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Honey: an important nutrient and adjuvant for maintenance of health and management of diseases

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Abstract

Honey got its significance, both as medical and non-medical purposes. Honey is a complex matrix of several carbohydrates, amino acids, minerals and many more. Honey's carbohydrate components include a variety of mono- and disaccharide forms such as fructose, glucose, sucrose and other reducing sugars. Proline, lysine, phenylalanine, β -alanine, arginine, serine, glutamic acid and aspartic acid are the main amino acids that are present in honey. Immense nutritional benefits make honey a high demanding item in food and in medical. It is a multivitamin tonic enriched with the antimicrobial, antioxidant, cough preventing, hepato-protective, wound healing and immune modulating properties. Being a high demand item, most of the honeys available in market are adulterated by several means. Eventually, human practices developed a number of ways for detection of adulteration in honey. Even modern instrumentation like NMR is becoming a powerful and reliable tool in detection of high-rising adulteration. The present article aims to highlight a thorough of review of medicinal applications of honey with special emphasis on the traditional practices along with an overview of the history, composition, physical and nutritional properties and testing of adulteration.

Keywords Adulteration, Ayurveda, Honey bees, Medicinal values, Nutritive values

Introduction

Honey is one of the most valuable gifts of nature to mankind. It is the purest of all foods when it is properly ripened. Smt. Sarojini Naidu once said about that it is 'the food of Gods'. The word honey has been derived from the Arabic word '*han*' meaning 'product' [1]. Honey was the only available source of sweetening agent to the ancient. Man started collecting honey from combs by driving away bees forcibly for his own use since time immemorial. Honey has also been used for centuries as a treatment in traditional systems largely for external

and internal use. However, modern medical practitioners use honey as a flavouring agent in cough mixtures, gargles, confections and in preparations of oxymels and linctuses [2]. It is used for domestic, industrial and sacred purposes. Honey plays an important part in many of the ceremonial customs of the Hindus. It is regarded as one of the most sacred things and that is used as one of the constituents in making *Madhupanchaka* (combination of five sweet items). Honey is used in purification ceremony, and little honey is placed in the mouth of a newly born. For medicinal purposes, one can use any kind of honey provided it is pure and of proper time. There is restriction in the use of honey which has been collected in the month of June and mainly in rainy season. Honey forms the basis of several very popular preparations and has been an important vehicle for other medicines in the *Hindu Materia Medica*. Honey being an important agent

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in social and medical domain throughout the globe, every major language across the world has mentioned it with different names [3], e.g. Injubin/Asal-ul-khal (Arabic), Madhu/Shahad (Hindi/Sanskrit), Piya-ye (Burmese), Honey (English), Meli (Greek), Mhou (Kannada), Mhach (Kashmiri), Mel (Latin), Ayurmadar (Malay), Ten (Malayalam), Angabina (Persian), Miere (Roman), Mipanny (Sinhalese), Ten (Tamil), Tene (Telugu), etc.

Honey has been utilized extensively as a common food, flavouring agent and medicine throughout human history due to its unique physicochemical features and abundance of bio-active components. Therefore, the aim of this article is to provide a comprehensive overview of the history, origin, composition, physical characteristics, nutritional properties, testing of adulteration, general and medicinal applications of honey.

Origin, distribution of honey bees and formation of honey

There is as such no agreed upon remark which can clearly mention the origin of honey. The history of use of honey dates back to some 2000 BC [4]. Greek mythology, Indian mythology and other major civilizations have cautiously mentioned the uses and significances of honey. The use of honey both in medical and non-medical purposes have described around the world either by pictorial depiction or by writing books and traditional text and inscriptions [5].

Bees are flying insects closely related to wasps and ants, play major role in pollination and for producing honey and bee wax. As classified in Anthophila, there are nearly 20,000 known species of bees in seven to nine recognized families. They are found on every continent except one, i.e. Antarctica [5]. Generally, four types of bees are found to produce honey, they are, *Apis dorsata* L. or Rock bee, *Apis indica* Fabr. or Indian hive bee, *Apis florea* Fabr. or little bee and *Melipona* or *Trigona* species or Dammar bees [6, 7]. The true honey bees (genus *Apis*) have the most complex social behaviour among the bees. *Apis mellifera* L., the European or Western honey bee, is the best-known bee species [8]. *Apis mellifica* L., the hive or honey bee of Apidae family and Hymenoptera class, is found in most parts of the globe [6]. Bees are adapted for feeding on nectar and pollen, the former primarily as an energy source and the later primarily for protein and other nutrients [9].

The bees prepare two major products, i.e. Mel or honey, a saccharine secretion deposited by the insect in the honey comb and Cera or wax [10, 11]. Honey bees actually collect three other substances, viz. pollen, water and propolis (bee glue) [12]. One kilogram of honey is produced by around 120,000 bees [13]. It is learnt that collected nectar by bees is pumped into the mouths of

the young bees which stay at home in the hives. They also add enzymes from their own system and convert the sugars in nectar to levulose and dextrose and seal the cells of the hives with a waxy material. Due to enzymatic action on sugars green nectar in the sealed cells gets transformed magically into ripe honey after some weeks and is ready for extraction [14].

