseth NJ: Antioxidant capacity of honeys from various floral sources based on the determination of oxygen radical absorbance capacity and inhibition of in vitro lipoprotein oxidation in human serum samples. J Agric Food Chem 50:3050-3055, 2002.

33. Tomás-Barberán F.A, Martos I, Ferreres F, Radovic BS, Anklam E: HPLC flavonoid profiles as markers for the botanical origin of European unifloral honeys. J Sci Food Agric 81:485-496, 2001.

34. Kenjeric D, Mandic ML, Primorac L, Bubalo D, Perl A: Flavonoid profile of Robinia honeys produced in Croatia. Food Chem102:683-690, 2007.

35. Bogdanov S: Contaminants of bee products. Apidologie 38:1-18, 2006.

36. de Bodt G: Les miels de rhododendrons. Les Carnets de CARI 10-12, 1996.

37. Edgar JA, Roeder EL, Molyneux RJ: Honey from plants containing pyrrolizidine alkaloids: A potential threat to health. J Agric Food Chem 50:2719-2730, 2002.

38. Arcot J, Brand-Miller J: A preliminary assesment of the glycemic index of honey. pp 1-24, 2005. www.rirdc.gov.au/reports/HBE/05-027.pdf, assessed 13 June 2007.

39. Foster-Powell K, Holt SHA, Brand-Miller JC: International table of glycemic index and glycemic load values: 2002. Am J Clin Nutr 76:5-56, 2002.

40. Ischayek JI, Kern M: US honeys varying in glucose and fructose content elicit similar glycemic indexes. J Am Diet Ass 106:1260-1262, 2006.

41. Kreider R, Rasmussen C, Lundberg J, Cowan P, Greenwood M, Earnest C, Almada A: Effects of ingesting carbohydrate gels on glucose, insulin and perception of hypoglycemia. FASEB J 14:A490, 2000.

42. Ludwig D: Dietary glycemic index and obesity. J Nutr 130:280S-283S, 2000.

43. Jenkins D, Kendall C, Augustin L, Franceschi S, Hamidi M, Marchie A, Jenkins A, Axelsen M: Glycemic index: overview of implications in health and disease. Am J Clin Nutr 76:266S-273S, 2002.

44. Al-Khalidi A, Jawad FH, Tawfiq NH: Effects of bees honey, zahdi dates and its syrup on blood glucose and serum insulin of diabetics. Nutr Rep Int 21:631-643, 1980.

45. Jawad F.H, Al-Khalidi A, Tawfiq N.H: Effects of bees honey, zahdi date and its syrup on blood glucose and serum insulin of normal subjects. J Faculty Medicine, Baghdad 23:169-180, 1981.

46. Peretti A, Carbini L, Dazzi E, Pittau L, Spanu P, Manai M: Uso razionale del miele nell'alimentazione dei diabetici. Clin Dietolog 21:13-21, 1994.

47. Al-Waili NS: Natural honey lowers plasma glucose, C-reactive protein, homocysteine, and blood lipids in healthy, diabetic, and hyperlipidemic subjects: Comparison with dextrose and sucrose. J Med Food 7:100-107, 2004.

48. Al-Waili NS: Intrapulmonary administration of natural honey solution, hyperosmolar dextrose or hypoosmolar distill water to normal individuals and to patients with type-2 diabetes mellitus or hypertension: Their effects on blood

glucose level, plasma insulin and C-peptide, blood pressure and peaked expiratory flow rate. Eur J Med Res 8:295-303, 2003.

49. Bejan V, Lacatis D, Petrus V, Bejan VV, Creteanu G: L'emploi du fructose dans le regime du diabete sucre insulino-dependant. IIIe Symposium International d'Apitherapie, 11-15 Septembre 1978, Portoroz, Yougoslavie. Bukarest: Apimondia, 382-384, 1978.

50. Bornet F, Haardt M., Costagliola D, Blayo A, Slama G: Sucrose or honey at breakfest have no additional acute hyperglycaemic effect over an isoglucic amount of bread in Type 2 diabetic patients. Diabetologia 28:213-217, 1985.

51. Katsilambros NL, Philippides P, Touliatou A, Georgakopoulos K, Kofotzouli L, Frangaki D, Siskoudis P, Marangos M, Sfikakis P: Metabolic effects of honey (alone or combined with other foods) in type II diabetics. Acta Diabetol Lat 25:197-203, 1988.

