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A review of physico-chemical and biological properties of honey

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Abstract
Honey, a naturally occurring sweetener synthesized by honey bees possesses a delightful sweetness and exhibits a viscous texture. It boasts a beautiful golden-yellow hue and a complex composition with various physiochemical and antioxidant properties. Essentially, honey comprises an extremely concentrated sugar solution, which is composed of a carbohydrate mixture. The medicinal benefits of honey are acknowledged and recorded in different ancient societies like India, Egypt, and Greece. Throughout history, humans have widely consumed honey, utilizing it in the food, medicine, and beverage industries. Notably, honey possesses antibacterial and antifungal properties, further enhancing its value. Honey is valued for its rich content of vitamins, organic acids, amino acids, minerals, and phenolics as stated by various researchers. In addition, honey has been recognized for its therapeutic benefits in treating different illnesses, with its antioxidant properties being a key factor in its healing properties. The characteristics and excellence of honey can differ significantly, influenced by certain factors like its botanical source, geographical location, seasonal changes, processing methods, storage conditions, etc. In this review, efforts have been made to compile information on various properties possessed by honey.

Keywords: Quality, honey, properties, beekeeping, nectar

Introduction
Since the beginning of time, human beings have been portrayed as caretakers of the natural world, utilizing the natural resources for their prosperity. However, when it comes to honeybees and their pollination services, humans must take care of and assist the bees instead of harming or controlling them. The desire for adventure, sweetness, and survival was what initially led to the practice of beekeeping. The first times that hunter-gatherer societies came into contact with beehives in African forests, savannahs, and mountain cliffs were undoubtedly very painful. Before humans started directly tending to bees, "honey hunting" was considered the preferred technique of obtaining honey from wild bees. Eventually, humans began attempting to domesticate wild honey bees by creating hives with the help of timber boxes, straw baskets made by hand, hollow logs, and clay vessels known as "skeps". Egypt has seen beekeeping practices since ancient times. Beekeeping in hives has been documented since the Old Kingdom of Egypt. Over time, movable hives were developed based on the knowledge and observations of ancient beekeepers. Both the contemporary traditional apiculture & ancient world provide documentation of beekeeping. The bees continue to follow their instincts, while humans create a supportive environment for them. The beekeeping sector, which involves the upkeep of bee colonies to obtain hive products such as honey, royal jelly, pollen, etc., has captivated mankind due to its irreplaceable qualities. Bees perform a crucial role in pollination and serve as environmental indicators. Research on the physicochemical properties of honey has been ongoing for many years. (Bogandov *et al*., 1999; AOAC, 1990) [10]. Apiculture has seen a growing interest in recent years, both the science & art of beekeeping, primarily because of numerous health advantages that are linked to bee products. The advancements in beekeeping techniques and renovations have proven to be advantageous for beekeepers, farmers, and the rest of the public by aiding crop pollination. However, these crucial practices have faced numerous challenges due to various abiotic and biotic factors lately. These factors have had a detrimental impact on honeybees and the valuable products they produce, both individually and in combination.

Climatic elements such as high temperatures, relative humidity, scarcity of water, deforestation (especially of floral resources), as well as human-related elements like improper methods implied in apiculture, synthetic pesticides, diseases, and pests have all contributed to the reduction in colonies of honeybees and the products they synthesize. Despite these challenges, the worldwide demand for beef products mainly honey has seen a significant increase over the past years due to their importance in a broad range of applications and uses. This is especially crucial in developing nations, where beekeeping has a rich tradition and serves as a major source of income and food security (Gupta, 2014) [32]. Nevertheless, beekeeping encounters a broad array of obstacles, such as changes in climatic conditions, inadequate management techniques, & the utilization of artificial pesticides (Wakgari, 2021) [73]. To tackle these challenges, it is essential to establish legislation and guidelines that safeguard bees and their products, as well as to encourage sustainable beekeeping methods. Beekeeping is a livestock branch that relies on nature to collect nectar from various vegetable sources in different regions, transforming them into various bee products during the most suitable seasonal periods. Bees have a crucial role in the ecosystem as pollinators of numerous plant species worldwide, including fruits and vegetables grown in greenhouses. The pollination by bees enhances the quality of the products obtained. Furthermore, bees contribute to the preservation of endangered plants and promote ecosystem balance by increasing plant and animal diversity. In addition to pollinating plants that require external pollinators, bees also enhance the products qualitatively and quantitatively in self-pollinating plants.

Bees, whether wild or domesticated, have a significant impact on human well-being through their pollination services and other benefits to the ecosystem. Bees are essential for pollinating crops and wild plants, as ten key species have been recognized for the role they play in global crop pollination. Their contribution to ecosystem services is substantial, underscoring the wide range of benefits they provide for human health and emphasizing the importance of additional research. (Klein, 2018) [41]. For ages, human beings have utilized animal resources for their therapeutic benefits. This practice dates back to the earliest times and is documented in various sources (Weiss, 1947; Rosner, 1992) [74, 60]. Folk remedies were developed using different parts of the animal body, as well as substances obtained from metabolic processes, like secretions and excrements. Additionally, non-animal components like cocoons and nests were also used in these traditional treatments. This interaction between humans and animals for therapeutic purposes, known as ethnozoology, has been observed in both indigenous and Western society's worldwide (Branch and Silva 1983) [11]. It is worth acknowledging that both wild and domesticated animals have proven to be valuable resources regarding therapy.

One of the most important products of beekeeping is honey. The dependence of humans on honey bees is not a less known fact. From pollination to different bee products like wax, honey, royal jelly, propolis, and pollen, an important role is played by the bees in maintaining the ecosystem. The Codex Alimentarius Commission (2001) [1], describes honey as a sugary substance created by honeybees using nectar or various secretions found on living plants. The bees gather, alter, and store this substance in honeycombs. Honey possesses a sweet taste and is a thick golden liquid food generated by bees through a natural process during regurgitation and evaporation of nectar and other material in their gastrointestinal tract and stomach. The bees gather nectar from various flowers found in nature. Honey has been utilized by humans for countless generations. It holds significant value as a staple food and is revered as Amrut in the Vedas. Honey, the nutritious sugary jelly produced by bees, is considered the healthiest food in the world. It comes in a variety of colors and flavors and is modified using natural techniques such as regurgitation and evaporation to transform the nectar collected from different flowers in nature.