History on medicinal uses of honey

The ancient Egyptians and Greeks used honey to embalm their dead persons and also to preserve meat [15]. Stalwart's physicians/philosophers like Pythagoras, Democritus, Hippocrates, Aristotle, Galen, Ibn sina (Avicenna), from early mediaeval periods advocated the use of honey for well-being and remedy of diseases. Hippocrates, a well-known Greek physician, who lived for 107 years, had opined, honey as nourishing and health giving agent [2]. Long ago Mr. Pollius Romillius, a Roman senator on his 100th birth day celebration said that he owed his bodily and mental health to honey and added that he practiced 'Honey within and oil without' in his daily routine. Saint Ambrose (337–397 AD), well known as Aurelius Ambrosius, was an archbishop of Milan and was one of the four doctors of the Church said that the fruit of bees is desired by all, and is equally sweet to kings and beggars, and it is not only pleasing but profitable and healthful; it sweetens their mouths, cures their wounds and conveys remedies to inward ulcers [16, 17]. A number of historical figures have shared their insightful opinions and explained the functions and importance of honey. Honey has the ability to heal wounds, according to the Papyri of Egypt (1550–1553), and Galen identified it as an antidote for numerous poisons. Honey is a gift from nature, according to Greek philosopher and atomic theory creator Democritus (c. 600 BC). Hippocrates, (460–370 BC) used honey to cure various diseases and advocated to use honey along with food because it can enhance the food value; and can improve the complexion of face on application. According to the Aristotle, (384–322 BC), Greek philosopher and the father of natural sciences, honey enhances human health and prolongs life span. Dioscorides, (40–90 AD), Greek physician scientist, expressed through paintings that honey is very effective for the treatment of intestinal diseases and infection of injuries. Publius Ovidius Naso known as Ovid, (43 BC–17/18 AD), famous Roman poet advocated that everyone should always drink honey and milk to stay fit and healthy. Ibn Sina or Avicenna, (980–1037 AD), the Arab Muslim scientist of mediaeval times described beneficial properties of honey and wax in Al-Qanoon and said 'Honey can help healing when we are attacked by cold; can make us feel happier, feel healthier, digestion, treat colds and make food taste more delicious. Honey is a liquid to keep your body to stay looking young

and fresh, improve memory and increase intelligence'. He recommended that people aged 45 years and above must take honey regularly with the hard fleshy fruits that contain lots of oil. Abdul Latif, (1161–1263), an Arabic physician and traveller once found a vessel containing the dead body of a new born embalmed with honey at Gezeh. The people of Rome and Greece during ancient times used honey to preserve meat [18]. Both the more advanced cultures of Mediterranean Africa and the more backward cultures in the southern portions of the continent have a long history of using beeswax for honey production. In Ghana and Nigeria, honey is used to heal earaches, infected leg ulcers [19] and to treat constipation and stomach ulcers [20]. For centuries, honey has been used in traditional medicine [21]. Honey has long been known to be beneficial for treating digestive, cardiovascular and liver issues [22]. Numerous pathogens, such as *Shigella*, *Escherichia coli*, *Helicobacter pylori*, *Shigella* and *Salmonella*, are susceptible to the bactericidal activity of natural honey [23–25]. Over the past few decades, different materials such as collagen, gelatine, starch, cellulose, alginate or agarose have been impregnated into honey to create a variety of medical formulations that offer targeted therapeutic applications. A variety of honey-based products, including gels, dressings, ointments, pastes, syrups, eye drops, pastilles and lozenges, have been approved by the US Food and Drug Administration (FDA) [26].

References from non-medical literature

Buddhist literature

During Lord Buddha's period, honey seems to have been in use. *Ghrita* (clarified butter), butter, honey and sugar are the four sweets known. *Madhupiñcika* (honey-ball) were referred in the context of offerings to Lord by the merchants of *Tapussa* and *Bhallika* [27]. *Madhugolaka* (honey balls) and *Puuva* (sweet cakes) were the two main preparations made with honey referred in the literature [27]. Honey was considered as a beverage, and amongst all the eight beverages honey was allowed by Lord Buddha for his followers as a drink. *Buddhaghosha*, a great exponent of Buddhist canons while defining *Bhesaja* (medicine) cited honey as one of the examples along with oil and *Ghrita*, and they are for the cure of sick [28]. Honey was also referred as a cure for disease *Udaravatabadha* (flatulence or tympanitis), and it subsides the colic pain if mixture of *Ghrita*, honey, sugar, etc. and rice gruel with pure milk was given [28].

According to Buddhist literature, there are five kinds of *Bheshajani* (medicines), viz. *Ghrita* fresh butter, oil, honey and molasses, which are allowed for monks if they fall ill. These medicines could be stored and used only for seven days, and its use beyond seven days was treated as an offence during the Buddhist period [17].