52. Samanta A, Burden AC, Jones GR: Plasma glucose responses to glucose, sucrose and honey in patients with diabetes mellitus: an analysis of glycaemic and peak incremental indices. Diabet Med 2:371-373, 1985.

53. Liu SM, Manson JE, Stampfer MJ, Holmes MD, Hu FB, Hankinson SE, Willett WC: Dietary glycemic load assessed by food-frequency questionnaire in relation to plasma high-density-lipoprotein cholesterol and fasting plasma triacylglycerols in postmenopausal women. Am J Clin Nutr 73:560-566, 2001.

54. Pi-Sunyer FX: Glycemic index and disease. Am J Clin Nutr 76:290S-298S, 2002.

55. Elliott SS, Keim NL, Stern JS, Teff K, Havel PJ: Fructose, weight gain, and the insulin resistance syndrome. Am J Clin Nutr 76:911-922, 2002.

56. Busserolles J, Gueux E, Rock E, Mazur A, Rayssiguier Y: Substituting honey for refined carbohydrates protects rats from hypertriglyceridemic and prooxidative effects of fructose. J Nutr 132:3379-3382, 2002.

57. Yamada S, Itoh E, Murakami Y, Asano M: Prevention of ethanol-induced erythrocyte transformations by fructose and natural honey in low alcohol tolerance mice. Pathophysiology 6:163-170, 1999.

58. Onyesom I: Effect of Nigerian citrus (Citrus sinensis Osbeck) honey on ethanol metabolism. S Afr Med J 94:984-986, 2004.

59. Onyesom I: Honey-induced stimulation of blood ethanol elimination and its influence on serum triacylglycerol and blood pressure in man. Ann Nutr Metab 49:319-324, 2005.

60. Molan PC: Honey as an antimicrobial agent“In: Mizrahi, A. and Lensky, Y. (eds.) *Bee Products: Properties, Applications and Apitherapy.* Plenum Press, New York, pp. 27-37, 1997.

61. Molan PC: The antibacterial activity of honey. 1. The nature of the antibacterial activity. Bee World 73:5-28, 1992.

62. Molan PC: The antibacterial activity of honey. 2. Variation in the potency of the antibacterial activity. Bee World 73:59-76, 1992.

63. Bogdanov S: Nature and origin of the antibacterial substances in honey. Lebensm.-Wiss -Technol 30:748-753, 1997.

64. Zeina B, Othman O, Al-Assad S: Effect of honey versus thyme on Rubella virus survival in vitro. J Altern Complement Med 2:345-348, 1996.

65. Zeina B, Zohra BI, al Assad S: The effects of honey on Leishmania parasites: an in vitro study. Trop Doct 27 (Suppl 1):36-38, 1997.

66. Kilicoglu B, Kismet K, Koru O, Tanyuksel M, Oruc MT, Sorkun K, Akkus MA: The scolicidal effects of honey. Adv Ther 23:1077-1083, 2006.

67. White JW, Subers MH, Schepartz AJ: The identification of inhibine, the antibacterial factor in honey, as hydrogen peroxide and its origin in a honey glucose-oxidase system. Biochim Biophys Acta 73:57-70, 1963.

68. Dustmann JH: Über die Katalaseaktivität in Bienenhonig aus der Tracht der Heidekrautgewächse (Ericacea). Z Lebensm Unters Forsch 145:292-295, 1971.

69. Russell KM, Molan PC, Wilkins AL, Holland PT: Identification of some antibacterial constituents of New Zealand Manuka honey. J Agric Food Chem 38:10-13, 1988.

70. Cushnie T, Lamb A: Antimicrobial activity of flavonoids. Int J Antimicrob Agents 26:343-356, 2005.

71. Weston RJ, Mitchell KR, Allen KL: Antibacterial phenolic components of New Zealand manuka honey. Food Chem 64:295-301, 1999.

72. Yatsunami K, Echigo T: Antibacterial action of honey and royal jelly (japanese). Honeybee Sci 5:125-130, 1984.

73. Ames BN, Shigenaga MK, Hagen TM: Oxidants, antioxidants, and the degenerative diseases of aging. Proc Natl Acad Sci USA 90:7915-7922, 1993.

74. Parthasarathy S, Steinberg D, Witztum JL: The role of oxidized low-density lipoproteins in the pathogenesis of atherosclerosis. Annu Rev Med 43:219-225, 1992.

75. Beretta G, Granata P, Ferrero M, Orioli M, Facino RM: Standardization of antioxidant properties of honey by a combination of spectrophotometric/fluorimetric assays and chemometrics. Anal Chim Acta 533:185-191, 2005.

