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REVIEW

Contribution of honey in nutrition and human health: a review

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Abstract Our manuscript shows that honey has a variety of positive nutritional and health effects. It contains at least 181 substances, is a supersaturated solution of sugars, and contains small amounts of proteins, enzymes, amino acids, minerals, trace elements, vitamins, aroma compounds and polyphones. This article reviews reports on the use of honey in the treatment of human disorders, which are supported by clinical tests and published in medical journals. First, the composition of honey is described, followed by its physiological and nutritional effects. Finally, the influence of honey on gastroenterology and cardiovascular effects is illustrated.

Keywords Honey · Natural products · Gastroenteritis · Gastric ulcer · Wound healing · Antibacterial activity

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Introduction

Honey has been used as a food and medical product since the earliest times. It is a natural substance produced by honeybees, *Apis mellifera*, from the nectar of blossoms or from exudates of trees and plants giving nectar honeys or honeydews, respectively. As the only available natural sweetener, honey was an important food for Homo sapiens from his very beginnings. Indeed, the relationship between bees and man started as early as the Stone Age [1]. The first written reference to honey, on a Sumerian tablet dating back to 2100–2000 BC, mentions the use of honey as a drug and an ointment [2]. In most ancient cultures honey was used for both nutritional and medical purposes [2–5]. According to the bible, King Solomon 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 continued to the present time. For a long time in human history it was an important source of carbohydrates and the only widely available sweetener, until the production of industrial sugar 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]. Honey has been used in many cultures for its medicinal properties, including as a remedy for burns, cataracts, ulcers and wound healing, simply because it has a soothing effect when initially applied to open wounds [6]. Given its physical properties, honey provides a protective barrier and, owing to its high osmolarity, creates a moist wound-healing environment in the form of a solution that does not stick to wounded tissues. This moist wound environment is believed to prevent bacterial colonisation. Thus, honey reduces inflammation and also reduces exudate formation more promptly than standard treatments

[6]. Currently, information on the use of honey for the treatment of many human diseases can be found in general magazines, beekeeping journals and natural products leaflets, suggesting a wide variety of unfounded properties. An alternative medicine branch, called apitherapy, has developed in recent years, offering treatments based on honey and other bee products for many diseases.

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 greatly from country to country. The major honey exporting countries, China and Argentina, have small annual consumption rates of 0.1–0.2 kg per capita. Honey consumption is higher in developed countries, where domestic production does not always meet 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 the USA, Canada and Australia the average per capita consumption is 0.6–0.8 kg/year [7].

In this review, different surveys on nutritional and health aspects of honey have been compiled. We describe the nutritional characteristics of honey and examine the available information that is supported by laboratory or clinical studies in which honey has shown positive results for human health.

Composition of honey

The composition of honey is rather variable and primarily depends on the floral source; however, certain external factors also play a role, such as seasonal and environmental factors and processing. Honey contains at least 181 substances [8]; it is a supersaturated solution of sugars, mainly composed of fructose (38%) and glucose (31%), containing also minerals, proteins, free amino acids, enzymes and vitamins [9, 10]. A wide range of minor constituents is also present in honey, many of which are known to have antioxidant properties. These include phenolic acids and flavonoids [11–13], certain enzymes (glucose oxidase, catalase) [14] and amino acids [15–17]. Summarising the data shown in Table 1, it can be concluded that the contribution of honey to the recommended daily intake (RDI) is small. However, its importance with respect to nutrition lies in its manifold physiological effects [18]. It should be noted that the composition of honey depends greatly on its botanical origin [19], a fact that has seldom been considered in nutritional and physiological studies.

Table 1 Average composition in honey (data in g/100 g) [7–10]

Component	Average (%)
Water	17.2
Fructose	38.19
Glucose	31.28
Sucrose	1.31
Disaccharides, calculated as maltose	7.31
Higher sugars	1.5
Free acid as gluconic	0.43
Lactone as gluconolactone	0.14
Total acid as gluconic	0.57
Ash	0.169
Nitrogen	0.041
Minerals	0.2
Amino acids, proteins	0.3
pH value	3.9

