Health Benefit, Traditional, and Modern Uses of Natural Honey

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Contents

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A. Husen et al. (eds.), *Non-Timber Forest Products*,
https://doi.org/10.1007/978-3-030-73077-2_12

Abbreviation

H_2O_2	Hydrogen peroxide
HMF	5-Hydroxymethylfurfural
IL-6	Interleukin
LDL	Induced low-density lipoprotein
MRSA	Methicillin-resistant *Staphylococcus aureus*
ROS	Reactive oxygen species
TNF-α	Tumor necrosis factor- α
VRE	Vancomycin-resistant Enterococci
VZV	Varicella Zoster virus
WHO	World Health Organization

1 Introduction

Honey is a natural, golden brown beehive product that is sweet in taste and viscous in consistency (Krishnakumar et al. 2020). It is produced from nectarous plants by the action of enzymes present in the gut of bees (Beegum et al. 2019). Owing to sweetness and therapeutic properties, it has been used for centuries as a sweetener, flavoring agent, and medicine (Beegum et al. 2019). Honey has been classified on the basis of its origin and method of harvesting and processing. Based on origin, honey can be blossom, honeydew, monofloral (unifloral), or multifloral (polyfloral). Honey collected mainly from plant nectar is called blossom honey, whereas honey produced after the collection of honeydew from plants is called honeydew or forest dew honey. Honey originated from single plant species (having total pollen content >45% from same plant species) is termed monofloral and is named according to the plant of origin such as acacia honey, manuka honey, etc. (Jibril et al. 2019). In contrast, honey produced from nectar of multiple plant species is known as multifloral honey and is named based on bee species, e.g., *Trigona thoracica* honey (Jibril et al. 2019). Monofloral honey is considered a better quality product and has high market value (Soares et al. 2015). Honey is also classified as natural or fabricated (synthetic) depending upon its collection by bees, i.e., from plant nectar or saturated solution of sugar and water (Zafar et al. 2020). In addition, honey can be raw or pasteurized. Raw honey is natural honey that is packed directly after harvest and contains impurities such as beewax, pollens, and microorganisms (yeast), whereas pasteurized honey is processed to remove impurities and improve shelf-life (Subramanian et al. 2007). Honey is primarily a carbohydrate-based liquid product containing proteins, acids, vitamins, minerals, enzymes, and secondary metabolites (flavonoids, phenols) in minor quantities which provide multiple health benefits (Waykar and Alqadhi 2016; Cenet et al. 2017). For instance, due to the presence of flavonoids, honey displays a potential to reduce the risk of heart diseases, asthma, skin ulcer, and microbial infections (Alvarez-Suarez et al. 2010a; Nik Man et al.

2015). The medicinal properties of honey are determined by its chemical composition, which varies with change in biotic and abiotic factors, such as floral species from which nectar has been collected, harvesting season, production method as well as environmental factors such as climate, geographical location, etc. (Ayaad et al. 2012; Cenet et al. 2017; Chew et al. 2018). Thus, the use and benefits of honey are function of variation in its quality and composition (Cenet et al. 2017). For example, the amount of 5-hydroxymethylfurfural (HMF) in honey is correlated with climatic condition of the plant source, aging of honey, and overheating during processing (Subramanian et al. 2007; Yap et al. 2019), and its concentration determines the degree of deterioration of honey (Umarani et al. 2015). The high value of HMF corresponds to greater loss of freshness and darkening of honey (Subramanian et al. 2007). The maximum limit of 40 mg/kg (80 mg/kg for tropical honey) for HMF has been set by Codex Alimentarium Standard Commission (FAO 1981).

2 Physicochemical Properties of Honey

Due to differences in botanical and geographical origin, honey has variable chemical composition and physical properties (da Silva et al. 2016). The basic chemical constituents and major physical properties of honey are shown in Fig. 1. Chemically, honey contains nearly 200 compounds (da Silva et al. 2016) and is mainly composed of water, sugars, proteins, organic acids, polyphenols, vitamins, and minerals (Nisbet et al. 2018). Carbohydrate, being the major constituent, comprises approximately 95% of the total dry weight and 80% of the total weight of honey (Krishnakumar et al. 2020). Sugars are present in both monosaccharides and oligosaccharides (disaccharides and polysaccharides) form; however, the percentage of monosaccharides is much higher than oligosaccharides (Santos-Buelga and Gonzalez-Paramas 2017). Fructose and glucose are chief monosaccharides representing approximately 38% and 31% of honey, respectively (Alvarez-Suarez et al. 2013). Honey also contains sucrose (disaccharide) comprising only 2% of the total composition (Chen et al. 2019). Monosaccharides are easily digested and transported through bloodstream; thus, honey is considered as a good source of energy. Consumption of 20 g of honey can fulfill 3% of daily energy requirement of humans (Bogdanov et al. 2008). Oligosaccharides like sucrose, maltose, trehalose, panose, raffinose, and others are also found in honey, and their concentrations vary depending on the type of honey. For instance, the concentration of oligosaccharide, raffinose, and melezitose is higher in honeydew when compared to blossom honey (Bogdanov et al. 2008).