76. D'Arcy BR: Antioxidants in Australian floral honeys -Identification of health-enhancing nutrient components. RIRDC Publication No 05/040, 1, 2005.

77. Gheldof N, Wang XH, Engeseth NJ: Identification and quantification of antioxidant components of honeys from various floral sources. J Agric Food Chem 50:5870-5877, 2002.

78. Frankel S, Robinson GE, Berenbaum MR: Antioxidant capacity and correlated characteristics of 14 unifloral honeys. J Apic Res 37:27-31, 1998.

79. Aljadi AM, Kamaruddin MY: Evaluation of the phenolic contents and antioxidant capacities of two Malaysian floral honeys. Food Chem 85:513-518, 2004.

80. Inoue K, Murayarna S, Seshimo F, Takeba K, Yoshimura Y, Nakazawa H: Identification of phenolic compound in manuka honey as specific superoxide anion radical scavenger using electron spin resonance (ESR) and liquid chromatography with coulometric array detection. J Sci Food Agric 85:872-878, 2005.

81. Fahey JW, Stephenson KK: Pinostrobin from honey and Thai ginger (Boesenbergia pandurata): A potent flavonoid inducer of mammalian phase 2 chemoprotective and antioxidant enzymes. J Agric Food Chem. 50:7472-7476, 2002.

82. Blasa M, Candiracci M, Accorsi A, Piacentini M, Albertini M, Piatti E: Raw Millefiori honey is packed full of antioxidants. Food Chem 97:217-222, 2006.

83. Nagai T, Inoue R, Kanamori N, Suzuki N, Nagashima T: Characterization of honey from different floral sources. Its functional properties and effects of honey species on storage of meat. Food Chem 97:256-262, 2006.

84. Perez RA, Iglesias MT, Pueyo E, Gonzalez M, de Lorenzo C: Amino acid composition and antioxidant capacity of Spanish honeys. J Agric Food Chem 55:360-365, 2007.

85. Gheldof N, Wang XH, Engeseth NJ: Buckwheat honey increases serum antioxidant capacity in humans. J Agric Food Chem 51:1500-1505, 2003.

86. Schramm DD, Karim M, Schrader HR, Holt RR, Cardetti M, Keen CL: Honey with high levels of antioxidants can provide protection to healthy human subjects. J Agric Food Chem 51:1732-1735, 2003.

87. Al-Waili NS: Effects of daily consumption of honey solution on hematological indices and blood levels of minerals and enzymes in normal individuals. J Med Food 6:135-140, 2003.

88. Baltrusaityte V, Venskutonis PR, Ceksteryte V: Radical scavenging activity of different floral origin honey and beebread phenolic extracts. Food Chem 101:502-514, 2007.

89. Kücük M, Kolayli S, Karaoglu S, Ulusoy E, Baltaci C, Candan F: Biological activities and chemical composition of three honeys of different types from Anatolia. Food Chem 100:526-534, 2007.

90. Vela L, de Lorenzo C, Pérez RA: Antioxidant capacity of Spanish honeys and its correlation with polyphenol content and other physicochemical properties. J Sci Food Agric 87:1069-1075, 2007.

91. Wang XH, Gheldof N, Engeseth NJ: Effect of processing and storage on antioxidant capacity of honey. J Food Sci 69:C96-C101, 2004.

92. Turkmen N, Sari F, Poyrazoglu ES, Velioglu YS: Effects of prolonged heating on antioxidant activity and colour of honey. Food Chem 95:653-657, 2006.

93. Wang XH, Andrae L, Engeseth NJ: Antimutagenic effect of various honeys and sugars against Trp-p-1. J Agric Food Chem 50:6923-6928, 2002.

94. Murosaki S, Muroyama K, Yamamoto Y, Liu T, Yoshikai Y: Nigerooligosacharides augments natural killer activity of hepatic mononuclear cells in mice. Int Immunopharmacol 2:151-159, 2002.

95. Orsolic N, Basic I: Honey as a cancer-preventive agent. Periodicum Biolog 106:397-401, 2004.

96. Orsolic N, Knezevic AH, Sver L, Terzic S, Heckenberger BK, Basic I: Influence of honey bee products on transplantable murine tumours. Vet Comp Oncology 1:216-226, 2003.

97. Swellam T, Miyanaga N, Onozawa M, Hattori K, Kawai K, Shimazui T, Akaza H: Antineoplastic activity of honey in an experimental bladder cancer implantation model: in vivo and in vitro studies. Int J Urol 10:213-219, 2003.