In the Quran, there exists a Surah known as al-Nahl (the Bee) in Islam. According to the hadith, the use of honey is highly recommended by the Prophet Muhammad due to its healing properties. Honey is emphasized by the Quran as a food that is highly nourishing and beneficial. English translation of the certain verses is described below "And your Lord inspired the Bee, saying: 'Take your habitations in the mountains, on trees, and in the structures created by humans. Then, consume from all the fruits of the earth and follow the paths ordained by your Lord.' From their bellies comes a drink of varying colors, containing healing for mankind. Surely, in this is a sign for those who reflect."

Properties of Honey

Numerous scientists have documented the physiochemical characteristics of various honey varieties (Gupta *et al*., 1992; Terrab, Diez, & Heredia, 2002, Beretta *et al*., 2005, Iftikhar *et al*., 2011, Kek *et al*., 2017, Wu *et al*., 2020, Sharma *et al*., 2021; Kumari & Kumar, 2022; Sharma *et al*., 2023; etc.) [31, 70, 6,, 35, 39, 76, 65, 45, 66]

Joshi *et al*., (2000) [36] analyzed the physiochemical properties of honey from *Apis dorsata*, *cerana*, and *mellifera* from Nepal. The moisture content (g/100 g honey) of honey obtained from *Apis dorsata*, *Apis cerana*, and *Apis mellifera* was 21.5, 20.1, and 17.1 respectively. The EC (mS/cm) values were 0.96, 0.65, and 0.31 for the same species. In terms of invertase (Siegenthaler U/kg), the values were 373.4, 218.2, and 110.9, while for proline (mg/kg), the values were 875.8, 323.0, and 610.2. There were negligible differences in pH, glucose oxidase, and glucose content among the different honey types. However, *A. dorsata* and *A. cerana* honey had significantly higher fructose content compared to *A. mellifera* honey. Additionally, *A. dorsata* honey had significantly higher levels of oligosaccharide L2 and lower levels of sucrose compared to *Apis cerana* and *Apis mellifera* honey.

The physical and chemical characteristics of honey hold great significance as they can alter its flavor by influencing the enzymes present within it. The physical attributes of honey, including pH, color, flavor, ash content, enzyme activity, and electrical conductivity, may differ based on the type of honeybee, location, and the existence of contaminants (Terrab *et al*., 2003) [3].

Iftikhar *et al*., 2011 [35], gathered samples of honey from the colonies of *Apis cerana, Apis florae, Apis dorsata,* and *Apis mellifera* directly from the combs to make sure of quality and purity (free from adulteration). All honey samples were analyzed for their physico-chemical properties. The values for pH, total sugars, acidity, moisture, electrical conductivity, sucrose, and diastase activity varied considerably among the different types of honey.

In 2013 [50], Moniruzzaman and co-workers conducted research to analyze both antioxidant and physicochemical characteristics shown by monofloral honey samples obtained from Malaysia. The honey samples were generated by various species of bees, such as *Apis cerana* and *Apis dorsata*. There were notable variances in physiochemical properties when comparing honey from *Apis mellifera* and *Apis florea*. Kek *et al*. (2017) [39] directed their attention towards the categorization of honey by examining its physicochemical characteristics, with a particular emphasis on the entomological source of the honey. This offered valuable insights into the physicochemical properties exhibited by honey from various bee species, including *Apis cerana* and *dorsata*.

The physicochemical & antioxidant characteristics of unprocessed honey originating in Malaysia were utilized as indicators in identifying the bee species that were responsible for its production, namely *Apis dorsata, Apis mellifera, Apis cerana,* and Heterotrigonaitama. Kelulut honey, which is produced by stingless bees (*Heterotrigonaitama*), exhibited distinct characteristics compared to honeys produced by the regular honey bee species (Apis spp.). Additionally, Li and team (2017) [47] examined the distinct physiological impacts of neonicotinoid insecticides on *Apis mellifera* and *Apis cerana*, underscoring the significance of comprehending how various bee species react to environmental stressors.

Recent studies have shown a growing interest in the physiochemical parameters of honey obtained from different species of bees. In a study conducted by Al-Hasani (2018) [1], the antimicrobial properties of honey were emphasized, with its effectiveness attributed to specific physiochemical characteristics like high osmotic pressure and low pH.

Wu *et al*., 2020 [76] analyzed the physicochemical parameters, like sugar content, minerals, and volatile compounds as main factors for the evaluation of multifloral honey obtained from *Apis cerana cerana* Fabricius, *Apis dorsata* Fabricius, and *Lepidotrigona flavibasis* Cockerell. The overview of the physicochemical profile of honey of multifloral origin showed significant variance, from that of *A. mellifera* honey.

In Eastern Thailand, a study was conducted by Khongkwanmueang *et al*. (2020) [40] where they gathered various honey samples of a species complex of stingless bee *Tetragonulalaeviceps.* Sharma *et al*. conducted another study in 2021 [66] about the physico-chemical characteristics of honey samples obtained from *Apis cerana* in the Western Himalayan region. The main objective behind this research was to assess the quality of honey produced by *Apis cerana* found in this particular geographical location.

The examination of honey's physicochemical properties by Kumari and Kumar, 2022 [66] has shown that its quality remains intact even when artificial diets are provided to bees, thus upholding both national and international standards. Ramlan *et al*. (2023) [58] examined the physiochemical properties of *Heterotrigonaitam (stingless honey bee*) from various regions of Peninsular Malaysia. Sharma *et al*., 2023 [65] considered three distinct species, namely *Apis, mellifera, Apis dorsata*, and *Apis cerana*, as the sources of honey samples that were evaluated for the physio-chemical and antioxidant properties shown by them in both stored & fresh states. The values of the honey samples (both fresh and stored) from all three species were compared with data from previous studies conducted by various researchers worldwide and were found to fall within acceptable ranges.