Carbohydrate composition

Honey is mainly made up of carbohydrates, which constitute about 95% of its dry weight. It is a highly complex mixture of sugars, most of which are in the immediately digestible form in the small intestine. In addition to those named in Table 1, the following constituents have also been identified in honey: isomaltose, nigerose, turanose, maltulose; kojibiose; alpha beta-trehalose, gentiobiose, laminaribiose; maltotriose, 1-kestose, panose, isomaltosyl glucose, erlose, isomaltosyltriose, theanderose, centose, isopanose, isomaltosyltetraose and isomaltosylpentaose [20]. However, sensitive analytical and separation techniques have revealed more than 30 different types of honey. Table 2 summarises different di- and trisaccharides reported by Moreira and De Maria [21]. Many of these sugars are not found in nectar but are formed during the ripening and storage effects of bee enzymes and the acids of honey [20]. In the process of digestion after honey intake the principal carbohydrates, fructose and glucose, are quickly transported into the blood and can be utilised for energy requirements by the human body. A daily dose of 20 g of honey will cover about 3% of the required daily energy [7].

Proteins, enzymes and amino acids

Honey contains roughly 0.5% proteins, mainly enzymes and free amino acids. Protein content has been reported in honey from different floral sources, where high protein contents were considered as over 1000 μg/g [22]. Nevertheless the contribution of that fraction to human protein intake is low. 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, and glu-

Table 2 Di- and Trisaccharide reported in honey [21]

Trivial nomenclature	Systematic nomenclature
Disaccharide	
Cellobiose [2]	O-β-D-glucopyranosyl-(1 → 4)-D-glucopyranose
Gentiobiose [2]	O-β-D-glucopyranosyl-(1 → 6)-D-glucopyranose
Isomaltose [2]	O-α-D-glucopyranosyl-(1 → 6)-D-glucopyranose
Isomaltulose [4]	O-α-D-glucopyranosyl-(1 → 6)-D-fructofuranose
Kojibiose [1]	O-α-D-glucopyranosyl-(1 → 2)-D-glucopyranose
Laminaribiose [3]	O-β-D-glucopyranosyl-(1 → 3)-D-glucopyranose
Leucrose [4]	O-α-D-glucopyranosyl-(1 → 5)-D-fructofuranose
Maltose [1]	O-α-D-glucopyranosyl-(1 → 4)-D-glucopyranose
Maltulose [2]	O-α-D-glucopyranosyl-(1 → 4)-D-fructose
Melibiose [4]	O-α-D-galactopyranosyl-(1 → 6)-D-glucopyranose
Neo-trehalose [3]	O-α-D-glucopyranosyl-β-D-glucopyranoside
Nigerose [2]	O-α-D-glucopyranosyl-(1 → 3)-D-glucopyranose
Palatinose [2]	O-α-D-glucopyranosyl-(1 → 6)-D-fructose
Saccharose [1]	O-α-D-glucopyranosyl-β-D-fructofuranoside
Turanose [1]	O-α-D-glucopyranosyl-(1 → 3)-D-fructose
Trisaccharide	
Kestose [4]	O-α-D-glucopyranosyl-(1 → 4)-O-α-D-glucopyranosyl-(1 → 2)-D-glucopyranose
1-Kestose [4]	O-a-D-glucopyranosyl l-(1 → 2)-β-D-fructofuranosyl-(1 → 2)-β-D-fructofuranoside
Erlose [1]	O-α-D-glucopyranosyl-(1 → 4)-α-D-glucopyranosyl-β-D-fructofuranoside
Isomaltotriose [2]	O-α-D-glucopyranosyl-(1 → 6)-O-α-D-glucopyranosyl-(1 → 6)-D-glucopyranose
Isopanose [2]	O-α-D-glucopyranosyl-(1 → 4)-O-α-D-glucopyranosyl-(1 → 6)-D-glucopyranose
Laminaritriose [4]	O-β-D-glucopyranosyl-(1 → 3)-O-β-D-glucopyranosyl-(1 → 3)-D-glucopyranose
Maltotriose [2]	O-α-D-glucopyranosyl-(1 → 4)-O-α-D-glucopyranosyl-(1 → 4)-D-glucopyranose
Melezitose [2]	O-α-D-glucopyranosyl-(1 → 3)-O-β-D-fructofuranosyl-(2 → 1)-α-D-glucopyranoside
Panose [2]	O-α-D-glucopyranosyl-(1 → 6)-O-α-D-glucopyranosyl-(1 → 4)-D-glucopyranose
Raffinose [2]	O-α-D-galactopyranosyl-(1 → 6)-O-α-D-glucopyranosyl-β-D-fructofuranoside
Teanderose [2]	O-α-D-glucopyranosyl-(1 → 6)-α-D-glucopyranosyl-β-D-fructofuranoside

[1] Majority; [2] Minority; [3] Traces; [4] Not confirmed

cose oxidase, producing hydrogen peroxide and gluconic acid from glucose [7].