The second important component of honey is water that constitutes less than 18% of the total weight (Krishnakumar et al. 2020). Other constituents such as proteins, minerals, vitamins, organic acids, etc. represent only a small fraction of honey and, nevertheless, are an important part in terms of health benefits. Proteins on average constitute 0.5% of the total weight of honey (Alvarez-Suarez et al. 2010b; Kek et al. 2017); however, its value varies according to floral source and species of

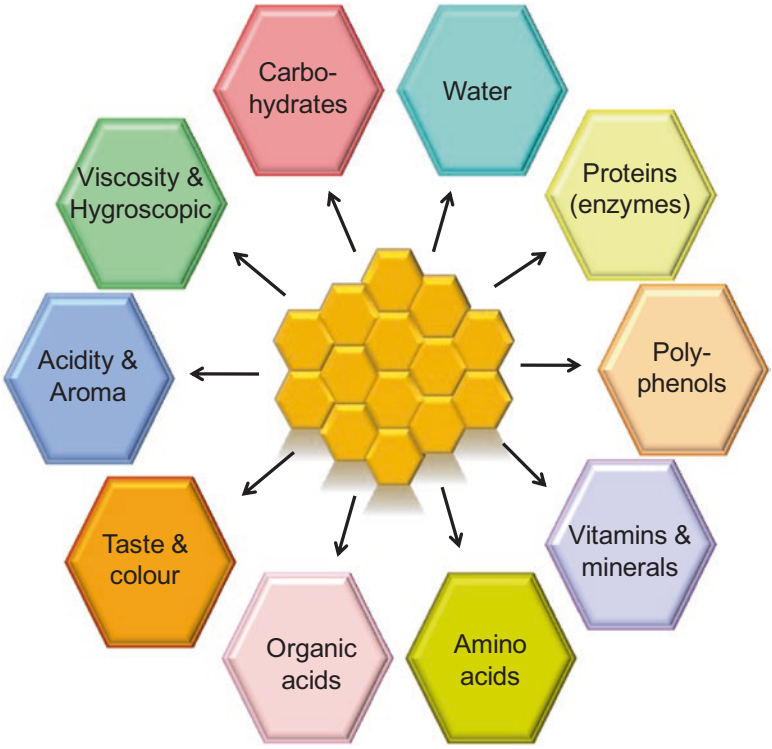

Fig. 1 Physicochemical characteristics of honey

honeybees (Nisbet et al. 2018). A small part of the protein represents enzymes like invertase (α-glucosidase), diastase (amylase), glucose oxidase, acid phosphatase, proteases, esterases, and catalase (Bogdanov et al. 2008; Santos-Buelga and Gonzalez-Paramas 2017). The primary function of enzyme invertase is the conversion of sucrose into glucose and fructose; amylase decomposes starch or glycogen into a simpler form of sugar; enzyme glucose oxidase transforms glucose into hydrogen peroxide (H_2O_2) and gluconic acid which facilitates calcium absorption; and catalase convert H_2O_2 into water and oxygen (Eteraf-Oskouei and Najafi 2013). Similar to protein, the amino acid content in honey depends on nectar plant source and honeybee species (Nisbet et al. 2018). Amino acid content varies from 50 to 300 mg/kg, with proline being the most abundant form (Nisbet et al. 2018). Besides these, honey contains a minute amount of vitamins (thiamin, riboflavin, niacin, ascorbic acid, and pantothenic acid) and minerals primarily potassium, magnesium, sodium, phosphorus, selenium, sulfur, and calcium representing the maximum percentage of total mineral content with a trace amount of manganese, iron, zinc, copper, and chromium (Bogdanov et al. 2008). Potassium is one of the major and most abundant element present in honey, representing one-third composition of total mineral content (Eteraf-Oskouei and Najafi 2013; da Silva et al. 2016). Polyphenol is a

group of bioactive compounds like flavonoids (quercetin, kaempferol, apigenin) and phenolic acid that imparts antioxidant, antiviral, anti-inflammatory, antiulcer, and antineoplastic property to honey (Jibril et al. 2019). In various honey samples, >200 polyphenols have been identified (Jibril et al. 2019). Polyphenols' value ranges from 56 to 500 mg/kg depending on the type of honey. Organic acid in honey comprises 0.57% of its composition (Eteraf-Oskouei and Najafi 2013). Gluconic acid is the most dominant form of organic acid present in honey (Eteraf-Oskouei and Najafi 2013). Other acids found in honey include citric, butyric, oxalic, acetic, lactic, formic, aspartic, malonic, malic, succinic acids, etc. (Ball 2007). About 0.2% of each, dietary fibers, and ash are also present in honey.