Physical properties

- **Color:** The color of honey primarily influences its appearance in the global market**,** making color the most significant characteristic. Numerous methodologies have been proposed by scientists and researchers to identify the hue of honey. Research suggests that the color of honey in directly influenced by its ash contents, specifically the copper and iron contents (Einset and Clark, 1957) [16]. Kaushik's research in 1988 revealed that fresh Himachal honey with an optical density of 0.35 adhered to the U.S.D.A. color standard outlined in White's publication from 1975 [75]. The color of honey ranges from light yellow to deep red or even black, based on the plant source. Temperature changes primarily influence the dark hue of honey. The findings indicate that as moisture contents increase, the rate of honey darkening may also escalate (Schade *et al*., 2006). Moreover, subsequent work concluded that variances in the color of honey may also be impacted by storage conditions, including the type of container, temperature fluctuations, and other related factors (Bertoncelj *et al*., 2007) [7]. The consensus is that the lighter the color of honey, the purer it is. Different other factors such as floral source, HMF, polyphenolic compounds, etc. also affect the color of honey (Gomes *et al*., 2010) [24]. Numerous researches have focused on the correlation existing between the floral source of honey and its color, processing techniques utilized in industries, and also the temperature and duration of storage (Crane, 1984; Terrab *et al*., 2004) [4]. Aryal and colleagues (2015) [5] presented a comprehensive analysis of the beekeeping industry in Nepal, emphasizing the wide range of honeybee species found in the area. These species include *Apis laboriosa, A. dorsata, A. cerena, A. florea,* and *A. mellifera*. Aljohr and colleagues (2018) documented significant variations in the color of honey samples analyzed from the Shimla hills.
- **pH:** One unique characteristic of honey is the formation of granules, which distinguishes it from other sweeteners. The texture and stability of honey is affected by pH (Terrab *et al*., 2002) [75]. Over some time, the fermentation process also causes an increase in the pH level of honey. The range of pH of Brazilian honey was found to be between 3.42 and 4.68, whereas Bangladeshi honey exhibited a pH range of 3.2 to 4.5. In a study conducted by Wang and QX in 2011, it was concluded that the plant source and geographical origin of honey are significant elements contributing to variations in pH values. This is because the pH of nectar and soil can greatly impact the physiochemical properties of honey. In terms of unbranded and branded honey samples, the pH levels were determined to be 4.13 and 3.14 to 4.09 respectively (Bhargava *et al*., 2015) [8].
- **Moisture:** Moisture content has a peculiar role to play in determining the solidity of honey, with elevated moisture content being a distinctive factor that typically falls within the range of 13-20%. At a temperature of 24 °C and a moisture content of 18.9%, the viscosity of honey is determined approximately 9.9 psa. In Pakistani honey samples, moisture content was 14.3 to 18.6% (Latif *et al*., 1956) [46] Phadke, in 1967 [55], studied 80 various honey samples, finding an average moisture content of 20.90%. Narayana (1970) noted that the high moisture content in India compared to foreign honey from *A. mellifera*. Mesallan and El-Shaarawy (1987) conducted a study comparing the characteristics of honey produced locally and imported into the Saudi market, finding that the

moisture levels were higher in imported samples than in the local ones. Singh and Bath (1997) [67] also established the corresponding moisture percentage ranges (18.7-21.8) for certain Indian samples. According to various studies (Finola *et al*., 2007; Buba *et al*., 2013) [19, 12], significant variation was found in the moisture content of different honey samples. In the arid regions, the moisture content ranged between 13.63% and 20.60%. Algerian honey samples, as reported by Ahmed *et al*. (2014), had a moisture content ranging from 15.87% to 18.055%.

- **Specific gravity:** Specific gravity is a significant physical attribute of honey. According to the United States standards, honey classified as "A" Grade must possess a specific gravity of lower than 1.4155, while the specific gravity of Standard honey should exhibit a value exceeding 1.406. Perti and Panday, 1967 [54] analyzed honey samples for the specific gravity collected from *Apis dorsata* found in the forests of Nainital, with values ranging from 1.3492 to 1.4401.
- **Electrical conductivity:** Blossom honey possesses electric conductivity values lower than 0.80 ms/cm as per European legislation (European Economic Community, 2002), whereas honeydew honey surpasses the same threshold. Honey samples from dry areas showed an electrical conductivity varying from 0.25 to 0.69 mS/cm, as reported by Habib *et al*. (2014) [33].

Chemical Properties

The honey composition can vary due to different factors including climatic conditions, floral origin, soil characteristics, species of the bee, honey maturation, and the health of the colony. These volatile compounds can offer insights into the source of honey, whether it is derived from flower nectar or secretions of plants or insects (Radovic *et al*., 2001; Serra-Bonvehí & Ventura-Coll, 2003) [57, 64].

- **Sugar:** Honey's high sucrose content makes it resistant to spoilage, making it a valuable preservative for other food substances. There exists a significant disparity in the sugar consumption within honey. Latif *et al*. (1956) [46] investigated honey samples and documented the existence of fructose ranging from 39.01% to 53.8%, glucose ranging from 27.7% to 34.2%, and sucrose ranging from 1.9% to 2.75%. Phadke (1967) [55] discovered variations in reducing sugars among five honey samples obtained from each species of honey bee (*Apis indica*, *Apis florae*, and *Apis dorsata*), ranging from 66.45% to 77.79%. Additionally, non-reducing sugars range between 0.73% and 10.03%. The analysis of five variable honey samples from three different honey-producing bee species, *Apis indica*, *Apis florae*, and *Apis dorsata*, demonstrated variations in sugar composition. According to the study by Phadke in 1967 [55], the amount of reducing sugar content exhibited by the different samples of honey ranged from 66.45% to 77.79%, while non-reducing sugar content varied from 0.73% to 10.03%. Minh and colleagues (1971) [72] conducted research on the chemical makeup of seven *A. dorsata* honey samples and single combined sample of *A. mellifera* honey gathered in the Philippines. *A. dorsata* honey was found to contain higher levels of D-fructose but lower levels of D-glucose compared to *A. mellifera* honey.