Hindu texts

Reference of *Madhu* is found in *Rigveda*, and other Hindu texts also have given a great importance to honey. *Madhu* (honey) is referred by Manu, the author of *Manusmriti*, one of the important texts amongst the Hindu literature, ascribed ritual importance to it and showered great importance of honey [29, 30]. Honouring a famous and learned person with *Madhuparka* (honey mixture) was referred as a norm [31]. The King and *Srotriya* (officiating priest) should also be welcomed and honoured with honey mixture if they arrive at a place of performance of a sacrifice, where a guest is offered honey mixture on his arrival at a place of sacrifice and at a rite performing place in honour of the manes etc [32, 33].

Holy Bible

There are references of honey found in *Holy Bible* and accepted term for honey is *D' vosch*. *Rashi* said' the term signifies not only the honey of bees, but all forms of sweetness, including the sweet juices of fruits and the sap of trees. There is a reference in the *Holy Bible* that Jacob once sent honey in the combs also along with other things to Joseph, who was in Egypt [34].

Islamic literature

In Islam, an entire chapter (*Surah*) in the *Qur'an* is called *an-Nahl* (the Bees). According to his teachings (*hadith*), Muhammad strongly recommended honey for healing purposes. The *Qur'an* promotes honey as a nutritious and healthy food [35].

Presence and mentions in middle East Asia

It was evident that Palestine and Arabia were abounding in honey. Honey bee and its industrious life were well known to the ancient Israelites. At one reference, bees are compared to an enemy's army. According to *Rashi*, the Amorites defeated themselves by attacking the Hebrews, suffering 'just as the bee, after stinging a person, dies'.

Bee keeping was also engaged by early people. There was a reference about 'Building of a city called Honey town, Diboin, by the Sons of God' which may have been a centre for apiculture [36]. It was also referred that honey was used in cooking honeyed dough for making dainty pastries (just like almond paste). But interestingly, honey was excluded from sacrifices on account of its fermenting properties or may be due its origin from a *traypho* or forbidden insect (bee). During the period, honey was made from figs and dates. According to *Josephus*, honey formed one of the ingredients of the embalming process of ancient Egypt.

References from medical literature with special reference to Ayurveda

Honey (*madhu*) has major role in maintenance of health and management of diseases as per Ayurveda, the science of life which is catering the needs of mankind since time immemorial. Synonyms of *Madhu* (honey) referred by *Bhavamishra* (author of *Bhavaprakasha*) are, viz. *Maksika*, *Madhveeka*, *Kshaudra*, *Saragha*, *Makshikavanta*, *Varativanta*, *Bhngavanta* and *Pusparasodbhava* [37].

Honey is used as an *anupana* (vehicle), and it is considered as best *anupana dravya* for several Ayurvedic drugs both single and compound formulations with preventive and curative properties [38]. *Ayurveda* has two main objectives (i.) maintenance of health of a healthy person and (ii.) to provide cure to the diseased person. It advises honey in several instances while discussing preventive aspects and maintenance of health. During the *Hemanta* (winter) one should drink *Madhu* after having the meat. During *Ādana* (summer) period, one should use food and drinks often mixed with *Ksaudra* (a class of honey). While using any drink either wine or other fermented liquor, it should be mixed with *Ksaudra* [37]. *Ayurveda* has praised the effect of *Madhu* in pacifying *Kapha dosha*. It is because of its properties like *Ruksha* (roughness), *Tikshna* (sharpness) and *Kashaya* (astringent) taste and opposite qualities of *Kapha* such as *Snigdha* (unctuous), *Manda* (dull) and *Madhura* (sweet) [37].

Ayurveda in its classical texts elaborately described *Madhu*, and its properties such as sweet as the principal taste; astringent as *Anurasa* (associated taste), it is rough, cold; promotes appetite, complexion and voice; reduces fat, beneficial to *Hrudaya* (heart), aphrodisiac, union promoting, cleansing, healing, wholesome for eyes, pleasing, permeates through minute channels; alleviates *doshas* *Pitta* (biliary disease), *Kapha* (phlegm), *Sthaulya* (obesity), *Prameha* (diabetes), *Hicca* (hiccup), *Svasa* (respiratory distress), *Kasa* (cough), *Atisara* (diarrhoea), *Vamana* (vomitting), *Pipasa* (polydipsia), *Krimi* (worm infestation) and *Visa* (poisoning). It exhilarates and pacifies *Tri-dosa*. It pacifies *Kapha* due to lightness; *Vata* and *Pitta doshas* due to *Snigdha*, *Madhura* and *Kasaya gunas*. On the contrary, old *Madhu* possess properties of roughness, lightness, etc. acts as appetizer [39]. Local application of *Madhu* and *Ghruta* on accidental wounds to control heat produced in the abrasion and also to promote reunion is advocated by *Sushruta* [39]. *Madhu* if administrated along with several formulations can alleviate many diseases because it is an excellent *Yogavahi* (synergist). It should be used in conditions free from heat. Its constituents, taste, properties, *Virya* and *Vipaka*, etc. vary due to its origin from different flowers.