98. Al-Waili NS, Boni NS: Natural honey lowers plasma prostaglandin concentrations in normal individuals. J Med Food 6:129-133, 2003.

99. Bilsel Y, Bugra D, Yamaner S, Bulut T, Cevikbas U, Turkoglu U: Could honey have a place in colitis therapy? Effects of honey, prednisolone, and disulfiram on inflammation, nitric oxide, and free radical formation. Dig Surg 19:306-311, 2002.

100. Postmes T: The treatment of burns and other wounds with honey. In Munn P, Jones R (ed): “Honey and healing.” Cardiff: IBRA International Bee Research Association, pp 41-47, 2001.

101. Al-Waili NS, Haq A: Effect of honey on antibody production against thymus-dependent and thymus-independent antigens in primary and secondary immune responses. J Med Food 7:491-494, 2004.

102. Duddukuri GR, Kumar PS, Kumar VB, Athota RR: Immunosuppressive effect of honey on the induction of allergen-specific humoral antibody response in mice. Int Arch Allergy Immunol 114:385-388, 1997.

103. Shannon IL, Edmonds EJ, Madsen KO: Honey: sugar content and cariogenicity. J Dent Children 46:29-33, 1979.

104. Lembke A, Kay HW, Rathjen G: Kariogene Wirkungen von zuckerhaltigen Lebensmitteln am Beispiel von Aufstrichen. Milchwissenschaft 37:467-471, 1982.

105. Thylstrup A, Fejerskov O: “Textbook of Cariology.” Copenhagen: Munksgaard, 1986.

106. Bowen WH, Lawrence RA: Comparison of the cariogenicity of cola, honey, cow milk, human milk, and sucrose. Pediatrics 116:921-926, 2005.

107. Decaix C: Comparative study of sucrose and honey. Chir Dent Fr 46:59-60, 1976.

108. Steinberg D, Kaine G, Gedalia I: Antibacterial effect of propolis and honey on oral bacteria. Am J Dent 9:236-239, 1996.

109. Molan PC: Honey for oral health. J. Dental Res 80:1-130, 2001.

110. Sela MO, Shapira L, Grizim I, Lewinstein I, Steinberg D, Gedalia I, Grobler SR: Effects of honey consumption on enamel microhardness in normal versus xerostomic patients. J. Oral Rehabil 25:630-634, 1998.

111. Edgar WM, Jenkins GN: Solubility-reducing agents in honey and partly-refined crystalline sugar. Br Dent J 136:7-14, 1974.

112. English HK, Pack AR, Molan PC: The effects of manuka honey on plaque and gingivitis: a pilot study. J Int Acad Periodontol 6:63-67, 2004.

113. Grobler SR, du Toit IJ, Basson NJ: The effect of honey on human tooth enamel in vitro observed by electron microscopy and microhardness measurements. Arch Oral Biol 39:147-153, 1994.

114. al-Bukhaari M: “Holy Hadith (Sahih Al-Bukhari, Arabic).” 3rd ed. Chicago: Kazi Publications, 1994.

115. Celsus C: “De medicina.” London: Heinemann, 1935.

116. Khotkina ML: Honey as part of therapy for patients with stomach ulcers. Collection of papers Irkutsk State Medical Institute 252-262, 1955.

117. Ludyanskii EA: “Apiterapia.” Vologda, Russia: Poligrafist, 1994.

118. Menshikov FK, Feidman SI: Curing stomach ulcers with honey. Sovetskaya Meditsing 10:13-14, 1949.

119. Mladenov S: “Pcelnite produkti hrana i lekarstvo (BG) / The bee products - food and medicine.” Sofia: Medizina i Fizkultura, 1978.

120. Slobodianiuk AA, Slobodianiuk MS: Complex treatment of gastritis patients with high stomach secretion in combination with (and without) a 15-20% solution of honey. Ufa, Bashkir. Khniz. izd.-vo, 1969, cited after [8].

121. Salem SN: Honey regimen in gastrointestinal disorders. Bull Islamic Med 1:358-362, 1981.

122. al Somal N, Coley KE, Molan PC, Hancock BM: Susceptibility of *Helicobacter pylori* to the antibacterial activity of Manuka honey. J R Soc Med 87:9-12, 1994.

123. Ali ATMM, Chowdhury MNH, Al-Humayyd MS: Inhibitory effect of natural honey on Helicobacter pylori. Trop Gastroenterol 12:139-143, 1991.