  Lin *et al*. (1977) [48] demonstrated the levels of inverted sugar between 66 and 77 percent, glucose ranged from 30 to 36 percent, fructose ranged from 34 to 40 percent, and sucrose ranged from 0.1 to 5.7 percent. Similarly, Dozo (1984) [15] examined 66 honey samples obtained from different regions of Buenos Aires and discovered that the reducing sugars exceeded the percentage of 65.5%, with the lowest value being 71.1%. White *et al*. (1988) examined 87 honey samples from the U.S. and demonstrated that 81 of these honey samples exhibited a mean value of around 3.1 mg (as glactose) per 100g of honey. Raffinose, a type of carbohydrate (sugar) commonly found in honey, was also detected. Goshdastidar and Chakarbarti (1992) [23] found that the honey samples from the Central Bee Research Institute located in Pune contained total reducing sugars of 65.5-75.1 percent, sucrose as 0.8-6.2 percent, and a fructose/ dextrose ratio ranging from 1.0 to 1.3. Additionally, it was discovered that *Apis dorsata* honey comprised a lower amount of d-glucose compared to that of honey by *Apis mellifera*. The percentage of glucose and fructose in honey varies between 85-95%, with their quantity being influenced by the floral/nectar source (Cavia *et al*., 2002) [13]. Apart from these sugars, more than 22 other sugars, with dextrose and laevulose being the predominant ones are also found in honey. The disaccharides present in honey are Maltose, Sucrose, Maltulose, Turanose, Isomaltose, B-trehalose, Laminaribiose, Nigerose, Kojibiose and Gentiobiose. Additionally, trisaccharides like Theanderose, Panose, Psopanose, Erlose, Melezitose, Centose 3-α5, Isomaltosylglucose, l-Kestose, Isomaltotriose, and Erlose have also been detected in small amount in honey. In their study, Linkon *et al*. (2015) analyzed Bangladeshi honey and found that the total amount of carbohydrates ranged from 83.97% to 84.49%. In their study, Sharma *et al*. (2021) [66] analyzed Italian honey and documented the combined quantity of glucose and fructose as 72.3%, while sucrose was 5.55%.
- **Acidity:** The Yemeni and Egyptian samples of honey projected the highest acidity when compared with the honey samples from Saudi and Kashmir. The increased acidity in honey samples may be because of the fermentation of carbohydrates present in honey. Acidity is an important factor which determines the flavor and firmness of honey, as well as its ability to resist microbial spoilage (Bogdanov *et al*., 2008) [9]. The Kashmiri honey exhibited acidity level to be approximately 4.637 (El Sohaimy *et al*., 2015) [17].
- **Ash Content:** Ash content is an important aspect which determines the property of honey. Phadke (1968) [56] examined honey of different varieties from India and noted elevated levels of ash content in the natural honey samples. According to their findings, wild honey samples reportedly exhibit elevated levels of ash content. The researchers analyzed Japanese honey (60 samples), imported honey (89 samples), and commercial honey (190 amples). The results indicated that the content of crude ash was below 0.04%. In 1992 [31], Gupta *et al*. conducted a study that revealed 0.47% ash content in the honey samples obtained from Indian beehives colony of *Apis cerana* situated in Jammu and Kashmir. According to a study conducted by Fasasi in 2012, it came out that Nigerian natural honey samples had ash content of 0.4%. Habib *et al*. (2014) [33] recorded the ash content value ranged between 0.7 to 0.50%.
- **Hydroxymethyl furfural:** Hydroxymethyl furfural

aldehydes are the substances formed when sucrose is commercially converted into invert sugar. HMF aldehydes serve as a medium to indicate the purity of honey. After examining 75 honey samples from different countries, different plants, and seven-year-old samples from Belgium, Piette concluded that the HMF values underwent no significant changes when honey was heated at 400C for 48 to 120 hours. However, this heating process did lead to the generation of a considerable quantity of HMF. Adulterated honey may contain HMF at different levels, and the techniques employed at that time were unable to detect its presence accurately. Phadke (1968) [56] employed the Fiche test to conduct a quantitative examination of honey samples in India. Subsequently, the honey samples can be categorized into different grades based on the following criteria: Grade I for honey containing 0 to 10ug HMF/gm, grade II for honey containing 11 to 20ug HMF/gm, and grade III for honey containing 21 to 30ug HMF/gm. In their study, Fini and Sabatini (1972) conducted an analysis of HMF content in 400 honey samples. The samples were divided into two groups: group A consisted of honey obtained directly from beekeepers, while Group B comprised commercially available honey in Italy. According to the results, samples of group A had an average HMF content of 13.4 mg/kg, which was below the maximum limit of 40 mg/kg as per the European Codex. However, 59.6 mg/kg of average HMF content was present in group B, only 292 honey samples complied with the Codex regulations, while 24 honey samples exceeded the limit of 100 mg/kg. Kaushik (1988) [38] documented that the newly harvested Himachal honey lack HMF. According to Bricage (1989), 16 out of 88 newly harvested honey samples exceeded the legal threshold of 40mg HMF/kg. On the other hand, HMF content below 15 mg/kg was present in 35 out of 38 honey samples sold directly by local beekeepers. Ghoshdastidar and Chakrabarti (1992) [23] analyzed the samples in CBRTI, Pune. They recorded the HMF levels within the range of 1 to 12 ppm. Martinez Gomez *et al*. (1993) [26-27] observed presence hydroxy methyl furfuraldehyde (HMF) in honey as an indicator of its quality, as the concentration of HMF tends to increase during the process of conditioning and storage.