There is mention of a condition known as *Madhvama* (Ama or indigestion caused by *madhu*) in *Charaka*

samhita occurs due to its irrational or conflicting usage for treatment which can lead to death immediately like a poison [30]. Honey is fatal like a poison if applied topically to a person suffering from heat; if combined with hot drugs, or used in hot season because of its delicate nature, coldness, origin from juices of various plants and also shows toxic effects even if used with rain water. But when combined with hot substances for use as emetic *Madhu* does not show any adversity. There will not be any indigestion like that of '*madhvama*' which can kill a person like poison does [39].

Classifications of Madhu

Ancient physicians of Indian subcontinent have classified *Madhu* based on the insects that collect or originate *Madhu*. They also have briefly described the properties associated with it and somewhere they suggested limitations of its uses [11, 38–40].

Classification of Madhu as per Charaka

As per *Acharya Charaka*, *Madhu* is of four types based on originating insects, viz. i. *Makshika* (derived from *Manksika*) which has oil like colour, ii. *Bhramara* (derived from *Bhramara*) appears white, iii. *Kshaudra* (derived from *Ksaudra*) is brownish in colour and iv. *Pauttika* (derived from *Puttika*) whose colour looks like ghee. *Charaka* advocated *Makshika* as best one and *Bhramara* is the heaviest one [37].

Bhavamisra on classification of Madhu

According to *Bhavamishra*, there are eight varieties of *Madhu*, viz. *Maksika*, *Bhramara*, *Ksaudra*, *Pauttika*, *Chatra*, *Aarghya*, *Auddalaka*, *Dala* in the same lines as *Sushruta* has done [38]. *Bhramara*, *Pauspika*, *Ksaudra*, *Maksika* are good in order of succession and last two are used most [40].

Classification of Madhu as per Sushruta

Sushruta has described eight types of *Madhu* classified on the basis of hosting trees or by the bees from which honey originate [39]. Classifications of *Madhu* by Ayurvedic stalwarts are summarized in Table 1.

Pauttika is brown in colour and generally found on big trees. It is rough and hot in properties and aggravates *Vata* and *Raktapitta*, breaks *Medas* (fat) & *Kapha*. It causes burning and intoxication. This *Pauttika* type of honey is collected by a small black bee resembling a gnat, called *Puttika*.

Bhramara obtained from *Bhramara* type of bees which are large and black. It is heavy due to *Snigdha* and *Madhura*. It is clear like a crystal and useful in *Kasa*, *Raktapitta*, etc.

Table 1 Types of Madhu referred in different texts

Text	Maksika	Bhramara	Ksaudra	Pauttika	Chhatra	Ārghya	Auddalaka	Dala
Charaka samhita	+	+	+	+	-	-	-	-
Bhava prakasha	+	+	+	+	+	+	+	+
Susruta samhita	+	+	+	+	+	+	+	+
Astangha sangraha	+	+	+	+	-	-	-	-

- = not mentioned, + = mentioned.

Ksaudra is from the brown and big bees. It is cold, light and decreases *Medas*. It is collected from small bee of tawny colour called *Ksudra*. It possesses all the properties of *Maksika madhu*.

Maksika Obtained from *Maksika* type bees. It is lighter than *Ksaudra* and rough in nature. It has best qualities and is used in diseases like *Svasa*.

Chatra obtained from umbrella-shaped beehives formed by yellow–brown bees in the forest of the Himalayas and *Malava*. It has excellent qualities. It is *Madhura vipaka*, heavy, cold, slimy and alleviates intrinsic *Raktapitta*, *Svitra*, *Prameha* and *Krimi*. It is formed by tawny or yellow wasps which makes their hives in the shape of umbrellas. Useful in *Visa*, *Bhrama*, hysteria, etc.

Arghya- This is formed on *Madhuuka* trees and is called 'Svetaka' (white honey) by inhabitants of *Malwa*. Some consider that this type is obtained from bees known as *Arghya*, the yellow ones with pointed mouth. This variety of Madhu does not contradict with heated items. Extremely wholesome for eyes, pacifies *Kapha*, *Pitta*, astringent, pungent *Vipaka*, strength promoting and bitter and slightly increases *Vata*. It is a wild honey collected by a sort of yellow bee like the *Bhramara* and useful in eye diseases, piles, cholera, cough, phthisis, jaundice and ulcers.

Auddalaka- *Uddalaka* is brownish small insect which store honey within ant hills. It is relishing, promotes voice and alleviates *Kustha* and *Visha* (poison). It is bitter and acrid substance found in the nests of white ants.