124. Osato MS, Reddy SG, Graham DY: Osmotic effect of honey on growth and viability of *Helicobacter pylori*. Dig Dis Sci 44:462-464, 1999.

125. Ali ATM: Natural honey accelerates healing of indomethacin-induced antral ulcers in rats. Saudi Med J 16:161-166, 1995.

126. Kandil A, El-Banby M, Abdel-Wahed K, Abdel-Gawwad M, Fayez M: Curative properties of true floral and false nonfloral honeys and induced gastric ulcers. J Drug Res Egypt 17:103-106, 1987.

127. Gharzouli K, Amira S, Gharzouli A, Khennouf S: Gastroprotective effects of honey and glucose-fructose-sucrose-maltose mixture against ethanol-, indomethacin-, and acidified aspirin-induced lesions in the rat. Exp Toxicol Pathol 54:217-221, 2002.

128. Gharzouli K, Gharzouli A, Amira S, Khennouf S: Prevention of ethanol-induced gastric lesions in rats by natural honey and glucose-fructose-sucrose-maltose mixture. Pharmacol Res 43:509, 2001.

129. Al Swayeh OA, Ali ATMM: Effect of ablation of capsaicin-sensitive neurons on gastric protection by honey and sucralfate. Hepato-Gastroenterol 45:297-302, 1998.

130. Nasuti C, Gabbianelli R, Falcioni G, Cantalamessa F: Antioxidative and gastroprotective activities of anti-inflammatory formulations derived from chestnut honey in rats. Nutr Res 26:130-137, 2006.

131. Ali ATMM: Natural honey exerts its protective effects against ethanol-induced gastric lesions in rats by preventing depletion of glandular nonprotein sulfhydryls. Trop Gastroenterol 16:18-26, 1995.

132. Ali ATMM: Natural honey prevents ischaemia-reperfusion-induced gastric mucosal lesions and increased vascular permeability in rats. Eur J Gastroenterol Hepatol 9:1101-1107, 1997.

133. Baltuskevicius A, Laiskonis A, Vysniauskiene D, Ceksteryte V, Racys J: Use of different kinds of honey for hepatitis A treatment and for reduction of increased acidity of gastric juice. Zemdirbyste, Mokslo Darbai 76:173-180, 2001.

134. Pokorn D, Vukmirovic V: Velocity of gastric emptying of saccharides after administering honey and pure invert sugar, III International Apitherapy, Symposium 11-15 September 1978, Portoroz, Yougoslava. Bukarest: Apimondia, pp. 277-279, 1978.

135. Sanz ML, Polemis N, Morales V, Corzo N, Drakoularakou A, Gibson GR, Rastall RA: In vitro investigation into the potential prebiotic activity of honey oligosaccharides. J Agric Food Chem 53:2914-2921, 2005.

136. Yun YW: Fructooligosaccharides - occurrence, preparation and application. Enzyme Microb Technol 19:107-117, 1996.

137. Ustunol Z: The effect of honey on the growth of bifidobacteria. Report for the National Honey Board 1-8, 2000. http://www.honey.com/downloads/bifido.pdf, accessed on 25 May 2007.

138. Kajiwara S, Gandhi H, Ustunol Z: Effect of honey on the growth of and acid production by human intestinal *Bifidobacterium* spp: An in vitro comparison with commercial oligosaccharides and inulin. J Food Prot 65:214-218, 2002.

139. Shin H.S, Ustunol Z: Carbohydrate composition of honey from different floral sources and their influence on growth of selected intestinal bacteria: An in vitro comparison. Food Res Int 38:721-728, 2005.

140. Shamala TR, Jyothi YS, Saibaba P: Stimulatory effect of honey on multiplication of lactic acid bacteria under in vitro and in vivo conditions. Lett Appl Microbiol 30:453-455, 2000.

141. Haffejee IE, Moosa A: Honey in the treatment of infantile gastroenteritis. Br Med J 290:1866-1867, 1985.

142. Ladas SD, Haritos DN, Raptis SA: Honey may have a laxative effect on normal subjects because of incomplete fructose absorption. Am J Clin Nutr 62:1212-1215, 1995.

143. Ladas SD, Raptis S.A: Honey, fructose absorption, and the laxative effect. Nutrition 15:591-592, 1999.

144. Riby JE, Fujisawa T, Kretchmer N: Fructose absorption. Am J Clin Nutr 58:748-753, 1993.

145. Sirnik V, Koch V, Golob T: L'influence du miel sur la digestibilité des substances nutritives chez le rat albinos. III International Apitherapy, Symposium 11-15 September 1978, Portoroz, Yougoslava. Bukarest: Apimondia, pp 286-290, 1978.