The chemical composition of honey determines its physical properties such as taste, aroma, viscosity, hygroscopicity, acidity, and color. Honey is an acidic liquid with pH ranging from 3.2 to 4.5 (Zafar et al. 2020). The acidity of honey is due to the presence of organic acid predominantly gluconic acid (da Silva et al. 2016). Organic acids along with amino acids, polyphenols, and volatile compounds establish the aroma of honey (Bogdanov et al. 2008; Jibril et al. 2019). More than 500 different types of volatile compounds have been identified in different honey (Bogdanov et al. 2008), including a mixture of C1-C5 aldehydes and alcohols (Ball 2007). Honey is a supersaturated sugar solution hence has high refractive index (1.49) and viscosity value (Ball 2007). Sugars present in honey are the main taste-building element (Bogdanov et al. 2008). Honey with high fructose content is sweeter when compared to honey with high glucose concentration (Bogdanov et al. 2008). In addition, the taste of honey is also determined by polyphenol content (Jibril et al. 2019). Color is one of the important characteristics of honey that correlates with its taste. Darker honey is known to have more intense flavor (Ball 2007). The color of honey depends on various chemical and physical factors, such as polyphenol content, minerals, season, floral source, processing techniques, and time interval between nectar collection and honey harvest (Ball 2007; da Silva et al. 2016; Jibril et al. 2019).

3 Biological Properties and Health Benefits of Honey

Honey is a natural product known for millenniums for its nutritional and therapeutic attributes. Honey has a very long history for its medicinal uses as antimicrobial, anti-inflammatory, antidiabetic, antimutagenic, antioxidant, and wound- and sunburn-healing agent (Liu et al. 2013) (Fig. 2). Evidence in scientific literature has demonstrated the potential of honey in lowering the risk of gastric and cardiovascular diseases (Alvarez-Suarez et al. 2010b), reducing hypersensitivity, ameliorating hormones related to fertility (Mosavat et al. 2014) as well as in treating ulcers, bedsores, and skin infections (Nooh and Nour-Eldien 2016).

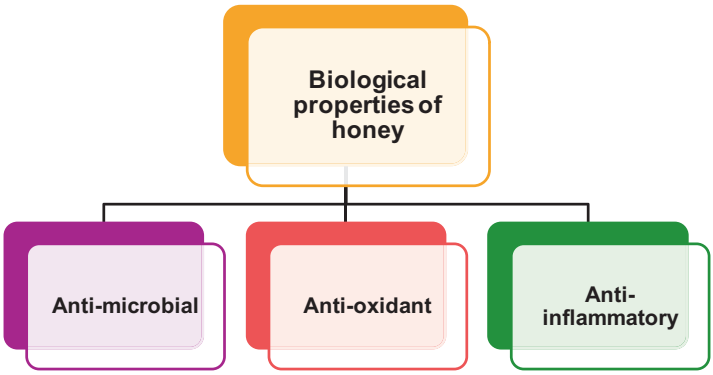

Fig. 2 Biological properties of honey

3.1 Antimicrobial Activity

Honey has been well recognized as antimicrobial agent that controls growth of numerous microorganisms (Rani et al. 2017). The antimicrobial activity of honey against a number of gram-positive and -negative bacteria, fungi, protozoa, and viruses such as *Helicobacter pyroli*, *Salmonella typhi*, *Staphylococcus aureus*, *Escherichia coli, Vibrio cholera*, *Aspergillus*, *Pencillium*, *Candida albicans*, *Giardia lambila*, rubella virus, herpes simplex virus, etc., has been reported (Eteraf-Oskouei and Najafi 2013; Mohammed et al. 2015; Rani et al. 2017; Khan et al. 2018). Shahzad and Cohrs (2012) documented antiviral activity of manuka and clover honey against Varicella Zoster Virus (VZV) under *in vitro* condition with EC50 = 4.5% (w/v). Similarly, antifungal activity of jujube honey investigated against *Candida albicans* and was found to inhibit the formation of fungal biofilm as well as disrupted the previously developed biofilm (Ansari et al. 2013). Honey acts as both bactericidal and bacteriostatic agent depending on concentration. The pasture and manuka honey demonstrated bacteriostatic property at 4–8% and 5–11% concentration, respectively, while at higher concentration, i.e., 5–10% and 8–15%, respectively, bactericidal effect was reported (Bansal et al. 2005). The antibacterial activity of honey has been attributed to its chemical composition and physical properties and possibly involves four mechanisms. (1) High osmolarity of honey due to high sugar content facilitates extraction of moisture from bacterial cell, thus causing dehydration; (2) acidic nature (low pH 3.2–4.5) of honey also responsible for inhibition of bacterial growth; (3) activity of enzyme glucose oxidase produces hydrogen peroxide that inhibits pathogen growth and is probably considered as the most important antibacterial mechanism; and (4) presence of phytochemical like methylglyoxal, defensin-1 (Kwakman et al. 2010; Eteraf-Oskouei and Najafi 2013; Bucekova and Majtan 2016; Rani et al. 2017). Long-term use of honey as antibacterial agents does not induce resistance in microorganisms (Emsen 2007). Even honey has been reported to be effective against microbes that are