Biological Properties

- **Enzyme activity:** In honey, the primary enzymes found include invertase, amylase (diastase), glucose oxidase and small amounts of catalase & acid phosphatase (White, 1975) [75]. Enzymes play a major role in determining the aging & freshness of honey. This particular enzyme acts as a hydrolase, facilitating the conversion of organic phosphates into inorganic phosphates. Some studies have indicated a potential connection between the botanical source of honey and a specific enzyme, as highlighted by Santana (1993) [61]. This enzyme is identified as a valuable parameter for characterizing honey. Furthermore, research conducted by Santana (1993) [61] demonstrated varying levels of activity of acid phosphatase in Galician honeys of different floral origins, with unifloral honey of *Rubus* sp. exhibiting the maximum activities.
- **Antibiotic:** Antibiotic residuals in honey have emerged as another significant issue to consumers in recent times. It is now clear that antibiotics present in honey is primarily a result of improper beekeeping practices rather than environmental factors. The existence of antibiotic residues in various honey samples has been emphasized in various international reports. From 2000 to 2001, a comprehensive study to examine the veterinary drug presence in both locally produced and imported honey was conducted. A total of 248 samples were analyzed, revealing that Streptomycin was found in 4 out of 248 samples, tetracycline was present in 2 out of 72 samples while sulfonamides was detected in 3 out of 72 samples. However, any residues of lactam antibiotics and chloramphenicol were not found. On the other hand, in imported honey samples, 51 samples showed presence of Streptomycin out of 102 samples, 29 out of 98 samples reported presence of tetracyclines, sulfonamides was present in 31 out of 98 samples, and chloramphenicol in 40 out of 85 samples. Mayande in 2007 notably detected the presence of antibiotic Streptomycin in Dabur Honey. During the peak flowering seasons of rubber and banana plantation crops in Southern Tamil Nadu, nectar and honey obtained from beehives were analyzed for traces of antibiotics. The examination revealed that the Nectar and honey samples contained streptomycin in the range of 4-17 and 11-29 g/kg respectively, ampicillin in the range of 2-29 and 3-44 g/kg respectively, and kanamycin in the range of 17-34 & 26-48 g/kg respectively (Solomon *et al*., 2006) [68}. In a separate study, 50 samples of honey of different floral origin including pine, chestnut, linden, and multiflower honey gathered from hives in the Southern Maramar region of Turkey were tested for residues of erythromycin using Liquid Chromatography-mass spectrometry with Electrospray ionization in the positive ion mode (LC-ESI-MS). Out of those 50 samples, four were found contaminated with erythromycin residues (concentrations ranged between 50 to 1776 ngg-1). Erythromycin-fortified cake-feeding assay was conducted in a controlled hive to further investigate about the transfer of erythromycin residue to the honey matrix. After 3 months, the level of residue present in the honey was found approximately 28 ngg-1 (Gunes *et al*., 2008) [29].
- **Antioxidants:** In their study (Aljadi *et al*., 2004; Gomes *et al*., 2010) [3, 24] classified honey as a functional food because of its various biological attributes such as antibacterial effects (bacteriostatic properties), antioxidant properties, wound healing abilities, anti-inflammatory capabilities, radical scavenging capabilities, antidiabetic effects, and antimicrobial activities. Numerous studies (Beretta *et al*., 2005; Bertoncelj *et al*., 2007) [6, 7] have showcased a robust association between the phenolic composition of honey and its antioxidant potential. Over the last few years, the interest in investigating the antioxidant properties of honey is increasing. They indicated the existence of a direct relationship between the antioxidant property and the concentration of total phenolics present in honey. Research has also shown that the color of honey correlates with antioxidant activity, with honey with a darker hue possessing higher phenolic content in total and consequently greater antioxidant capacities. Moniruzzaman and colleagues (2013) [50] conducted a research study to assess the physical, chemical, and antioxidant properties exhibited by Malaysian honey

samples of unifloral origin produced by various bee species, such as *Apis cerana*, *Apis dorsata*, and *Apis mellifera*. The study compared pineapple and acacia honey of *Apis mellifera* with Borneo honey by *Apis cerana* and tualang honey obtained from *Apis dorsata*. The study results aimed to offer insights into its antioxidant properties from different bee species. In comparison to tualang honey, the pineapple honey sample exhibits a minimum moisture content of 14.86% and the highest acidity with a pH of 3.53. This implied that both types of honey are more resistant to microbial spoilage. Acacia honey has the highest EC at 0.76 mS/cm, while the Borneo honey sample has the highest Total Dissolved Solids at 377 ppm. Malaysian honey has an average HMF content of 35.98. Tualang honey shows the highest color intensity. The sweetest honey has the highest total sugar concentration. Tualang honey also boasts the highest quantity of phenolic compounds (352.73±0.81 mg galic acid/kg), protein content (4.83±0.02 g/kg), flavonoids (65.65±0.74 mg catechin/kg), FRAP values (576.91±0.64 µM Fe (II)/100 g), and DPPH (59.89%), along with the lowest AEAC values (244.10±5.24 mg/kg), specifying its potent antioxidant attributes. The pineapple honey sample contains the maximum concentration of proline. A high degree of correlation was seen among the various parameters of Malaysian honey. Despite the overall good quality of Malaysian honey, tualang honey shines out for its unique and remarkable antioxidant properties. Gheldof *et al*., in their study, analyzed that after the intake of buckwheat honey combined with water, there was a notable rise in the antioxidant capability of the serum in individuals. Furthermore, Schramm *et al*., 2003 [62] inferred that honey consumption also proved to be successful in enhancing the overall antioxidant capacity as well as plasma's reducing capacity in humans. Pattamayutanon and team (2015) [53] explored the biochemical composition, antibacterial activity, and free radical reduction of honey samples from three distinct honeybee species, including *Apis mellifera*, *Apis cerana*, and *Apis dorsata*. The study considered different floral sources to examine different honey samples in Thailand to comprehend the influence of floral sources, bee species, and processing after collection (post-collection) on the biomedical activity and volatile compounds of honey. This investigation leads to the comprehension of the antioxidant attributes of honey samples from various bee species. The results obtained, indicate a significant relationship between the source of flowers and bee species, and also certain variations in total acidity, % Brix, protein content, antimicrobial properties, free radical reduction, and flavonoid and phenolic contents. Additionally, the volatile organic compounds in coffee & wild honey types differed significantly based on the floral origin. Both honey samples exhibited volatile organic compounds (VOC) characteristics, some of which contribute to antibacterial and antioxidant effects. The diverse plant origins and methods employed during processing (including floral origin, bee species, and post-collection modifications) of Thai honey leads to variations in antibacterial properties, physicochemical attributes, and aroma. Based on these findings it can be concluded that consumers of honey can choose a specific type of honey depending on their individual requirements and most favored scent. The research indicates that honey possesses antioxidant properties due to presence of phenolic content and flavonoids, aiding in reduction of oxidative stress within the body by the elimination of free radicals. Additionally, the study reveals that honey's antibacterial characteristics make it effective in treating various illnesses and enhancing wound healing, as supported by Sforcin *et al*. (2017). Moreover, the literature review underscores the diverse mechanisms responsible for honey's antibacterial effects, including osmolarity, acidic pH, hydrogen peroxide system, phytochemical factors, defensin-1, and methylglyoxal which are present. Devi *et al*., 2021 conducted a study to understand microbial diversity and antibacterial attributes possessed by honey collected from bees in Himachal Pradesh of species (*Apis cerana* and *Apis mellifera*). 26 bacteria were identified (14 in *Apis cerana* and 12 from *Apis mellifera*), with no fungal isolates found. A comparison of different species of bees and their locations based on the bacterial load (log CFU/g) showed the highest loads of 3.74 and 3.99 in honey from *Apis cerana* and the Mandi location, respectively. Most common strains (eg: HC3, HC5, HC6, HC8, and HM2) were identified by 16S rRNA ribotyping as *Staphylococcus haemolyticus* (MT742636), "*Bacillus subtilis stecoris*" (MT742637), *Bacillus safensis safensis* (MT742638), "*Bacillus zanthoxyli*" (MT742639), and *Bacillus safensis safensis* (MT938911). The honey derived from the apiary demonstrated a commendable inhibitory effect on Escherichia coli ATCC1041, ranging from good to excellent, and fair to close to good activity against Bacillus subtilis ATCC6633, *Pseudomonas aeruginosa* ATCC10662, *Salmonella typhi* NCTC786, and *Klebsiella pneumoniae* ATCC13883, indicating its potential as a therapy agent. Furthermore, honey has the potential to mitigate the diverse adverse reactions linked to the administration of artificial pharmaceuticals in the treatment of bacterial infections, emphasizing the significance of honey as a more wholesome substitute for synthetic medications.