Amino acids in honey account for 1% (w/w). The amount of total free amino acids in honey corresponds to between 10 and 200 mg/100g, with proline as their major contributor, corresponding to around 50% of the total free amino acids [23]. Besides proline, there are 26 amino acids in honeys, their relative proportions depending on its origin (nectar or honeydew). Since pollen is the main source of honey amino acids, the amino acid profile of a honey could be characteristic of its botanical origin. The main amino acids identified in honey from different botanical and geographical origin are: glutamic acid (Glu), aspartic acid (Asp), asparagine+serine (Asn+Ser), glutamine (Gln), histidine (His), glycine (Gly), threonine (Thr), b-alanine (b-Ala), arginine (Arg), a-alanine (a-Ala), g-aminobutyric acid (Gaba), proline (Pro), tyrosine (Tyr), valine (Val), ammonium ion (NH^{4+}), methionine (Met), cysteine (Cys), isoleucine (Ile), leucine (Leu), tryptophan (Trp), phenylalanine (Phe), ornithine (Orn) and lysine (Lys) [16, 17, 23, 24].

Vitamins, minerals and trace compounds

It is known that different trace and mineral element concentrations in honey depend on its botanical and geological origin [25]. Trace elements play a key role in the biomedical activities associated with this food, as these elements have a multitude of known and unknown biological functions. For this reason, the concentrations of minerals and trace elements in honey was investigated. Different trace (Al, Ba, Sr, Bi, Cd, Hg, Pb, Sn, Te, Tl, W, Sb, Cr, Ni, Ti, V, Co, Mo) and mineral (P, S, Ca, Mg, K, Na, Zn, Fe, Cu, Mn) elements were systematically investigated in botanically and geologically defined honey [26, 27]. The vitamin content in honey is low. Vitamins such as phyllochinon (K), thiamin (B1), riboflavin (B2), pyridoxin (B6) and niacin are reported in honey but in general the amount of vitamins and minerals is small and the contribution of honey to the RDI of the different trace substances is small [7].

Aroma compounds

The aroma profile is one of the most typical features of a food product, both for its organoleptic quality and authenticity [28]. Owing to the high number of volatile components, the aroma profile represents a ''fingerprint'' of the product, which could be used to determine its origin [29]. In the past decades extensive research on aroma compounds has been carried out and more than 500 different volatile compounds have been 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 the food industry and is also a selection criterion for the consumer's choice. Aroma compounds are present in honey at very low concentrations as complex mixtures of volatile components of different functionality and relatively low molecular weight [31]. An important number of organic compounds have been found as volatile components of different types of honeys. Thus, methyl anthranilate was identified as a compound characteristic of citrus honey. Other volatile compounds suggested as markers for citrus honey include lilac aldehyde [32–34],

hotrienol [34] and 1-p-menthen-al [32, 33]. Eucalyptus honey was shown to be distinctive because of the content of the volatile compounds nonanol, nonanal and nonanoic acid, and high levels of isophorone (3,5,5-trimethylcyclohexen-2-enone) were found in heather honey [31–34].

Polyphenolic composition

Polyphenols are another important group of compounds regarding the appearance and the functional properties of honey. Although studies on honeys, honeybees and the basic composition of honeys started a hundred years ago, interest in honey phenolic compounds has only recently increased. This is because of their potential role as biochemical markers for authenticating the geographical and antioxidant properties. Many authors have studied the phenolic and flavonoid contents of honey to determine if a correlation with floral origins exists [35–38]. The distribution of three main phenolic families (benzoic acids, cinnamic acids and flavonoids) shows different profiles in honey from different floral origins, with flavonoids being the most common in floral honeys. Therefore, a characteristic distribution pattern of phenolic compounds should be found in unifloral honeys sourced from the corresponding plant sources [39–43]. The flavonoids in honey and propolis have been identified as flavanones and flavanones/flavanols. In general, the flavonoid concentration in honey is approximately 20 mg/kg [44, 45]. Polyphenols in honey are mainly flavonoids (e.g., quercetin, luteolin, kaempferol, apigenin, chrysin, galangin), phenolic acids and phenolic acid derivatives [38, 39, 41, 42, 44–46]. The major flavonoids identified in various honeys are represented in Table 3.