resistant to chemical antibiotics, such as Methicillin-Resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant Enterococci (VRE), etc. (Eteraf-Oskouei and Najafi 2013; Rani et al. 2017).

3.2 Antioxidant Property

Reactive oxygen and nitrogen species formed under stress oxidizes important biomolecules, such as proteins, lipids, and nucleic acid, leading to oxidative damage. The occurrence of oxidative stress has been linked to several physiological problems, such as cancer, immunological disorders, heart-related diseases, diabetes, gastrointestinal diseases, liver and renal injuries, respiratory disorders, and neurological degeneration (Chua et al. 2013; Talebi et al. 2020). Bioactive compounds like flavonoids, phenols, and many more are known to possess antioxidant properties by virtue of which they scavenge free radicals and prevent oxidative stress (Hemmati et al. 2015). Honey is a natural source of several enzymatic and non-enzymatic antioxidants, namely, catalase, peroxidase, superoxide dismutase, glucose oxidase, ascorbic acid, phenolic compounds, tocopherols, and flavonoids (Waykar and Alqadhi 2016). Owing to antioxidant capacity, honey has several pharmacological implications and aids in preventing reactive oxygen species (ROS)-induced low-density lipoprotein (LDL) oxidation and hence prevents several chronic diseases and disorders such as cancer, cataract, Alzheimer's and Parkinson's diseases, and cardiovascular disorders (Bertoncelj et al. 2007; Waykar and Alqadhi 2016; Ibrahimi and Hajdari 2020). Antioxidants present in honey act as natural antidepressants during high emotional, physical, and intellectual stress (Waykar and Alqadhi 2016). In addition, honey also has the ability to lower the complications that arise due to diabetes such as atherosclerosis (Hemmati et al. 2015) by improving glucose and lipid metabolism that increases secretion of adiponectin content which in turn is considered to modulate oxidative stress leading to antidiabetic stress. In a study, honey has been found to reduce oxidative stress-mediated lipid peroxidation in diabetic model rats (Nakanishi et al. 2005; Katsuki et al. 2006). The excellent antioxidant property of polyphenols, especially phenolic compounds, is due to high mobility of hydrogen present in the skeleton of their chemical structure (Chua et al. 2013). Phenolic compounds have hydroxyl groups in their molecular structure which participate in the scavenging of free radicals (Chew et al. 2018). The number and position of these hydroxyl groups determine their scavenging potential (Chew et al. 2018). The free radical quenching potential of phenols has been reported to be affected by the presence of carboxyl group next to hydroxyl group that causes steric hindrance by reducing ease of hydrogen donation. For instance, the scavenging activity of caffeic acid is higher than its counterparts such as ferulic acid and coumaric acid (Chen and Ho 1997).

3.3 Anti-inflammatory Action

Inflammation is a defensive response of the body to negative or harmful stimuli such as pathogens, irritants, tissue damage, etc. (Hadagali and Chua 2014). If inflammation persists for longer times, as a consequence, it results in hay fever, arthritis, rheumatoid, and many more (Hadagali and Chua 2014). Honey possesses the ability to reduce inflammation and modulate immune cells of the skin immune system and is thus often used as an anti-inflammatory (Hadagali and Chua 2014) and immunomodulatory agent (Majtan 2014). Treatment of wounds with honey not only reduces inflammation and exudation but also diminishes scars and provides a soothing effect (Khan et al. 2018). Immunomodulatory activity of honey increases the production of cytokinin such as interleukin (IL-6) and tumor necrosis factor-α (TNF-α) by immune cells that escalate wound healing at early stage (Majtan 2014; McLoone et al. 2016) and stimulate tissue regrowth (Hadagali and Chua 2014; Khan et al. 2018). Several clinical evidences have confirmed the anti-inflammatory properties of honey. For instance, dressing of burns of biopsy samples with honey reduced the number of anti-inflammatory cells when compared to dressing done using silver sulfadiazine (Subrahmanyam 1998). Honey has been found to reduce activities of enzymes cyclooxygenase-1 and 2 which are involved in inflammation (Khan et al. 2018). Similarly, consumption of honey has been linked with reduction in concentration of prostaglandins (prostaglandin E2 and F2α) that cause itchiness, heat, and pain due to inflammation (Kassim et al. 2010) and thromboxane in plasma of normal persons (Al-Waili and Boni 2003).