- Guo and colleagues (2023) [30] assessed Shennongjia *Apis cerana* honey for its antioxidant activities and phenolic compounds by comparing it with honey of bee species (*Apis mellifera*) in China. The study concluded a statistically significant relation between total phenolic content or total flavonoid content (TFC) and antioxidant outcomes (DPPH, FRAP, and ABTS). This research provides significant findings regarding the antioxidant characteristics of honey derived from *Apis cerana* when compared to *Apis mellifera*.
- In summary, the literature review based on the provided documents underscores the importance of comparing the antioxidant characteristics among variable bee species, specifically *Apis mellifera*, *Apis cerana*, *and Apis dorsata*. These studies contribute to understanding the variations in the antioxidant characteristics of honey depending upon the bee species and floral sources and provide valuable insights into further research in this field. This research assesses the phenolic composition and antioxidant properties of Shennongjia honey by comparing it to honey obtained from China. The total flavonoid content (TFC) ranges from 35.9±0.4 to 102.2±0.8 mg epicatechin/kg while Total Phenolic Content (TPC) varies from 263±2 to 681±36 mg gallic

acid/kg. Correlations were observed between TPC (Total Phenolic Content) or TFC (total flavonoid content) and also the antioxidant activities (DPPH, FRAP, and ABTS) at a p-value being less than 0.01. Moreover, the phenolic compounds were examined using (HPLC-HRMS) high-performance liquid chromatography-high resolution mass spectrometry, which led to the tentative identification of 83 phenolic compounds. A metabolomics analysis of honey based on these polyphenols was conducted, followed by principal component analysis & orthogonal partial least squares-discriminant analysis. The findings demonstrated the ability to distinguish between the distinct types of honey based on their phenolic profiles. Various studies have examined the physicochemical attributes of honey obtained from different honeybee species, such as *Apis cerana*, *Apis dorsata*, and *Apis mellifera*, revealing variations in attributes like antioxidant capabilities. Additionally, the chemical and physical properties of stingless bee honey are contrasted with those of European bee honey, encompassing types from *Apis cerana* and *Apis dorsata*). The literature review emphasizes the significance of comprehending the physiochemical characteristics of honey from various bee species, including *Apis mellifera, Apis cerana*, and *Apis dorsata*, to uncover potential differences in quality, antimicrobial properties, and also the antioxidant activities among different honey bee species. Honey has a significant value due to its high nutritional content and quick absorption of carbohydrates when consumed, making it an effective source of energy.

Conclusion
Honey possesses properties that make it a miraculous product of nature. Nowadays, honey is a proven remedy against various communicable and non-communicable diseases. Due to its varying properties, honey is used as a sweetener, cosmeceutical, nutraceutical, and therapeutic agent. The entire world has recognized its potential as an immunity booster during the COVID-19 pandemic.

Conflict of Interest
There is no conflict of interest among authors.

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References
1. Al-Hasani HMH. Study antibacterial activity of honey against some common species of pathogenic bacteria. Iraqi Journal of Science. 2018;59(1):30-37.
2. Codex Alimentarius Commission. Revised codex standard for honey. Codex stan, 12: 1982. 2001.
3. Aljadi AM, Kamaruddin MY. Evaluation of the phenolic contents and antioxidant capacities of two Malaysian floral honeys. Food Chemistry. 2004;85(4):513-518.
4. Aljohar HI, Maher HM, Albaqami J, Al-Mehaizie M, Orfali R, Orfali R, *et al* Physical and chemical screening of honey samples available in the Saudi market: An important aspect in the authentication process and quality assessment. Saudi Pharmaceutical Journal. 2018;26(7):932-942.
5. Aryal S, Thapa R, Jung C. An overview of beekeeping economy and its constraints in Nepal. Journal of Apiculture. 2015;30(3):135-142.
6. Beretta G, Granata P, Ferrero M, Orioli M, Facino RM. Standardization of antioxidant properties of honey by a combination of spectrophotometric/fluorimetric assays and chemometrics. Analytica Chimica Acta. 2005;533(2):185-191.
7. Bertoncelj J, Doberšek U, Jamnik M, Golob T. Evaluation of the phenolic content, antioxidant activity and colour of Slovenian honey. Food Chemistry. 2007;105(2):822-828.
8. Bhargava HR, Umarani S, Eswaran VU, Elakkiya S. A relative study on the chemical composition among the pure and branded honey types collected from diverse sources of Tamilnadu, India. World Applied Sciences Journal. 2015;33(3):401-408.
9. Bogdanov S, Jurendic T, Sieber R, Gallmann P. Honey for nutrition and health: A review. Journal of the American College of Nutrition. 2008;27(6):677-689.
10. Bogdanov S, Lüllmann C, Martin P, Von Der Ohe W, Russmann H, Vorwohl G, *et al*. Honey quality and international regulatory standards: Review by the International Honey Commission. Bee World. 1999;80(2):61-69.
11. Branch LC, Silva MFD. Folk medicine of Alter do chao, Para, Brazil. Acta Amazonica. 1983;13:737-797.
12. Buba F, Gidado A, Shugaba A. Analysis of biochemical composition of honey samples from North-East Nigeria. Biochem Anal Biochem. 2013;2(3):139.
13. Cavia MM, Fernandez-Muino MA, Gömez-Alonso E, Montes-Pérez MJ, Huidobro JF, Sancho MT. Evolution of fructose and glucose in honey over one year: influence of induced granulation. Food Chemistry. 2002;78(2):157-161.
14. de Conconi JRE, Moreno JM. The utilization of insects in the empirical medicine of ancient Mexicans. *Journal of Ethnobiology*. 1988;8:195-202.
15. Dozo AD. Determination of sugars in honeys produced in the province of Buenos Aires, Argentina. Anais do 5° Congresso Brasileiro de Apicultura, Viçosa, MG, Brasil. 1984.
16. Einset E, Clarrk W. The effect of copper contamination upon the development of color in the processing and storage of honey. Food Technology. 1957;11(1):12-14.
17. El Sohaimy SA, Masry SHD, Shehata MG. Physicochemical characteristics of honey from different origins. Annals of Agricultural Sciences. 2015;60(2):279-287.
18. Fasasi KA. Physicochemical attributes of Nigerian natural honey from honeybees (*Apis mellifera adansonii*) (Hymenoptera: Apidae) and its shelf life in storage at room temperature. Pakistan Journal of Biological Sciences. 2012;15(21):1027-1033.
19. Finola MS, Lasagno MC, Marioli JM. Microbiological and chemical characterization of honeys from central Argentina. Food Chemistry. 2007;100(4):1649-1653.
20. George EA, Pimplikar S, Thulasi N, Brockmann A. Similarities in dance follower behaviour across honey bee species suggest a conserved mechanism of dance communication. Animal Behaviour. 2020;169:139-155.
21. Gheldof N, Wang XH, Engeseth NJ. Identification and quantification of antioxidant components of honey from various floral sources. Journal of Agricultural and Food Chemistry. 2002;50(21):5870-5877.