Table 3 The phenolic acid and flavonoids identified in honey from different floral sources [11, 12, 35, 36, 38, 39, 44–46, 57–59]

Phenolic acid	Flavonoids
4-Dimethylaminobenzoic acid	Apigenin
Caffeic acid	Genistein
p-Coumaric acid	Pinocembrin
Gallic acid	Tricetin
Vallinic acid	Chrysin
Syringic acid	Luteolin
Chlorogenic acid	Quercetin 3-methyl ether
	Kaempferol
	Kaempferol 8-OMe
	Kaempferol 3-OMe
	Quercetin[a]
	Quercetin 3-OMe
	Quercetin 3,7-OMe
	Quercetin 3,3'-OMe
	Quercetin 7-3'-OMe
	Galangin
	Pinobanksin
	Myricetin[a]
	Myricetin 3-OMe
	Myricetin 3,7,4',5'-OMe

[a]Aglycones found in honeybee pollen

Physiological and health effects

Antibacterial activity

The factors responsible for the antimicrobial activity of honey are high osmolarity, acidity and particularly hydrogen peroxide [47], which is formed from the oxidation of glucose by the enzyme glucose oxidase, during the period when honey is ripening [48]. Glucose oxidase originates from the hypopharyngeal glands of honeybees [49]. When hydrogen peroxide is removed by adding catalase, some honeys still show significant antibacterial activity [50] and this activity is referred to as non-peroxide antibacterial activity. The non-peroxide factors of honeys include lysozyme, phenolic acids and flavonoids [49]. Bogdanov [47] suggested that the main part of the non-peroxide antibacterial activity might be of honeybee origin, while part may be of plant origin. Wahdan [51] also suggested that flavonoids and phenolic acids might be a part of the antibacterial activities of honey. The non-peroxide antibacterial activity is more heat- and light-insensitive than the hydrogen peroxide, and remains intact after storage of honey for long periods. Therefore, some authors have found that the non-peroxide antibacterial activity is more important than the hydrogen peroxide in terms of antibacterial effects [49]. However, the contribution to antibacterial properties of non-peroxide antibacterial activity may be smaller than that of hydrogen peroxide [52]. Thus, for optimum antibacterial activity, honey should be stored in a cool, dark place and be consumed when fresh.

Furthermore, it was reported that honey has also been shown to inhibit the Rubella virus *in vitro* [53], three species of the *Leishmania* parasite [54] and *Echinococcus* [55].

Nevertheless, there are differences in the antibacterial activity of different unifloral honeys [47]. Notably, the greatest activity is from manuka honey (*Leptospermum scoparium*), originating from New Zealand, particularly the East Cape region of the North Island. The high antibacterial activity of New Zealand manuka honey is in many cases due entirely to the non-peroxide components. Manuka honey contains several phenolic compounds, including methyl syringate and syringic acid [48, 56]. By examining the antimicrobial activity against *Staphylococcus aureus*, methyl syringate was found to

possess significant antibacterial activity. An Australian honey from a very similar source (*Leptospermum polygalifolium*) has also recently been found to possess a high level of non-peroxide antibacterial activity [52], though the cause of the non-peroxide antibacterial activity is still unclear and requires further investigation.

Antioxidant capacity

Antioxidant activity, or simply antioxidant capacity, is the ability and potential of honey to reduce oxidative reactions within the food systems and human health. Notably, these oxidative reactions can cause deleterious reactions in food products (e.g., lipid oxidation in meat, and enzymic browning in fruits and vegetables) and adverse health effects, such as chronic diseases and cancers [57, 58]. The antioxidants that naturally occur in honey contribute to its antioxidant capacity. These compounds are flavonoids, phenolic acids and some enzymes (e.g., glucose oxidase, catalase), ascorbic acid, carotenoid-like substances, organic acids, Maillard reaction products, amino acids and proteins [16, 40, 43, 53, 59–66].