4 Traditional Uses of Honey

Honey has been used by humans since ancient times for dietary and therapeutic purposes. Several historical evidence clearly advocate the art of honey collection, and their uses were well recognized by our ancestors. Archeological records proclaim that wild honey harvesting was carried out by people around 10,000 years back (Zafar et al. 2020). Some references indicate that beekeeping was practiced by Egyptians in 2400 BC (Zafar et al. 2020). A scene of two individuals collecting honey from beehives comes across in an 8000-year-old rock cave in Bicorp near Valencia in eastern Spain (Crane 1977). Similarly, a post-mesolithic rock painting in Rajat Pratap in central India representing collection of honey from *Apis dorsata* (Crane 1977) was uncovered. The first written reference on honey was a Sumerian tablet dating back to 2100–2000 BC narrating the uses of honey as an ointment and a drug (Crane 1975). During the ancient Vedic period, honey was considered one of the most amazing gifts of nature to humans, and in Ayurveda honey is mentioned as "Madhu" or "Kshaudra" (Arawwawala and Hewageegana 2018). Traditionally, honey was used for its taste and health benefits as well as to treat wounds and intestinal diseases by ancient Egyptians, Chinese, Romans, Assyrians, Indians, and Greeks (Ayaad et al. 2012; Waykar and Alqadhi 2016). As per Prophet Muhammad,

drinking honey was beneficial for health. In several ancient sacred books, honey has been referred to several times. In Egyptian text, the use of honey has been mentioned in 900 remedies (Eteraf-Oskouei and Najafi 2013). Similarly, a Sanskrit text Sushruta Samhita on Ayurveda medicine and surgery describes eight types of honey and its health benefits (Arawwawala and Hewageegana 2018). Honey is a Yogavahi substance, which means it carries other compounds effectively without changing its attributes; therefore, it was used in combination with other substances to enhance their properties as well as function (Arawwawala and Hewageegana 2018).

4.1 Therapeutic and Dietary Uses of Honey

According to Smith papyrus (an Egyptian text), dated from 2600 to 2200 BC, honey was used as wound ointment along with grease and lint. Use of honey as wound healer was preferred due to its antimicrobial activities. According to the Indian Ayurvedic literature, honey was used to aid in digestion and treating cough, urinary infections, diarrhea, wounds, nausea, and vomiting (Arawwawala and Hewageegana 2018). Honey was used to keep gums and teeth healthy (Eteraf-Oskouei and Najafi 2013). Honey shows hypnotic action and is used to treat insomnia during Vedic period (Eteraf-Oskouei and Najafi 2013). In addition to this, honey was applied on skin to treat skin disorders (Arawwawala and Hewageegana 2018). Honey was recommended for cardiac pain, palpitation, for curing all imbalances of lungs, and anemia (Eteraf-Oskouei and Najafi 2013). As per Ayurvedic text, young honey was used to gain weight, whereas old honey was effective in reducing weight (Arawwawala and Hewageegana 2018). In ancient Greek, honey was mixed with unfermented grape juice called Oenomel, which was sometimes used to treat gout and certain nervous disorders (Eteraf-Oskouei and Najafi 2013). In addition, honey was used to reduce pain in combination with vinegar as oxymel; to alleviate thirst, honey was used with water as hydromel; to treat acute fever, it is used along with water and certain medicinal compounds; and to cure problems like cough and sore throat, wounds, baldness, constipation, eye disease, prevention and treatment of scars (Eteraf-Oskouei and Najafi 2013). In the Islamic medicinal system, honey was considered a healthy drink, and its nutritional properties are described in Quran (Beegum et al. 2019).

4.2 Religious Use of Honey

In the Hindu religion, honey has been considered as one of the five elixirs of immortality (Panchamrita) and is offered by pouring over deities during a ritual known as "Madhu Abhisheka" (Beegum et al. 2019). In India and Bangladesh, Buddhists celebrate "Madhu Purnima" festival by offering honey to monks. Ancient Egyptians also used honey to offer deities as a sacrifice as well as for embalming the dead (Eteraf-Oskouei and Najafi 2013).