Dala- Is collected from leaves but some consider *Dala* are small bees usually found in cavities of trees and hence the name *Dala*. It is astringent, sour and hot, increases *Pitta*, *Katu vipaka*, rough and useful in *Vamana* (vomiting) and *Prameha*. It is un-prepared honey found on flowers. It is 'product of digestive fire, generative of bile and beneficial in phlegm, gonorrhoea and vomiting'. Among all these varieties the first four only are described by writers and the first alone is used in medicine. The types of honey found in India have been described in various important classical texts such as Charaka samhita (CS) [37], Bhava Prakasha (BP) [38], Susruta samhita (SS) [39], Astangha sangraha (AS) [40] as mentioned in Table 1.

Properties of Madhu

Ayurveda has mentioned honey as a nectar for all good things and described all possible properties and uses. This system of medicine elaborately mentioned the *rasa*, *guna*, *veerya* and *vipaka* [37–40].

Rasa (taste)- *Madhu* is having *Madhura* (sweet) and *Kashaya* (astringent) taste.

Guna (property)- *Laghu* (lightness), *Raksa* (roughness) *Sakshma* (minute) and *Yogavahi* (synergizer); *Snigdha* (unctuous), *Manda* (dull) [37].

Veerya (potency)- *Shita* (cold). It has cooling effect. It is light to digest, palatable, drying, absorbent, depletory of body fats, beneficial to vision, appetizer. Honey promotes voice, clears and heals ulcers, makes skin delicate and good texture enters minute channels also. It is sweet in taste, which is followed by astringent, pleasant, gives feeling of comfort. Honey enhances complexion, intelligence, aphrodisiac. Useful in skin diseases, piles, cough, pacifies aggravated *pitta*, *rakta* and *kapha prameha*. It is best adjuvant and causes slight vitiation of *vata* [37, 38].

Karma (Action)- Causes mild vitiation to *Vata*; pacifies *Pitta* and *Kapha*; *Tridosha Shamaka* (pacifies all the three Doshas (*Sushruta*). Promotes appetite, complexion and voice; light, soft, reduce fat, beneficial to *Hrudaya* (heart), aphrodisiac, union promoting, cleansing, healing, wholesome for eyes, pleasing, permeates through minute channels; alleviates *Pitta*, *Kapha* [39]. Effects of *Madhu* are aggravation of *Vata*, heavy, cold, alleviates disorders of *rakta*, *pitta* and *kapha*; acts as *sandhana dravya* (unites or union promoter). If it is heated or taken by a person suffering from heat becomes fatal due to its combination with poisons. Honey is useful in small quantity due to its properties like heavy, rough, astringent and cold [37, 38].

Freshly collected *Madhu* promotes *dhatu*; decreases *kapha* to some extent; old one decreases *medas* and *sthauilya*; acts as *grahi* and causes emaciation. Matured or well-formed *madhu* can pacify all the three *doshas* while immature one is sour and vitiates *dosha* [39]. At one context *Ayurveda* has mentioned that normal human semen smells sweet like *madhu* (honey) and also resembles it [39]. The concept of after drink was considered in *Ayurveda*. After drinks referred are of two types i. alcoholic

and ii. Non-alcoholics including water. For the *sthaulya* (obese) persons who are on the reduced diet after drink of *Madhu* and water are considered the best. As per *Susruta*, the new born is given a mixture of butter and honey for the first three or four days, *i.e.* before starting the breast feeding [41]. Honey is the only substance which relieves habitual constipation if used daily for considerable period [42].

References from medical literature with special reference to Unani

In Unani system of medicine, honey is known as *Asl* and *Al-Quran* where honey is called as 'rivers of purified *Asl* (in heaven)' in which they will have essence of all kinds of fruits'. Holy Prophet used honey repeatedly in a person suffering with diarrhoea. It is suggested that if a person is suffering from an allergy of a particular plant, he may be given honey collected from that plant so that he will develop resistance to that particular allergy. Honey is considered hot and dry in its properties. It is included as an ingredient in some of the important formulations like *Majun*, *Jawarish*, etc [43].

Physical and chemical properties of honey

Honey is a yellowish sometime golden yellowish viscous liquid. The physical properties of honey vary, depending on water content, the type of flora used to produce it, temperature and the proportion of the specific sugars it contains. Fresh honey is a super saturated liquid, containing more sugar than the water can typically dissolve at ambient temperatures. In general, honey has density in the range between 1.36 and 1.45 g/mL, it means it is denser than water. Honey contains many kinds of organic and amino acids. However, the different types and their amounts vary considerably, depending on the type of honey. These acids may be aromatic or aliphatic (non-aromatic). The aliphatic acids contribute greatly to the flavour of honey by interacting with the flavours of other ingredients. The pH of honey is generally between 3.2 and 4.5. This relatively acidic pH prevents growth of many bacteria [44]. Organic acids comprise most of the acids in honey, accounting for 0.17–1.17% of the mixture, with gluconic acid formed by the actions of glucose oxidase as the most prevalent. Minor amounts of other organic acids are present, consisting of formic, acetic, butyric, citric, lactic, malic, pyroglutamic, propionic, valeric, capronic, palmitic and succinic acids, among many others [45]. Moisture content in honey is an important factor towards its quality. Moisture content in honey can be lowered by passing warm air over the combs, mostly by placing them in special warm rooms, where the humidity of the rooms should be kept low with a dehumidifier. Typical odour of orange honey is because of the presence

of methyl anthranilate (also known as MA, methyl 2-aminobenzoate or carbomethoxyaniline, is an ester of anthranilic acid; its chemical formula is $C_8H_9NO_2$) [46].