22. Gheldof N, Wang XH, Engeseth NJ. Buckwheat honey increases serum antioxidant capacity in humans. Journal of Agricultural and Food Chemistry. 2003;51(5):1500-1505.
23. Ghoshdastidar N, Chakrabarti J. Studies on hydroxy methyl furfural formation during storage of honey. Journal of Food Science and Technology. 1992;29:399-400.
24. Gomes S, Dias LG, Moreira LL, Rodrigues P, Estevinho L. Physicochemical, microbiological and antimicrobial properties of commercial honeys from Portugal. Food and Chemical Toxicology. 2010;48(2):544-548.
25. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. John Wiley & Sons; 1984.
26. Gomez ME, Harnandez GE, Gomez MJY, Marin MJL. Physicochemical analysis of Spanish commercial Eucalyptus honeys. Journal Apic. Res. 1993;32(3/4):121-126.
27. Gomez MM, Hernández EG, Gomez JM, Marin JM. Physicochemical analysis of Spanish commercial Eucalyptus honeys. Journal of Apicultural Research. 1993;32(3-4):121-126.
28. Gudger EW. Stitching wounds with the mandibles of ants and beetles. A minor contribution to the history of surgery. Journal of the American Medical Association. 1925;84(24):1861-1864.
29. Gunes N, Cibik R, Gunes ME, Aydin L. Erythromycin residue in honey from the Southern Marmara region of Turkey. Food Additives and Contaminants. 2008;25(11):1313-1317.
30. Guo J, Ding Q, Zhang Z, Zhang Y, He J, Yang Z, Gong X. Evaluation of the antioxidant activities and phenolic profile of *Shennongjia Apis cerana* honey through a comparison with *Apis mellifera* honey in China. *Molecules*. 2023;28(7):3270.
31. Gupta JK, Kaushik RAJESH, Joshi VK. Influence of different treatments, storage temperature and period on some physico-chemical characteristics and sensory qualities of Indian honey. Journal of Food Science and Technology. 1992;29:84-87.
32. Gupta RK. Quality and Regulation of Honey and Bee Products. In Beekeeping for Poverty Alleviation and Livelihood Security. Springer, Dordrecht; c2014. p. 637-647.
33. Habib HM, Al Meqbali FT, Kamal H, Souka UD, Ibrahim WH. Physicochemical and biochemical properties of honeys from arid regions. Food Chemistry. 2014;153:35-43.
34. Helrich K. Official Methods of Analysis of the Association of Official Analytical Chemists. Association of Official Analytical Chemists; c1990.
35. Iftikhar F, Masood MA, Waghchoure ES. Comparison of *Apis cerana Apis dorsata Apis florea Apis mellifera*: Honey from Different Areas of Pakistan. Asian Journal of Experimental Biological Science. 2011;2(3):399-403.
36. Joshi SR, Pechhacker H, Willam A, von Der Ohe W. Physico-chemical characteristics of *Apis dorsata, A. cerana* and *A. mellifera* honey from Chitwan district, central Nepal. Apidologie. 2000;31(3):367-375.
37. Kaushik R. Effect of storage conditions on the quality of honey (Doctoral dissertation, M. Sc. Thesis, Department of Entomology and Apiculture, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan); c1988.
38. Kaushik R. Effect of storage conditions on the quality of honey (Doctoral dissertation, M. Sc. Thesis, Department of Entomology and Apiculture, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan); c1988.
39. Kek SP, Chin NL, Yusof YA, Tan SW, Chua LS. Classification of entomological origin of honey based on its physicochemical and antioxidant properties. International Journal of Food Properties. 2017;20(sup3):2723-2738.
40. Khongkwanmueang A, Nuyu A, Straub L, Maitip J. Physicochemical profiles, antioxidant and antibacterial capacity of honey from stingless bee *Tetragonula laeviceps* species complex. In E3S Web of Conferences, 141: 03007. EDP Sciences; 2020.
41. Klein AM, Boreux V, Fornoff F, Mupepele AC, Pufal G. Relevance of wild and managed bees for human well-being. Curr Opin Insect Sci. 2018;26:82-88.
42. Krishnasree V, Ukkuru PM. Nutrient and antioxidant profile of bee honey from Kerala. Indian J Entomol. 2018;80(3):879-884.
43. Kumar R, Agrawal OP, Hajam YA, editors. Honey: A Miraculous Product of Nature. CRC Press; c2021.
44. Kumar S, Verma M, Hajam YA, Kumar R. Honey infused with herbs: A boon to cure pathological diseases. Heliyon. 2024;10(1):e23302.
45. Kumari I, Kumar R. Impact of stimulative diet fed to honeybees with special reference to quality of honey. J Entomol Res. 2022;46(1):168-175.
46. Latif A, Quyyum A, Haq MU. Research on the composition of Pakistani honey. Pak J Sci Res. 1956;8:163-166.
47. Li Z, Li M, He J, Zhao X, Chaimanee V, Huang WF, *et al*. Differential physiological effects of neonicotinoid insecticides on honey bees: A comparison between Apis mellifera and *Apis cerana*. Pestic Biochem Physiol. 2017;140:1-8.
48. Lin YC, Sheu SY, Kong HH. Physicochemical characteristics of certain Taiwan honeys. Taiwan ke Hsueh. 1977;31(1):34-39.
49. Linkon MR, Prodhan UK, Elahi T, Talukdar J, Alim MA, Hakim MA. Comparative analysis of the physico-chemical and antioxidant properties of honey available in Tangail, Bangladesh. Universal J Food Nutr Sci. 2015;3(1):19-22.
50. Moniruzzaman M, Khalil MI, Sulaiman SA, Gan SH. Physicochemical and antioxidant properties of Malaysian honeys produced by *Apis cerana*, Apis dorsata and Apis mellifera. BMC Complement Altern Med. 2013;13:1-12.
51. National Honey Board. Carbohydrates and the Sweetness of Honey [Internet]. 2012 Jun 01. Available from: [provide URL]
52. Ouchemoukh S, Louaileche H, Schweitzer P. Physicochemical characteristics and pollen spectrum of some Algerian honeys. Food Control. 2007;18(1):52–58.
53. Pattamayutanon P, Angeli S, Thakeow P, Abraham J, Disayathanoowat T, Chantawannakul P. Biomedical activity and related volatile compounds of Thai honeys from 3 different honeybee species. Journal of Food Science. 2015;80(10):M2228-M2240.
54. Perti ON, Pandey P. Study of some physicochemical constants of Apis dorsata honey. Part II. Specific gravity. Indian Bee Journal. 1967;29:1-3.
55. Phadke RP. Studies on Indian honeys. 1. Proximate composition and physico-chemical characteristics of Indian multifloral apiary honeys from *Apis índica* bee.