4.3 Honey as a Cosmetic and Eye Care Product

According to the archeological records of the predynastic age of Upper Egypt nomadic tribes of Tasian culture (around 4500 BC), honey was used along with malachite, fat, copper, and spar for making eye cosmetic. Sumerian (3000 BC) and Egyptian (1500 BC) archeological records state the use of honey in skin care (Beegum et al. 2019). According to Indian ayurveda, honey was considered to cure eye ailments and used by the people to improve their eyesight and prevent cataract (Eteraf-Oskouei and Najafi 2013; Arawwawala and Hewageegana 2018).

5 Modern Uses of Honey

Due to its rich nutritional and therapeutic properties, honey was always a significant part of traditional medicine and food. In the modern era also, the role of honey in food, skincare products, and medicines for treating health ailments like cancer, microbial infection, wounds, burns, etc. has been well recognized through laboratory and clinical studies (Cenet et al. 2017; Beegum et al. 2019). The list of commodities containing honey as an ingredient and their commercial marketed products is presented in Table 1.

5.1 Honey for Healing Wounds

Honey possesses antimicrobial, anti-inflammatory, and immune-modulatory activities and therefore is used for treating all types of wounds, burns, amputations, ulcers, and surgical incisions (Eteraf-Oskouei and Najafi 2013; Krishnakumar et al. 2020). The antimicrobial activity and high viscosity provide a barrier to prevent infection and moist environment around the wound, respectively, that facilitates healing (Waykar and Alqadhi 2016). Anti-inflammatory and immunomodulatory properties of honey alleviate inflammation, boost immune system responses which in turn promote tissue regeneration and accelerate wound healing activity (Eteraf-Oskouei and Najafi 2013; Waykar and Alqadhi 2016). The high osmolarity of honey due to high solute content causes osmotic outflow which facilitates the removal of dirt and debris from the wounds, and the presence of amino acids, vitamins, and minerals provide nutrition directly to regenerating tissues (Eteraf-Oskouei and Najafi 2013; Krishnakumar et al. 2020). Due to these properties, Russians used honey to treat wounds during World War I (Eteraf-Oskouei and Najafi 2013). Germans used honey along with cod liver oil to cure burns, boils, ulcers, and even fistulas (Bansal et al. 2005). Application of sterilized manuka honey dressing pad to non-responsive knee amputation severely infected with *Pseudomonas* and *Staphylococcus aureus* was found to heal completely within 10 weeks (Dunford

Table 1 Modern use of honey and commercial products available

Uses	Commodities	Commercial products
Medicines	Cough syrups	Dabur honitus cough syrup; Broxol honey cough syrup; Honicadd honey based cough syrup
	Ointment for wounds and burns	Derma science medihoney gel wound and burn dressing; Activon tube-medical grade manuka honey; L-Mesitran ointment
	Eye drops	Jiwadaya netraprabha plus ayurvedic herbal honey base eye drops
Oral health	Mouthwash	Melora manuka honey and oil mouthwash
Nutraceuticals	Health drinks and supplements	Rasna Native Haat HoneyVita (chocolate drink); Nourish vitals—Apple cidar vinegar with ginger, garlic, lemon, and honey
	Nutrition products	Nutriorg vedic chyawanprash
Food	Tea	Prince of peace—Instant ginger, honey crystals (instant tea); Tetley green tea–Lemon and honey
	Cookies	Hey grain honey oatmeal cookies; Polka honey almond cookies
	Yogurt	Basta goat milk yogurt–honey with banana; Waggy zone frozen yogurt–honey flavor; Again drinkable yogurt–Alphonso mango, honey
	Candies	PrakrutAgro pure honey amla candies; The honey shop–honey mango jelly; Worth 2 Deal–Honey amla
	Cereals	Nourish organics honey crunch muesli; Kellogg's cornflakes real almond and honey
	Baby food	Nestle cerelac with wheat, honey, dates
	Dry fruits	Nutri forest honey rose petals coated almonds; Zohran–Honey with figs; Food library the magic of nature-mixed nuts in honey
Cosmetics	Foot cream	dr.organic Manuka honey foot cream
	Lip balm	Forest essentials Luscious Kokum and Honey lip balm; Khadi Natural Kiwi Fruit Lip balm with beeswax and honey
	Scrubs	Oriflame Sweden Milk and Honey Gold sugar scrub
	Moisturize and day cream	Good vibes honey gel; VLCC almond honey body lotion
	Antiaging cream	Good vibes plus jojoba + Honey + moisturizing + nourishing night cream; Forest essentials India–Body mist honey and vanilla
	Eye creams	Wild Ferns Manuka honey eye cream; Antipodes Manuka honey skin brightening eye cream
	Body wash	Biotique bio-honey honey rejuvenating body wash; The body shop shower gel–Almond milk and honey
	Face wash and cleansers	Forest essentials women's face wash and cleansers; Khadi natural herbal sandalwood and honey face wash
	Soaps	The coco factory–Natural handmade coconut honey soap; TNW–The natural wash handmade oats and honey moisturizing soap
	Shampoo	Indus valley color protection shampoo; Forest essentials hair cleanser amla, honey, and mulethi