Crystallization of honey is an important physical property [47]. The melting point of crystallized honey is between 40 and 50 °C (104 and 122°F), depending on its composition. The rate of crystallization is affected by many factors, but the primary factor is the ratio of the main sugars: fructose to glucose. Crystallization is also affected by water content, because a high percentage of water inhibits crystallization, as does a high dextrin content. Temperature also affects the rate of crystallization, with the fastest growth occurring between 13 and 17 °C (55 and 63°F) [48]. Honey is viscous liquid, and its viscosity is affected greatly by both temperature and water content. The higher the water percentage, the more easily honey flows. Beside these two factors temperature and water content, the composition has also some contribution in altering viscosity [49]. For example, at 25 °C (77°F), honey with 14% water content generally has a viscosity around 400 poise, while a honey containing 20% water has a viscosity around 20 poise. The effect honey has on light is useful for determining the type and quality. Variations in its water content alter its refractive index. Water content can easily be measured with a refractometer. Typically, the refractive index for honey ranges from 1.504 at 13% water content to 1.474 at 25%. Individual honey from different plant sources contains over 100 volatile organic compounds (VOCs), which play a primary role in determining honey flavours and aromas. VOCs are carbon-based compounds that readily vaporize into the air, providing aroma, including the scents of flowers, essential oils or ripening fruit. The typical chemical families of VOCs found in honey include hydrocarbons, aldehydes, alcohols, ketones, esters, acids, benzenes, furans, pyrans, norisoprenoids and terpenes, among many others and their derivatives [50].

Nutritive values of honey

Honey by its name considered as nectar which is truly depicted by its nutritive values. It contains several nutrition factors including minerals, vitamins, carbohydrates, fats, proteins, etc [51]. As per the National Nutrient Database for Standard Reference Release 28 published by the National Agricultural Library, United States Department of Agriculture (USDA), nutritional values per 100 g honey are as follows: Energy (1,272 kJ/304 kcal), carbohydrates (82.4 g), sugars (82.12 g), fructose (38.2%), glucose (31.3%), maltose (7.1%), sucrose (1.3%), higher sugars (1.5%), dietary fibre (0.2 g), fat (0 g), protein (0.3 g), amino acids (0.05–0.1%), water (17.10 g), riboflavin (0.038 mg), niacin or vitamin B3 (0.121 mg), pantothenic acid or vitamin B5 (0.068 mg), pyridoxine or vitamin B6 (0.024 mg),

folate or vitamin B9 (2 µg), ascorbic acid or vitamin C (0.5 mg), calcium (6 mg), iron (0.42 mg), magnesium (2 mg), phosphorus (4 mg), potassium (52 mg), sodium (4 mg) and zinc (0.22 mg). The other components that are thought to be highly significant in the bioactivity profiles of different honeys include phenolics, organic acids, carotenoids, flavonoids (flavonols, flavones, flavanols, flavanones, anthocyanidin, chalcones and isoflavones) and a variety of enzymes, including invertase, amylase, catalase and glucose oxidase [52].

Pharmacological actions

Several studies have been carried to know about the biological activities of honey [53–56]. It was found as gentle laxative, sedative. On proper administration, it gives soothing effect to stomach. It can relieve aphthous ulcers if used along with water for gargling. It relieves cough and pain in the condition of arthritis [2]. Its antibacterial property has been studied by many investigators [57]. Even in dental care, honey along with charcoal makes very good tooth paste and gives freshness to mouth and whiteness to teeth [58]. Honey has the ability to regulate some cardiovascular risk factors which include blood glucose, cholesterol, CRP (C-reactive proteins) and body weight [59].

The mixture of honey and cinnamon is known for hundreds of years for their excellent curing power without any side effects. Honey is also an excellent medium for transmitting the benefits of herbs such as ginger to the body. Ginger honey candies are also very popular in clearing the congested throat and controlling the motion sickness. This combination can cure respiratory problems and indigestion; both of them are having antioxidant activity and can improve immunity [60]. Wound healing property of honey was studied by Gozenbach and Hoffmann (1936) on guinea pigs by inducing skin lesion which was healed very fast. This wound healing property of honey is due to the organic acid present in it [61].

Glycaemic index (GI) describes the rate and extent to which 50 g of a carbohydrate-rich food will raise blood glucose levels [62]. Food with higher glycaemic index leads rise in blood sugar levels. Honey has an average glycaemic index of 55 and sugar has glycaemic index of 68. Hence, honey can be considered as a good substitute of table sugar [61].