Indian Bee Journal. 1967;29:14-26.
56. Phadke RP. Studies on Indian honeys. 3. Proximate composition and physicochemical characterizations of honeys from the wild honey bees, Apis dorsata, Apis florea and Trigona. Indian Bee Journal. 1968;30:3-8.
57. Radovic BS, Careri M, Mangia A, Musci M, Gerboles M, Anklam E. Contribution of dynamic headspace GC–MS analysis of aroma compounds to authenticity testing of honey. Food Chemistry. 2001;72(4):511-520.
58. Ramlan NAFM, Mohamad Azman E, Muhammad K, Jusoh AZ, Johari NA, Yusof YA, *et al*. Physicochemical homogeneity of stingless bee honey (Heterotrigona itama) produced in the west coast, east coast and inland area of Peninsular Malaysia. Journal of the Science of Food and Agriculture. 2024;104(3):1756-1767.
59. Reybroeck W, van Veen JW, Gupta A. Beekeeping for poverty alleviation and livelihood security.
60. Rosner F. Pigeons as a remedy (segulah) for jaundice. New York State Journal of Medicine. 1992;92(5):189-192.
61. Santana FJ. Diastasa, invertasa, β-glucosidasa y fosfatasa en la miel. Tesina de Licenciatura. Facultad de Farmacia, Universidad de Santiago de Compostela; c1993.
62. Schramm DD, Karim M, Schrader HR, Holt RR, Cardetti M, Keen CL. Honey with high levels of antioxidants can provide protection to healthy human subjects. J Agric Food Chem. 2003 Mar 12;51(6):1732-5.
63. See MAD, Fajardo MAC, Fajardo Jr AC, Cervancia CR. Physico-chemical properties of Philippine honey and their implication in the establishment of standard for tropical honeys. J Apiculture. 2011 Jan;26(1):45-8.
64. Bonvehí SJ, Coll VF. Flavour index and aroma profiles of fresh and processed honeys. J Sci Food Agric. 2003;83(4):275-82.
65. Sharma A, Kumar R, Singh CS, Dogra N, Kumari S, Kuthleria K. Physico-chemical and antioxidant evaluation of honey collected from three different honeybee species in Chamba District, Himachal Pradesh, India. Int J Zool Investig. 2023;9(2):939-44.
66. Sharma S, Hajam YA, Kumar R. Physico-chemical analysis of honey samples collected from *Apis cerana* in Western Himalayan region. J Entomol Res. 2021;45(2):246-53.
67. Singh N, Bath PK. Quality evaluation of different types of Indian honey. Food Chem. 1997 Jan 1;58(1-2):129-33.
68. Solomon RJ, Santhi VS, Jayaraj V. Prevalence of antibiotics in nectar and honey in South Tamil Nadu, India. Integrative Biosci. 2006;10(3):163-7.
69. Subramanian R, Umesh Hebbar H, Rastogi NK. Processing of honey: A review. Int J Food Prop. 2007 Jan 1;10(1):127-43.
70. Terrab A, Díez MJ, Heredia FJ. Characterisation of Moroccan unifloral honeys by their physicochemical characteristics. Food Chem. 2002 Dec 1;79(3):373-9.
71. Terrab A, González AG, Díez MJ, Heredia FJ. Characterization of Moroccan unifloral honeys using multivariate analysis. Eur Food Res Technol. 2003 Feb;218:88-95.
72. Van Minh H, Mendoza BV, Laigo FM, Morse RA, Steinkraus KH. The chemical composition of honey produced by Apis dorsata. J Apicul Res. 1971;10(2):91-7.
73. Wakgari M, Yigezu G. Honeybee keeping constraints and future prospects. Cogent Food Agric. 2021;7(1):1872192.
74. Weiss HB. Entomological medicaments of the past. J New York Entomol Soc. 1947 Jun 1;55(2):155-68.
75. White Jr JW. Physical characteristics of honey. Honey: A Comprehensive Survey. E Crane, ed, 1975.
76. Wu J, Duan Y, Gao Z, Yang X, Zhao D, Gao J, Wang S. Quality comparison of multifloral honey produced by *Apis cerana* cerana, Apis dorsata and Lepidotrigona flavibasis. LWT. 2020 Sep;134:110225.
77. Yusuf'Ali A. An Nahl, Al-Quran Chapter 16 (The Bee) quoted from The Holy Qur'an: Original Arabic Text with English Translation & Selected Commentaries. Saba Islamic Media. Retrieved; c2013, 13.