et al. 2000). Similarly, topical application of honey on cesarean and hysterectomies postoperative wound infection increased annihilation of bacterial infection and healing process and minimized consumption of antibiotics, formation, and recovery time (Al-Waili 2005).

5.2 Honey as Medicine

Honey due to its antimicrobial, anti-inflammatory, and anti-oxidant properties shows a number of therapeutic effects. Antimicrobial property helps to prevent microbial infections. Honey has been reported effective in treating gastrointestinal infections like duodenitis and gastric ulceration and skin infections like athletes' foot, dandruff, seborrheic dermatitis, and many more (Al-Waili 2001; Al-Waili 2005; Eteraf-Oskouei and Najafi 2013). Application of honey in the management of labial and genital herpes infection was found comparable to that of acyclovir creams with reduced signs and symptoms of recurring lesions (Al-Waili 2004). In an in vitro study, 20% solution of honey was found to inhibit the growth of bacteria *H. pyroli*, a pathogen responsible for causing gastritis (Ali et al. 1991). Honey has a considerably lower glycemic index than glucose and sucrose and produce lower serum level sugar (glucose and fructosamine) when compared to sucrose and dextrose (Erejuwa et al. 2012; Eteraf-Oskouei and Najafi 2013) and hence can act as an antidiabetic agent and used in place of artificial sugars in the diet of diabetic patients. Administration of honey has been reported to improve blood lipid profile (Al-Waili and Haq 2004; Erejuwa 2014), homocysteine, and C-reactive protein level in healthy as well as in hyperlipidemic individuals (Al-Waili 2004). In addition, honey has also been reported to promote serum level insulin production in diabetic rats (Al-Waili and Haq 2004; Erejuwa 2014). Honey also shows anticancer property by virtue of its ability to prevent cell proliferation, promote apoptosis, induce mitochondrial membrane depolarization, and modify cell cycle progression in the cancer cell (Pichichero et al. 2010; Aliyu et al. 2013; Yaacob et al. 2013; Erejuwa et al. 2014). Honey can cure respiratory ailments like sore throat, cough, asthma, and acute bronchitis by reducing microbial infection and inflammation (Nanda et al. 2017; Samarghandian et al. 2017). The World Health Organization (WHO) has also recognized honey as a potential demulcent treatment for cough and other upper respiratory tract infections (Raeessi et al. 2013). Honey possesses the potential to reduce risk of cardiovascular diseases owing to its flavonoid content. Flavonoids enhance the coronary vasodilatation, reduce the ability of blood platelets to clot, and prevent oxidation of LDL and thus alleviate the risk of cardiovascular diseases (Afroz et al. 2016).

5.3 Honey and Oral Health Care

In oral health care, honey is used to reduce plaque, dental caries, gingivitis, oral malodor, radiation-induced oral mucositis and xerostomia, and periodontal disease (Atwa et al. 2014; Beegum et al. 2019; Ramsay et al. 2019). The antimicrobial property of honey reduces microbial growth as well as abridges biofilm formation. Dental plaque caused by bacteria with the ability to form biofilm and produce acids demineralizes and deteriorates tooth structure and causes dental caries (Ramsay et al. 2019). Application of manuka honey has been reported to prevent plaque formation by inhibiting biofilm growth and reducing production of acid (Nayak et al. 2010). Oral problem gingivitis occurs due to inflammation of gingival tissues. The manuka honey-based mouthwash has been found to be nearly as effective as chlorhexidine in reducing gingival scores (Singhal et al. 2018). Atwa et al. (2014) investigated the effect of chewing honey on plaque formation and bacterial count. The result showed reduction in bacterial count, highlighting effective role of honey in the prevention of dental caries and gingivitis.