Honey as home remedy

Honey induces sound sleep if taken with cold water before going to bed. Dose is of two table spoon full (40 g) with a cup of water (220 mL). Honey is useful when applied on sore nipples and to dry up milk in swollen mammary glands. Gargling of honey water

as emollient cures aphthae in the mouth. Honey when mixed with lime and applied on temples reduces headache, it subsides the colic if applied on abdomen or around the navel, other bruises and sprains are also cured. Honey alone or with clarified butter if applied to burns, ulcers and wounds will soothe and heal them rapidly. Honey is very useful in cough and cold. It may be given with juice of Tulasi (*Ocimum sanctum* / *O. Basilica*) in young children (which is in practice in Bengal). It checks fever if taken before one actually gets affected [63]. Honey with *suhaga/tankan* (borax) may be applied in mouth for stomatitis and other oral problems in children [64].

Non floral honey

In general, it is known to all that honey is produced by the bees from the nectar collected from flowers. Beside this, there are some other kinds of honey which are having very uncommon sources like, honey dew, radioactive honey, rock honey, etc.

- i. Honey dew: Lice, jumping plant lice, bark lice and scale–insects which feed on plant juices and their excretions fall on the foliage of trees like dew. It contains about 70% nitrogenic substances and dextrin. It is usually dark, viscous with a faint aroma and an inferior flavour. It is harmful due to high mineral-salt content. Honey dew can be considered as *Dala* type of honey described in Ayurveda.
- ii. Radioactive honey- It differs not only in colour, aroma and flavour but also in chemical, biological and curative properties. Alin Caillas, French Chemist in 1908, proved that some varieties of honey contain radium and caesium. It has therapeutic importance in malignant conditions [65].
- iii. Rock honey- It is made by wild bees, generally *Apis dorsata* L. They deposit honey in rock crevices which is pale yellow and has pleasant aroma and flavour. It is not sticky and can stay unchanged for many years but devoid of many nutritional values [66].
- iv. Poisonous honey- Honey produced in the mountain regions of central and northern Japan often causes a transient indisposition due to toxic action of nectar from some of the plants. In the Far East, bees produce poisonous honey from the nectar of leather leaf. (Fruit flies and other insects also exhibit symptoms of ethanol intoxication [67]). The varieties of Azalea, monk's hood and andromeda honey are also poisonous. Poisonous honey is called 'heady' because it causes dizziness, nausea, a state of inebriation, severe abdominal pains.

Testing of adulteration in honey

Origin and authenticity of honey are gaining immense attention, as the consumers demanding the information about the source of their honey. Being a highly valued product in food, cosmetics and medical industries, honey is majorly vulnerable to adulteration that commercially known as economically motivated adulteration (EMA). According to the U.S. Pharmacopeia's Food Fraud Database, honey ranks as the third "favourite" food target for adulteration (7%), only behind olive oil (16%) and milk (14%) (United States Pharmacopeia, 2018). Honey products must be labelled with the correct information about their botanical and geographic origin according to articles 7 and 9 of the European Regulation (EU) 1169/2011.

A good quality honey can be distinguished by fragrance, taste and consistency. Ripe, freshly collected, high-quality honey at 20 °C (68°F) should flow from a knife in a straight stream, without breaking into separate drops [68]. Honey will remain pure as it is even after the passage of time [69]. This was evident from the excavation of 3000 years old royal tomb in Egypt in which the dead body was embalmed with honey. It is almost impossible to imitate making of honey by mixing waxy honey comb and sell molasses of sugar. There are several indigenuous methods to detect such mal practices.

Honey is composed of several sugars, varied compositions of organic acids, amino acids, enzymes and minerals [70]. In adulteration, components may have been added or removed or there may be deviation from the normal concentration of sugars or amino acids present. Generally exogenous sugars are added in adulterated honey, viz. wheat sugars, corn/cane sugars (C4), rice syrups (C3), manuka sugars, brown rice syrup, jaggery syrup and few other invert sugars to make it denser than usual one [71]. Adulterations damage the authentic benefits of honey. Honey must be routinely tested at different stages of the supply chain in order to ensure quality and authenticity. The detection of the most common adulterations and quality deviations in honey were reported by Spiteri *et al* [72].

Classical/traditional methods to test adulteration in honey

There are several methods of testing of adulteration in honey. All these methods are based on some physical and chemical properties. When cotton thread is dipped in honey and burnt, burning with some crackling sound indicates the presence of added sugars in it, while smooth burning is the indication of pure quality [73]. Melissopalynology (microscopic study of pollen grains) and some physicochemical parameters such as sugar content, concentrations of proline, 5-hydroxymethylfurfural (HMF), free acids and diastase activity are some of the traditional

methods for determining honey quality; however, a set of parameters must be considered to draw a decision on honey quality. There is a significant demand for screening the authenticity of honey using a sophisticated, hands-off analytical method that is able to detect new modes of adulteration to protect the authenticity, integrity and economic viability of honey. Uses of many such analytical tools have already been reported for this purpose [74–76].