146. Al-Waili NS: Identification of nitric oxide metabolites in various honeys: effects of intravenous honey on plasma and urinary nitric oxide metabolites concentrations. J Med Food 6:359-364, 2003.

147. Al-Waili NS, Boni NS: Honey increased saliva, plasma, and urine content of total nitrite concentrations in normal individuals. J Med Food 7, 377-380, 2004.

148. Frauenfelder RA: Der Honig als Genuss-, Nähr- und Kräftigungsmittel. Buchdruckerei A. Umiker, Biel-Madretsch, pp.3-32, 1921.

149. Müller L: Der Bienenhonig in der Säuglingsernährung bei Berücksichtigung einer neuen Fertignahrung. Med Monatsschrift 10:729-732, 1956.

150. Ramenghi LA, Amerio G, Sabatino G: Honey, a palatable substance for infants: from De Rerum Natura to evidence-based medicine. Eur J Pediatr 160:677-678, 2001.

151. Mommsen H: Honig statt Zucker in der Ernährung des Säuglings. Dt Hebammen-Z 9:10-12, 1957.

152. Takuma DT: Honig bei der Aufzucht von Säuglingen. Monatsschrift Kinderheilkunde 103:160-161, 1955.

153. Tropp C: Der Honig und seine Bedeutung in der Säuglings- und Kinderernährung. Der Landarzt 33:250-252, 1957.

154. Rivero-Urgell M, Santamaria-Orleans A: Oligosaccharides: application in infant food (review). Early Hum Dev 65:43-52, 2001.

155. Hübner B: Säuglingsernährung mit Honigmilch (Nektar-Mil). Münchner Medizin Wochenschrift 100:311-313, 1958.

156. Bianchi EM: Honey: Its importance in children's nutrition. Amer Bee J 117:733, 1977.

157. Cox N, Hinkle R: Infant botulism. Am Fam Physician 65:1388-1392, 2002.

158. Tanzi MG, Gabay MP: Association between honey consumption and infant botulism. Pharmacotherapy 22:1479-1483, 2002.

159. McMaster P, Piper S, Schell D, Gillis J, Chong A: A taste of honey. J Paediatr Child Health 36:596-597, 2000.

160. Müller-Bunke H, Höck A, Schöntube M, Noack R: Säuglingsbotulismus. Monatsschrift für Kinderheilkunde 3:242-245, 2000.

161. European Commission: Honey and microbiological hazards. Report European Commission of Health & Consumer Protection Directorate-General 1-40, 2002. http://ec.europa.eu/food/fs/sc/scv/out53_en.pdf, assessed 13 June 2007.

162. Kreider RB, Rasmussen CJ, Lancaster SL, Kerksick C, Greenwood M: Honey: An alternative sports gel. Strength Conditioning J. 24, 50-51, 2002.

163. Leutholz B, Kreider R: Optimising nutrition of exercise and sport. In Wilson, T, Temple N (ed): "Nutritional Health". Totowa, NJ: Humana Press, pp 207-235, 2001.

164. Earnest C, Kreider R, Lundberg J, Rasmussen C, Cowan P, Greenwood M, Almada A: Effects of pre-exercise carbohydrate feedings on glucose and insulin responses during and after resistance exercise. J Strength Cond Res 14:361, 2000.

165. Earnest CP, Lancaster SL, Rasmussen CJ, Kerksick CM, Lucia A, Greenwood MC, Almada AL, Cowand PA, Kreider RB: Low versus high glycemic index meals carbohydrate gel ingestion during simulated 64 km cycling time trial performance. J Strength Cond Res 18:466-472, 2004.

166. Biswal BM, Zakaria A, Ahmad NM: Topical application of honey in the management of radiation mucositis. A preliminary study. Support Care Cancer 11:242-248, 2003.

167. Zidan J, Shetver L, Gershuny A, Abzah A, Tamam S, Stein M, Friedman E: Prevention of chemotherapy-induced neutropenia by special honey intake. Med Oncol 23:549-552, 2006.

168. Bousquet J, Campos J, Michel F.B: Food intolerance to honey. Allergy 39:73-75, 1984.

169. Helbling A, Peter C, Berchtold E, Bogdanov S, Müller U: Allergy to honey: Relation to pollen and honey bee allergy. Allergy 47:41-49, 1992.