Lots of methods for determining the antioxidant activity in honey have been used, e.g., determination of active oxygen species (viz. the superoxide anion, peroxyl and hydroxyl radicals), their radical scavenging ability [49, 52, 67], the 1,1-diphenyl-2-picrylhydrasyl (DPPH) antioxidant content [68], enzymatic or non-enzymatic measurements of lipid peroxidation inhibition [69], the ferric reducing/antioxidant power assay (FRAP) [70, 71] and the TEAC (Trolox equivalent antioxidant capacity) assay [72].

Gheldof et al. [57, 58] found that while phenolic compounds contribute significantly to the antioxidant capacity of honey, they are not solely responsible for it. However, the antioxidant capacity varies greatly depending on the honey floral source, possibly due to the differences in the content of plant secondary metabolites and enzyme activity.

The influence of honey ingestion on the antioxidant capacity of plasma was tested in two studies [67, 73]. In the first one, healthy subjects 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 volunteers 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% [67]. These data support the concept that phenolic antioxidants from processed honey are bioavailable and that they increase the antioxidant activity of plasma.

The protective activity of honey from different floral sources in a cultured endothelial cell line (EA.hy926) subjected to oxidative stress was studied. The results reported that honey, especially native honey, showed strong quenching activity against lipophilic cumoxyl and cumoperoxyl radicals, with significant suppression/prevention of cell damage, complete inhibition of cell membrane oxidation and intracellular ROS production, and recovery of intracellular GSH [74]. It can be speculated that the phytochemicals present in honey may augment defences against oxidative stress and might be able to protect humans, thus creating a potentially protective antioxidant barrier. Given that the average sweetener intake by humans is estimated to be over 70 kg/year, the substitution of traditional sweeteners by honey in some foods could result in an enhanced antioxidant defence system in healthy adults [67].

Antimutagenic, antitumour and anti-inflammatory activity

It has also been shown that honey reduces skin inflammation, oedema and exudation, promotes wound healing, diminishes scar size and stimulates tissue regeneration [75]. Hamzaoglu et al. [76] reported that tumour implantation in rats was markedly reduced by the application of honey pre- and post-operatively, suggesting that the physico-chemical action (decrease of oxygen availability in the tumour environment, i.e., anti-angiogenic effect) and its antioxidants can prevent the spread of metastatic cells [76, 77].

Until 1990, the chemopreventive action of honey was attributed to its hydrogen peroxide-releasing properties, through induction of cell apoptosis [78, 79], but recent findings point to a complementary role of the phytochemical antioxidant, which can act synergistically or independently from the release of H_2O_2 [52]. Honey contains an array of chemicals endowed with antiradical/anti-inflammatory activity, i.e., phenolic derivates, which can play an important role, alone or in combination, in their antitumour, anti-inflammatory effects [80].

The antitumoral effects of honey seem to be due to a multifactorial process, such as: (1) release of cytotoxic H_2O_2 (and of HO radicals after Fenton reaction) [79]; (2) a direct inhibition of COX-2 by some specific constituent (chrysin and caffeic acid penyl ethyl ester, CAPE) [81]; and (3) scavenging action against different reactive oxygen species (ROS) responsible for induction of the inflammatory burst, which if not properly quenched/contained can degenerate into cell malignancy [82].

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 [83]. All honeys exhibited a significant inhibition of Trp-p-1 mutagenicity. The anti-metastatic effect of honey and its possible mode of anti-tumour 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 [84]. In another study the anti-tumour effect of honey against bladder cancer was examined *in vitro* and *in vivo* in mice [85]. 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 of honey in humans were studied by Al Waili and Boni [86] after ingestion of 70 g of honey. The mean plasma concentration of thromboxane B(2) was reduced by 7%, 34% and 35%, and that of PGE(2) by 14%, 10% and 19% at 1, 2 and 3 h, respectively, after honey ingestion. The level of PGF(2α) was decreased by 31% at 2 h and by 14% at 3 h 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 [87].

Gastroenterology

Infections of the intestinal tract are common throughout the world, affecting people of all ages. Infectious diarrhoea exacerbates nutritional deficiencies in various ways, but as in any infection, the calorific demand is increased. Pure honey has bactericidal activity against many enteropathogenic organisms, including those of the *Salmonella* and *Shigella* species, and enteropathogenic *E. coli* [88].