Isotope ratio mass spectrometry (IRMS) analysis

The determinations of the traditional characteristics are operator-dependent, whereas IRMS is a sophisticated analytical technique that detect adulterations in honey by using carbon isotopic signature [77]. In an unadulterated honey, the carbon isotopic ratios of sugars and proteins should match. EA-IRMS (elemental analysis-coupled IRMS) and LC-IRMS (liquid chromatography-coupled IRMS), can be used to evaluate honey with extractable proteins; however, these schemes have recently been extended to analyse honey with non-extractable proteins also [78]. Although, IRMS can detects C3 sugar adulterants as low as 7% level, but it is a time-consuming procedure. Conversely, honey analysis from NMR spectroscopy requires less sample preparation and data collection times when compared with this method.

Nuclear magnetic resonance (NMR) analysis

NMR is considered one of the most vital and non-destructive spectroscopic tool to monitor the authenticity of honey [79–81]. The power of NMR lies in the fact that a small section of the NMR spectrum, covering chemical shift range (5.3–5.5 ppm) alone can discriminate honey adulterations. Therefore, more and more beekeepers and honey packers around the world are adopting the NMR-based honey profiling method in order to strengthen their premium brand image. NMR is also recognized as a powerful method by government agencies, in the global fight against food fraud and unfair competition. High-resolution NMR spectroscopy is based on the analysis of chemical fingerprint of honey, which is unique to each batch. Connected to a global database of honey samples, this technology reliably detects purity issues and furthermore, false declarations of country of origin and botanical variety. The inherent strength of NMR permits identification and quantification of all possible monosaccharides, disaccharides, oligosaccharides, acids, HMF and amino acids, separately from different well-resolved chemical shifts. These features can be easily exploited to discriminate geographical and botanical origins of honey since each honey variety has its unique NMR spectral features/signatures [82–84]. Several studies have shown that ¹H NMR and hetero-nuclear multiple bond

correlation (HMBC) spectroscopy are suitable for honey analysis to determine its botanical and geographical origin. The origin of acacia, rapeseed and forest honey can be confirmed with a combination of principal component analysis (PCA) and linear discriminant analysis (LDA) applied to the chemical fingerprint of ^1H NMR spectra, obtained from authentic honeys samples [85]. Also using ^1H NMR profiling coupled with chemo-metric procedures, labelling verification of mono-floral and multi-floral honey types is possible [86].

Toxicity and poisonous behaviour of honey

Honey may include a number of hazardous substances that can be harmful to human health, and it is not always a safe product. A few of these chemicals might have come from the improper handling, storage or storage conditions, or high moisture content and heating process. When honey is heated or preserved for long time, a cytotoxic and mutagenic substance known as 5-hydroxymethylfurfural (HMF), which is not found in honey naturally, may occur [87]. The amounts of pesticide residues in honey and their possible danger to reproduction have been brought to light by Yasser El-Nahhal [88]. These toxic chemicals can also be obtained via nectar collected from poisonous plants and from locations where ecologically dangerous metals are present. Heavy metals that may be hazardous, viz. Pb, As, Cd, Hg, Ni, Cr, Co, Se, etc. can be found in honey as a result of environmental contamination [89]. As a result, it is critical to locate beehives for honey production in places free of pollution and far from roads and railway tracks.

Non-medical uses of honey

Besides the medical utilization, honey is also used for non-medical purposes. Low quality honey is used for moistening, preparation of hand lotions, flavouring and preserving tobacco [90–92]. Honey as a moisturizing agent generally used in homely make up tools as a face-pack [90]. Honey is added to decoctions, tablets and powders, and used to make confections and electuaries [93, 94]. Honey is most wholesome amongst all foods with rich carbohydrates, and it is delicious.

Conclusion

Honey is a very useful nutrient which is having many medicinal properties. It was the only sweetening agent known to ancient people. Almost all traditional system of medicines mentions the benefit of honey. *Ayurveda* considers this as an important adjuvant, which is used abundantly along with several single and compound formulations effectively in varied number of diseases. As per *Ayurveda*, it should not be heated, and poisonous varieties should be identified and discarded from use.

The quality and flavour of honey depend much upon the nature of the plant from which it is obtained. Lot of information has been obtained from the ancient texts and modern researches and many more findings are yet to be discovered. More in-depth research should be done to find out the properties of honey and its miraculous actions in prevention and management of several diseases. This is necessary to bring awareness among people to take precautions about the ill effects if any. Myths about the usage of honey are also to be studied and clarified with further research. Despite numerous health benefits, there are less awareness about the storage, reasonable limits and regulations of the uses of honey. Use of biological control agents against pests of honey bees is also needs to be explored. The current available methods for identification of adulteration in honey are too expensive. Therefore, the development of cost-effective, simple and portable kits for on-site rapid identification of honey adulteration is the future scope for the growth of honey industry.

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