5.4 Honey and Ophthalmology

The role of honey in treating ophthalmological conditions is known since ancient times. Through clinical studies, it has been confirmed that topical application of honey is effective in curing non-responsive eye ailments like blepharitis, conjunctivitis, and keratitis (Emarah 1982). In the study, honey was applied as an ointment to the lower eyelid of 102 patients. It improved condition of 85% of the total patients while in the remaining 15% no deterioration or disease progression was documented (Emarah 1982). Honey has also been found to treat burns caused by chemical and thermal agents as well as corneal injuries and conjunctivitis due to antimicrobial and anti-inflammatory effects (Ajibola et al. 2012).

5.5 Honey in Food Industry as Preservative and Prebiotic

Several antioxidants and antimicrobial compounds present in honey prevent oxidation of food during storage and inhibit the growth of various bacteria and thus avoid food spoilage and hence is used as food preservative such as meat, juices, etc. (Bogdanov 2012). In contrast, honey also shows prebiotic effect and maintains the balance of intestinal microflora by supporting the growth of beneficial bacteria, such as bifidobacterium and suppressing other deleterious bacteria (Sanz et al. 2005). The prebiotic capacity of honey is associated with its oligosaccharide content. In a study, honey has been reported to support the growth of intestinal bacteria *Lactobacillus acidophilus* and *L. plantarum* in rats (Shamala et al. 2000). Unifloral

honey originated from Clover, Sage, Sour-wood, and alfalfa have been reported to possess strong prebiotic property (Kajiwara et al. 2002). Honey due to its flavor, texture, and moisture content is used in food industry in products such as cake, cereals, cookies, and many more (Bogdanov 2012).

5.6 Honey in Nutraceuticals

Honey is a rich source of carbohydrates along with proteins, minerals, antioxidants, and vitamins (Ajibola et al. 2012). The carbohydrate content of honey provides more energy than artificial sugars due to high proportion of fructose than glucose and other sugars (Ajibola et al. 2012). Therefore, athletes consume honey before, during, and after resistance and stamina-building exercises as an energy source (Bansal et al. 2005). A small fraction of honey constitutes antioxidants that participate in free radicals scavenging. Intake of honey improves antioxidant status of a body and fortifies against oxidative stress (Ajibola et al. 2012). Honey contains enzymes and micronutrients that facilitate easy digestion and absorption of important dietary nutrients required for proper metabolism and functioning of a body (Ajibola et al. 2012). Due to several nutritional benefits, honey is preferred over artificial sugars as a sweetener (Ajibola et al. 2012). In addition, consumption of honey provides calcium, which is easily absorbed by the body and prevents bone-related disorders like osteoporosis or low bone mass in elderly people (Ajibola et al. 2012). Honey not only provides benefits to adult human beings but is considered a boon for children. Feeding honey to infants has been reported to improve their memory and growth, blood profile, nourishes skin, results in steady weight gain, boosts the digestive system, alleviates anxiety, reduces susceptibility to diseases, and enhances their overall performance in later life (Ajibola et al. 2012).

5.7 Honey and Cosmetics

Honey is used in various cosmetic and skincare products, such as face wash, moisturizer, shampoo, anti-wrinkle cream, soaps, anti-acne products, etc. (Pavlackova et al. 2020). Honey is hygroscopic in nature and shows keratolytic property and thus nourishes skin, keeps it moisturized, and prevents wrinkles (Bogdanov 2012; Pavlackova et al. 2020). Honey is used in shampoos, soaps, and other shower products due to its cleansing property (Burlando and Cornara 2013). Exfoliating property of honey is attributed by fruit acids and thus used for removing dead skin (Kurek-Gorecka et al. 2020). The flavonoid content of honey prevents skin irritation and hence it is used in sunscreens (Kurek-Gorecka et al. 2020). The antimicrobial property of honey reduces microbial infection and cures acne (Bogdanov 2012). Honey also strengthens the upper protective skin layer by maintaining mild acidic pH (Bogdanov 2012; Burlando and Cornara 2013). Honey is used in place of

traditional emulsifiers in shampoos and body lotions (Pavlackova et al. 2020). Hydroxypropyltrimonium honey is used in shampoos and conditioners (Kurek-Gorecka et al. 2020). It nourishes hair and scalp and penetrates deep into the hair shafts and reestablishes its flexibility and elasticity (Burlando and Cornara 2013).

6 Conclusion

Honey is a wonderful organic compound that has been used for centuries for nutrition and curative purposes. Recent scientific studies have rediscovered the medicinal role of honey in curing multiple diseases and disorders, especially for treating wounds. Despite multiple beneficial attributes, the potential of honey is poorly utilized. The underutilized potential of honey is due to the lack of exact information regarding the biological role of every constituent of honey. Research has also demonstrated that different types of honey show variation in their physicochemical characteristics that affect their biological properties. Therefore, to maximize the unabridged potential of honey, it is important to ascertain the role of every component and standardize them through more scientific studies.

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