Honey is a potent inhibitor of the agent that causes peptic ulcers and gastritis, *Helicobacter pylori. In vitro* studies of *H. pylori* isolates that cause gastritis have shown it is inhibited by a 20% solution of honey. Even isolates that exhibited a resistance to other antimicrobial agents were susceptible [89, 90]. In a clinical study, the administration of a bland diet and 30 ml of honey three times a day was found to be an effective remedy in 66% of patients and offered relief to a further 17%, while anaemia was corrected in more than 50% of the patients [91]. A clinical study of honey treatment in infantile gastroenteritis was reported by Haffejee and Moosa [92]. They found that by replacing the glucose (111 mmol/l) in the standard electrolyte-containing oral rehydration solution recommended by the World Health Organization/UNICEF [93], as well as the solution of electrolyte composition 48 mmol/l sodium, 28 mmol/l potassium, 76 mmol/l chloride ions, with 50 ml/l honey [94], the mean recovery times of patients (aged 8 days to 11 years) were significantly reduced. Honey was found to shorten the duration of diarrhoea in patients with bacterial gastroenteritis caused by organisms such as *Salmonella*, *Shigella* and *E. coli*. They recommended that honey was a safe substitute for glucose as long as it provided 111 mmol/l each of glucose and fructose. The high sugar content of honey means that it could be used to promote sodium and water absorption from the bowel.

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 [95]. 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 [96]. According to an *in vitro* study on five bifidobacteria strains, honey has a growth-promoting effect similar to that of fructose and glucose oligosaccharides [97].

Cardiovascular effects

It has been found that honey ameliorates cardiovascular risk factors in healthy individuals and in patients with elevated risk factors. Yaghoobi et al. [98] investigated the effect of natural honey on total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triacylglycerole, C-reactive protein (CRP), fasting blood glucose (FBG) and body weight in overweight individuals. There were 55 patients, overweight or obese, who were randomly recruited in the study and assigned to two groups: control group (17 subjects) and experimental group (38 subjects). Patients in the control group received 70 g of sucrose daily for a maximum of 30 days and patients in the experimental group received 70 g of natural honey for the same period. In this experiment the body weight, body mass index, body fat weight, total cholesterol, LDL-C, HDL-C, triacylglycerole, FBG and CRP were measured before treatment and at day 31 after the commencement of treatment. Results showed that honey caused a mild reduction in body weight (1.3%) and body fat (1.1%). Honey reduced total cholesterol (3%), LDL-C (5.8), triacylglycerole (11%), FBG (4.2%) and CRP (3.2%), and increased HDL-C (3.3%) in subjects with normal values. Meanwhile, in patients with elevated variables, honey caused reduction in total cholesterol by 3.3%, LDL-

C by 4.3%, triacylglycerole by 19% and CRP by 3.3% ($p<0.05$). It is our conclusion that consumption of natural honey reduces cardiovascular risk factors, particularly in subjects with elevated risk factors, and it does not increase body weight in overweight or obese subjects [98].

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 [99]. Elevation of insulin and C-reactive protein was significantly higher after glucose intake than after honey consumption. Glucose reduced cholesterol and LDL-C. Artificial honey slightly decreased cholesterol and LDL-C and elevated TG. Honey reduced cholesterol, LDL-C and TG and slightly elevated HDL-C. In patients with hypertriglyceridaemia, artificial honey increased TG, while honey decreased TG. In patients with hyperlipidaemia, artificial honey increased LDL-C, while honey decreased LDL-C. In diabetic patients, honey caused a significantly lower rise of plasma glucose than dextrose [99].

Conclusions

The quality of honey depends on its chemical composition and floral origin. The composition of active components in plants depends on various factors, particularly on plant bio-, chemotype and climatic conditions. Consequently, it can be reasonably expected that honey properties from different locations should be different. 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. The above information shows that in microbiological and clinical tests, honey offers advantages in controlling bacterial growth and in the treatment of certain health problems. The ease of administration for the treatment of wounds, the absence of antibiotic resistance as found with conventional antibiotics, the lack of side effects in alleviating gastric pain and shortening the duration of diarrhoea are all desirable features. Even in our modern-day society, the medical use of honey still has a place.

Conflict of interest The authors declare that they have no conflict of interest related to the publication of this manuscript.

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